CHAPTER 7

The Water Cycle

KEY IDEAS

- The water on Earth is not distributed equally.
- All the water in, on, and around Earth circulates through the water cycle.
- Moving water and ice can change the shape of the land.
- The water cycle is affected by many factors.
- Water systems are managed to protect them from human activities.

Your school is an example of a system, a combination of interacting parts that form a unified whole. The human part of the system includes teachers, principals, superintendents, and custodians who work together to help students learn. The physical part of the system includes buses, buildings, and other facilities. There are many other examples of systems in your everyday life—transportation systems to carry people and goods, computer and communication systems to facilitate human interaction, and heating and cooling systems to regulate the temperature in your home. Systems also exist in the natural world.

Water is continuously moving above, on, and below Earth's surface. There are continuous changes in form—from solid to liquid to gas (water vapour), and from gas to liquid to solid. In what ways does water in all its forms make up a system? How might the parts of a water system interact?

In this chapter, you will learn about the parts of Earth's water system and the way that water constantly cycles through these parts. This will help you prepare for learning how water affects your life in many important ways.

Water in Our World

7.1

Imagine that you are on a space mission, orbiting Earth. As you travel above Africa, Europe, and Asia, you might think that there is a lot of land below you. As you pass over the Pacific Ocean, however, you begin to realize that most of Earth's surface is composed of water (**Figure 1**).

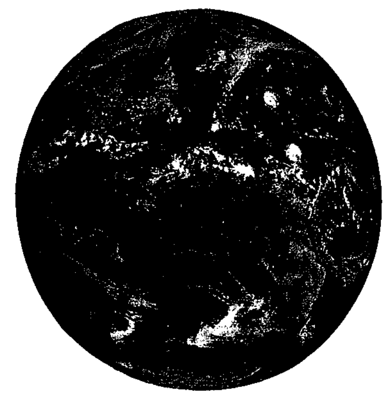
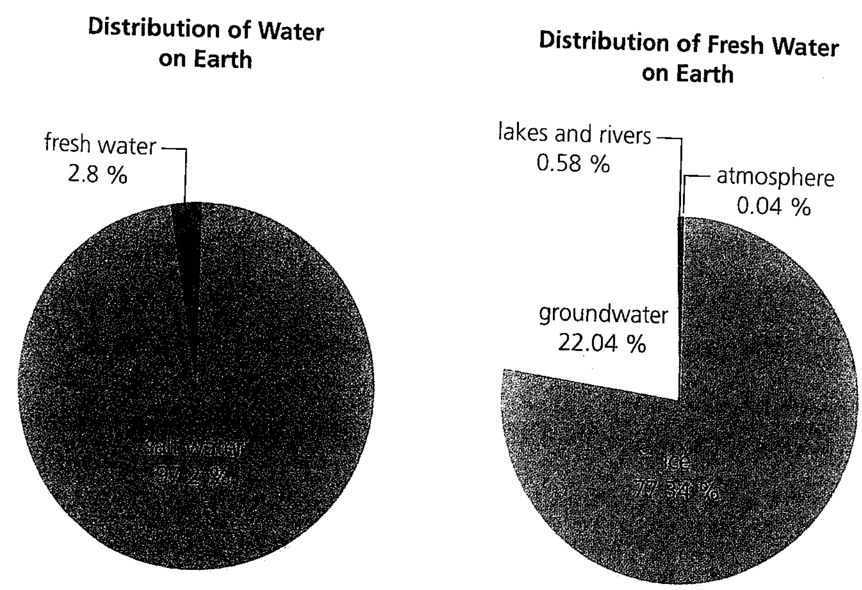


Figure 1
Water covers 71 % of Earth's surface.

Water Distribution

Most of Earth's liquid water is salt water in the oceans. In fact, less than 3 % of Earth's water is fresh water (**Figure 2**). **Fresh water** is water, whether liquid, solid, or gas, that contains a low concentration of dissolved salts.



(a) Only 2.8 % of all the water on Earth is fresh water.

(b) More than 77 % of the fresh water on Earth is solid, in glaciers or icecaps.

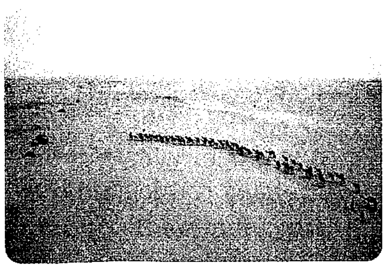
Figure 2
Water distribution on Earth

Salt Water

Oceans contain most of the world's salt water (**Figure 3**). The **salinity** (average concentration of salt) of ocean water is about 3.5 %. Most of the salt in ocean water comes from the land. As fresh water seeps through the soil, it dissolves some of the salt and other minerals. We cannot taste the salt in this water because the concentration is too low. This water, known as runoff, eventually makes its way in rivers and streams to the oceans. The dissolved salt and other minerals in runoff

Figure 3
Most of the world's salt water is found in oceans.

(a) Canadians are fortunate to live in a land where fresh water abounds.



(b) Many people live in places where little fresh water is available.

Figure 4

Figure 5
The licorice fern was used by Aboriginal peoples of British Columbia for its medicinal properties.

have accumulated in ocean water over many millions of years and made it salty. Salt water is also found in some swamps, marshes, lakes, and estuaries. Salt swamps and salt marshes occur where ocean water comes onto land and fills low-lying areas or depressions.

Estuaries, where rivers flow into an ocean, are affected by tidal action. High tides extend upstream, pushing the ocean's salt water inland to mix with fresh river water. This mixed water is less salty than the water in the ocean and is called brackish water.

Fresh Water

Scientists estimate that Canada contains 9 % of the world's fresh water, although it has only 0.5 % of the world's population (**Figure 4**). Canada has many rivers, glaciers, lakes, marshes, bogs, and swamps. Most of these contain fresh water and play vital roles in the water system. Wetlands (swamps, marshes, and bogs) filter and clean fresh water and help to moderate water levels in times of flood or drought. Wetlands are home to a tremendous variety of plants and animals. They are one of the most productive ecosystems on Earth.

The Three States of Water

Water is the only substance on Earth that exists naturally in all three physical states: solid, liquid, and gas. Water also changes easily from one state to another. Just over 2 % of the world's water is solid, in the form of snow, glaciers, and polar icecaps. The meltwater from glaciers, as it runs into rivers, is an important source of fresh water for many people.

Water is present in Earth's atmosphere as well, in the form of fog, clouds, and water vapour. You, like many other animals, exhale water vapour with every breath. Plants also add vast amounts of water to the atmosphere. Almost all the liquid water absorbed by the roots of a plant passes out through its leaves as water vapour. The roots of some plants gather moisture directly from water vapour in the air (**Figure 5**).

7.1 CHECK YOUR UNDERSTANDING

1. List two examples for each of the following forms of water: solid water, water vapour, salt water, and fresh water.
2. With so much water in the world, explain why some places suffer water shortages. List five ways that a water shortage would affect your life.

Inquiry Investigation 7.2

Comparing Salt Water and Fresh Water

INQUIRY SKILLS

- ○ Questioning
- ○ Hypothesizing
- ○ Predicting
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ○ Evaluating
- ● Communicating

Just how different are salt water and fresh water? In this Investigation, you will find out. You will examine four physical characteristics: appearance, odour, density, and buoyancy. Recall from Section 4.7 that density is the mass of a substance for one unit of its volume. For example, 1 cm^3 of distilled water has a mass of 1 g, so the density of distilled water is written as 1 g/cm^3. Recall from Section 4.10 that buoyancy is the upward push on an object by a fluid.

Never taste or drink anything used in a science class. Do not put the straw or pipette in your mouth.

Question

How is salt water different from fresh water?

Hypothesis

Salt water has a greater density, a greater force of buoyancy, and more residue left after evaporation than fresh water does.

Materials

- apron
- safety goggles
- salt water (3.5 % saline solution)
- fresh water
- distilled water
- 2 microscope slides
- medicine dropper
- desk lamp
- microscope
- 100 mL graduated cylinder
- triple-beam balance or scale
- beakers
- drinking straw or pipette
- food colouring
- 30 cm wooden dowel

(a) Copy **Table 1** into your notebook.

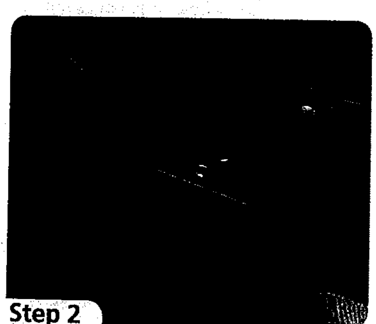
Table 1 Comparing Salt Water and Fresh Water

Characteristic	Fresh water	Salt water
Appearance (including colour)		
Odour		
Residue after evaporation		
Density		
• mass of empty graduated cylinder		
• mass of graduated cylinder and 100 mL of water		
• mass of 100 mL of water		
• density of water sample (g/mL)		
Buoyancy		
• depth to which dowel sank		
• float test: fresh water over salt water		
• float test: salt water over fresh water		

Procedure

1. Put on your apron and safety goggles. Obtain samples of fresh water and salt water from your teacher. Examine the appearance and odour of both water samples. Record these observations in your table.

2. Place three drops of fresh water on a clean microscope slide. Rinse the medicine dropper in distilled water. Place three drops of salt water on another slide.



Step 2

3. Place the slides under a desk lamp to evaporate the water. Using a microscope, examine any residue on the slides. Record your observations.

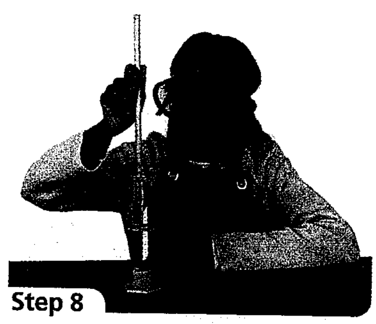
4. Measure and record the mass of an empty graduated cylinder.

5. Pour 100 mL of fresh water into the cylinder and measure the mass of the cylinder and water. Record the mass. Determine and record the mass of the water, and then calculate the density of the water.

6. Rinse the cylinder with distilled water.

7. Repeat step 5 using salt water. Then rinse the cylinder with distilled water.

8. Place a wooden dowel in a graduated cylinder that contains 100 mL of fresh water. Use the markings on the graduated cylinder to measure the depth at which the bottom of the dowel floats. Record the depth in your table.



Step 8

9. Repeat step 8 using salt water.

10. Add one drop of food colouring to 50 mL of fresh water. Half fill a beaker with uncoloured salt water. Use a straw or pipette to transfer the coloured fresh water to the surface of the salt water. Release the water from very near the surface. Repeat several times. Record your observations.

Step 10

11. Repeat step 10, this time transferring coloured salt water into uncoloured fresh water.

Analysis

(b) How does saltwater residue differ from freshwater residue? What appears to make up each residue?

(c) Explain any difference in the densities of the samples.

(d) Use your results to explain how you have demonstrated that salt water exerts a greater force of buoyancy than fresh water does.

PERFORMANCE TASK

How could you use your knowledge of what happens when salt water evaporates to help you create safe drinking water?

The Water Cycle

7.3

Water is always on the move, sometimes quickly and sometimes slowly. It is forever changing its state and location. The movement of water is not restricted to Earth's surface—water sinks deep below the ground and rises high into the atmosphere. It is this movement of water, known as the **water cycle** (**Figure 1**), that influences our weather, keeps rivers and lakes full, purifies water, and sustains many forms of life.

LEARNING TIP

Active readers interact with the text. As you read, note the highlighted words. These are words that you should learn and use when you answer questions. The words are also defined in the Glossary at the back of your student book.

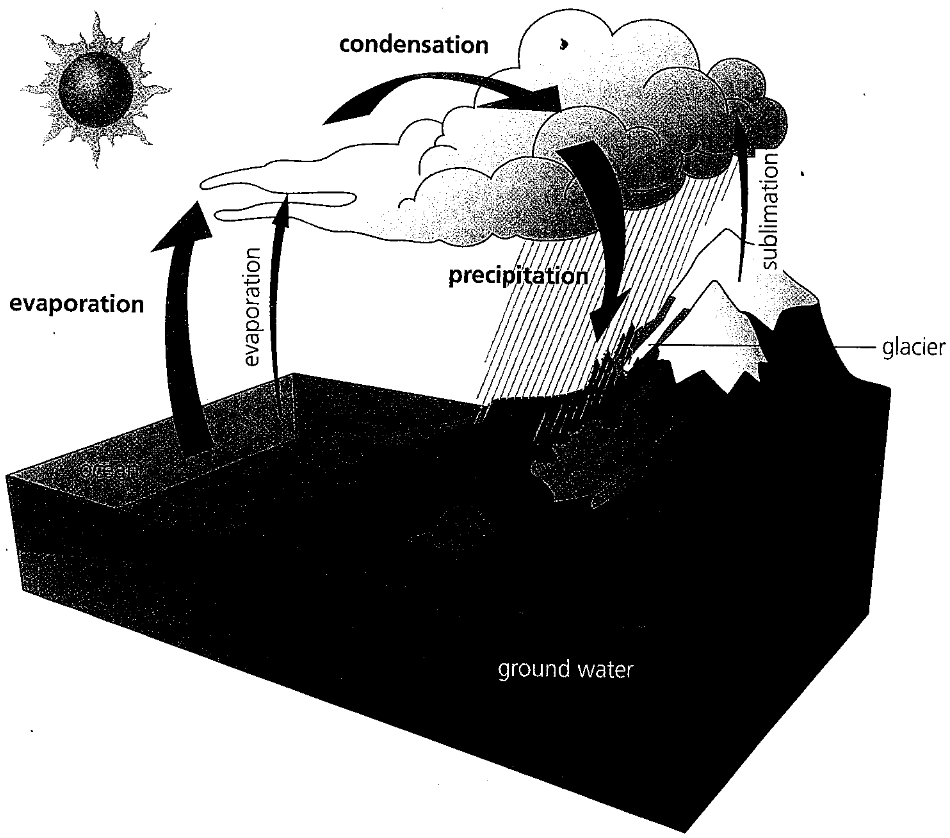


Figure 1
Earth's water is in a continuous cycle, always moving and changing state.

The Water Cycle

Heat energy from the Sun causes liquid water on Earth's surface to change to water vapour in a process called evaporation (recall Section 4.1). Water also evaporates from soil, animals, and plants. Salts, pollutants, and impurities are left behind as water rises into the air as water vapour.

As the air rises, it cools. Cool air cannot hold as much water vapour as warm air. The cooled water vapour in the air becomes liquid again, a process called condensation (recall Section 4.1). Tiny drops of water collect around dust particles, forming clouds or fog.

Eventually, so much water gathers in the clouds that the air currents can no longer keep it aloft. It falls to Earth as **precipitation**—rain, hail, sleet, or snow. Snow falling in the mountains or polar regions may remain frozen for years. Gradually, layers accumulate and their pressure turns the bottom layers of snow to ice, forming a glacier. Snow and ice at the surface of a glacier can change directly into water vapour again. This is called sublimation (recall Section 4.1).

Liquid water flows along the surface of the ground and gathers in rivers, lakes, and oceans. A lake or pond forms wherever a basin (a natural depression) allows water to gather.

Wetlands, including marshes, swamps, and bogs, are important reservoirs of water. A marsh is a low-lying, treeless area of soft, wet ground that is usually covered by water for at least part of the year. A marsh may contain either fresh or salt water and is characterized by the grasses, cattails, and other plants that grow there. A swamp, like a marsh, is an area of low-lying, wet land that at times is covered by water. A swamp also can contain fresh or salt water but, unlike a marsh, it contains many trees and shrubs. A bog (sometimes referred to as a peat bog or peatland) is dominated by mosses, which are the wetland sponges.

Ground water is water that has soaked into the soil. It passes through gravel, sand, soil, and porous rock on its way back to rivers, lakes, and oceans, or to longer-term storage deep underground. Because of water's ability to dissolve many substances in both liquid and vapour form, pollutants, chemicals, and dissolved minerals and salts can be carried by ground water and surface water into lakes and oceans.

DID YOU KNOW ?

Burn's Bog

Burns' Bog in Delta, British Columbia is one of the largest peat bogs in the world. It is named after Pat Burns of Burns Meat Packaging, who originally owned the bog.

DID YOU KNOW ?

Water Storage

Mosses are able to hold water in the many air spaces in their leaves. Sphagnum mosses have the ability to absorb and hold 20 to 30 times their weight in water.

LEARNING TIP

Are you able to explain the water cycle in your own words? If not, re-read the main ideas and examine **Figure 1** again.

PERFORMANCE TASK

How might you use your knowledge of the water cycle, and the changes of state that take place, to help you design a water purifier?

7.3 CHECK YOUR UNDERSTANDING

1. What is the water cycle?
2. Name and describe any four changes of state that occur in the water cycle.
3. Imagine that you are a molecule of water on the calm surface of a lake. You feel the Sun beating down on you, warming you, giving you energy. You begin to move. You move faster, and then faster still. The warmer it gets, the more energy you have. You move more freely. Suddenly, you break free from the water's hold. Now you are floating ...

   Create a presentation of the water cycle in an interesting way for young children—through a story (as in the example above), visually, dramatically, or musically.

The Water Table 7.4

The next time it rains, watch the raindrops hitting a window. You will notice that some of the raindrops run down the glass while others seem to stay stuck to the window. Two forces appear to act on the water: the force of gravity pulling it downward and a force of attraction to the glass. Because of its structure, water shows a "stickiness," an attraction to many materials. This stickiness is the force of adhesion, which causes water to cling to other surfaces (recall Section 4.3).

Water is composed of hydrogen and oxygen. The chemical formula for water is H_2O, since there are two hydrogen atoms for every oxygen atom. One side of a molecule has a slightly positive charge, and the opposite side has a slightly negative charge (**Figure 1**). These charges cause a cohesive force among the molecules and they act like tiny magnets, with the positive and negative charges attracting one another. The adhesive force makes them stick to other types of molecules as well, like those in the window glass. These charges also affect how water behaves underground.

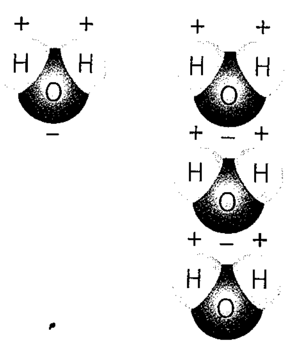


Figure 1
Water molecules have a slightly positive and a slightly negative charge at opposite ends.

LEARNING TIP

As you study **Figure 1**, ask yourself "What does this show?" Relate the information from the text to the information in the figure.

Water in the Ground

Most of the rain that strikes the ground runs off over the surface and collects in streams, rivers, ponds, and lakes. The rain that does not collect in bodies of water eventually makes its way underground. **Figure 2** shows the part of the water cycle that involves water movement through the ground.

Rain seeps into the soil. The force of adhesion between water molecules and soil particles causes the water to spread outward, moistening the ground where it hits. Gravity causes the water to sink into the ground, dissolving salts and minerals as it moves through the spaces between the soil particles. This process is called **percolation.**

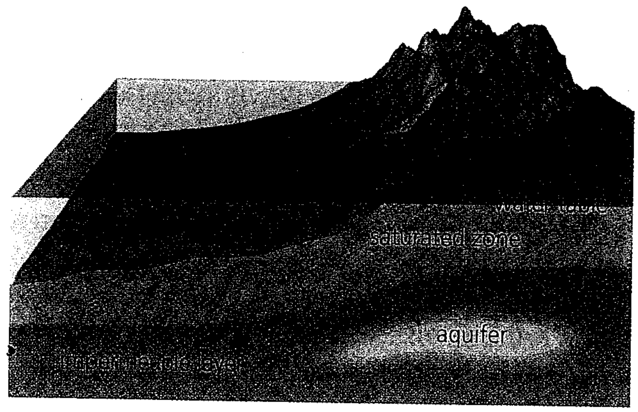


Figure 2
The rate at which water moves through the ground depends on the composition of the soil and rock.

The water eventually reaches a layer of clay, silt, or rock that will not allow it to pass through fast enough to be used as a water supply. As more rain falls, the water completely fills the spaces above this impermeable layer, causing the soil to become saturated with water. This is called the **saturated zone**. Wells must reach the saturated zone to be good sources of water for human use. The upper level of the saturated zone is called the **water table**.

Factors Affecting the Water Table

The depth of the water table is directly affected by what is happening locally in the water cycle. As rain falls, the water table starts to rise. When there is little rainfall, water evaporates from the surface of the ground much faster than it is replaced. As the water evaporates, **capillary action** draws more water up from below ground, due to the force of cohesion between water molecules and the force of adhesion between water molecules and soil particles. This causes the water table to drop. As well, considerable water is also lost through evaporation from ponds, rivers, and lakes. Water from the saturated zone moves to replace some of this lost water, and the water table drops even farther. When a well runs dry, the water table has sunk lower than the depth of the well.

Large accumulations of underground water in permeable rock, soil, or sand are called **aquifers**, which are excellent sources of water. Aquifers, however, can be depleted if water is being removed faster than it is being replenished by water percolating from above.

TRY THIS: Capillary Action in Soil

Skills Focus: creating models, measuring, interpreting data, inferring

In this activity, you will build a model to demonstrate capillary action.

1. Put on an apron. Roll a sheet of clear plastic into a tube, and tape the seam. Place the tube upright in an aluminum pie pan, and fill the tube with dry sand. Pour water into the pan, and let it stand for several minutes (**Figure 3**).
2. Observe how high the water travels up the tube. Try using different diameters for the tube to see if the distance changes. Measure the diameters and the distances. Use a table to record your measurements.

(a) Did the diameter of the tube affect the distance the water moved up?

(b) Would changing the type of soil or type of liquid affect your results?

(c) Based on your observations in this activity, what will happen to water deeper in the ground as water near the surface dries up?

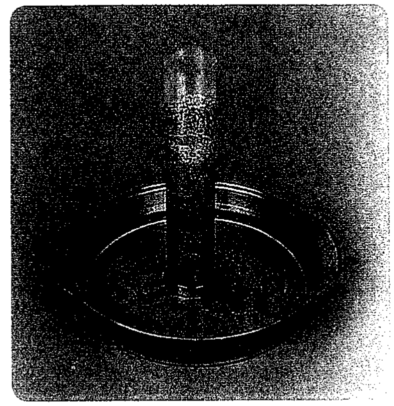


Figure 3

Human activities can affect the level of the water table. Some wells, for example, supply entire towns with water. If too much water is pumped from a well, the water table in the ground around the well can drop. Surrounding areas, with shallower wells, may completely lose their water supply. In urban areas, rain water that falls on buildings and parking lots runs into storm sewers and is emptied directly into streams and rivers. This water does not percolate into the soil to become ground water.

7.4 CHECK YOUR UNDERSTANDING

1. What happens to water that does not collect in streams, rivers, ponds, or lakes?
2. Can aquifers be depleted? How?
3. Explain how the water cycle affects the level of the water table.
4. Explain why, as rain begins to fall, the water does not flow down to the saturated zone immediately.
5. Describe how each of the following processes affects the movement of water underground.
   (a) capillary action
   (b) percolation
6. During a dry season, a family had 6000 L of water pumped into their well because it had run dry. By the evening, only 4000 L remained. The family did not have a swimming pool, they had not yet taken any baths, and they did not have livestock. Explain how 2000 L of water could disappear in less than a day.

PERFORMANCE TASK

How might you use your knowledge of the attraction of water molecules in the design of an oil spill eliminator?