13.8

The Hydrosphere

As the glacier in Figure 1 slowly melts each summer, the released water joins water from melting snow to form freshwater streams, rivers, and lakes. But snow, ice, water in rivers and lakes, and water vapour in the atmosphere make up only a small portion of all the water on Earth. Most of the water is found in oceans where the water is salty so we can't drink it. All of Earth's water, both fresh and salt, forms what is called the hydrosphere. The map in Figure 2 shows that the vast majority of Earth's surface is covered with water and ice.

Figure 1
This glacier in the Rocky Mountains was formed by layers of snow pressing down on previous layers.

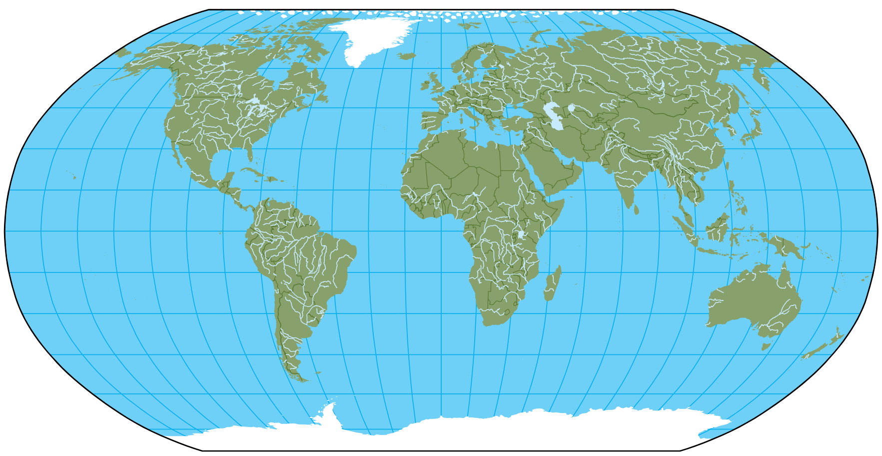

Figure 2
Approximately 70% of Earth's surface is covered with water; this includes salt and fresh water as well as ice.

Did You Know?

The Pacific Ocean is the largest ocean, comprising 46% of the total area of all oceans. The Arctic Ocean is the smallest, covering 2.6% of the total. The Pacific Ocean is also the world's deepest: one location has a depth of about 11 km, greater than Mount Everest.

Water Distribution in the Hydrosphere

The pie graphs in Figure 3 show that only a very small portion of the hydrosphere consists of fresh water. Furthermore, most of this fresh water is frozen in glaciers and in the ice caps around the North and South Poles. In fact, if we represented all the water in the world by one litre of water, then all the fresh, unfrozen water in the atmosphere, lakes, and rivers would be less than one drop!

With its vast freshwater supplies, Canada is one of the luckiest countries in the world. Our population is just 0.5% of the world total, yet we have almost 10% of the world's supply of fresh water.

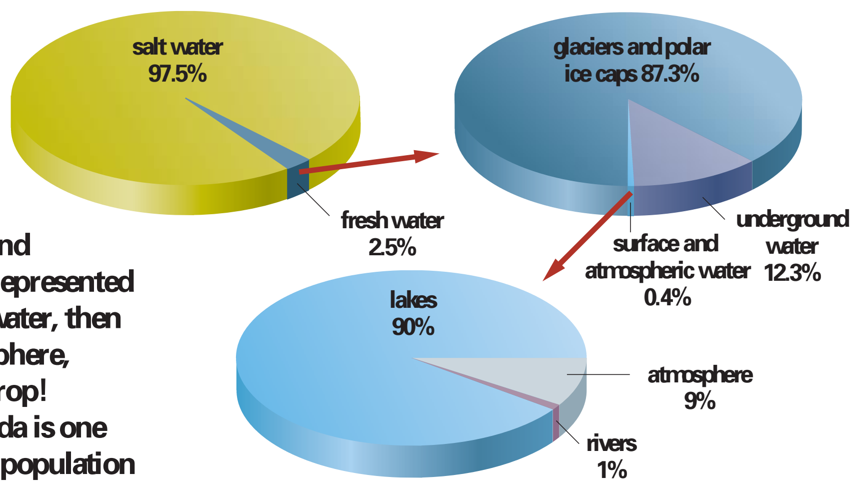

Figure 3
Earth's water resources

The Water Cycle

Because so much of Earth's surface is covered by water, our weather systems depend greatly on water in its three states: solid, liquid, and gas or vapour. Figure 4 shows the water cycle. Energy, mostly from the Sun, causes water to evaporate (change from liquid to vapour) or ice to sublimate (change directly from solid to vapour). The invisible water vapour rises, and eventually, as the pressure and temperature decrease, this vapour condenses (changes from vapour to liquid) into fog, mist, and clouds. In some cases, the water vapour may form ice crystals in the reverse process of sublimation (also called deposition). The resulting precipitation falls to the ground, and the cycle starts again.

As you study the causes of weather patterns in this unit, think about how much evaporation or sublimation occurs in the various parts of the world.

Did You Know?

In one growing season, the amount of water that evaporates from a one-hectare field of corn is estimated at 3×10^7 L, or 30 million litres. (A field that measures 100 m by 100 m has an area of 1 ha.) This means that about 7.5 L of water evaporates from a mature corn plant each day.

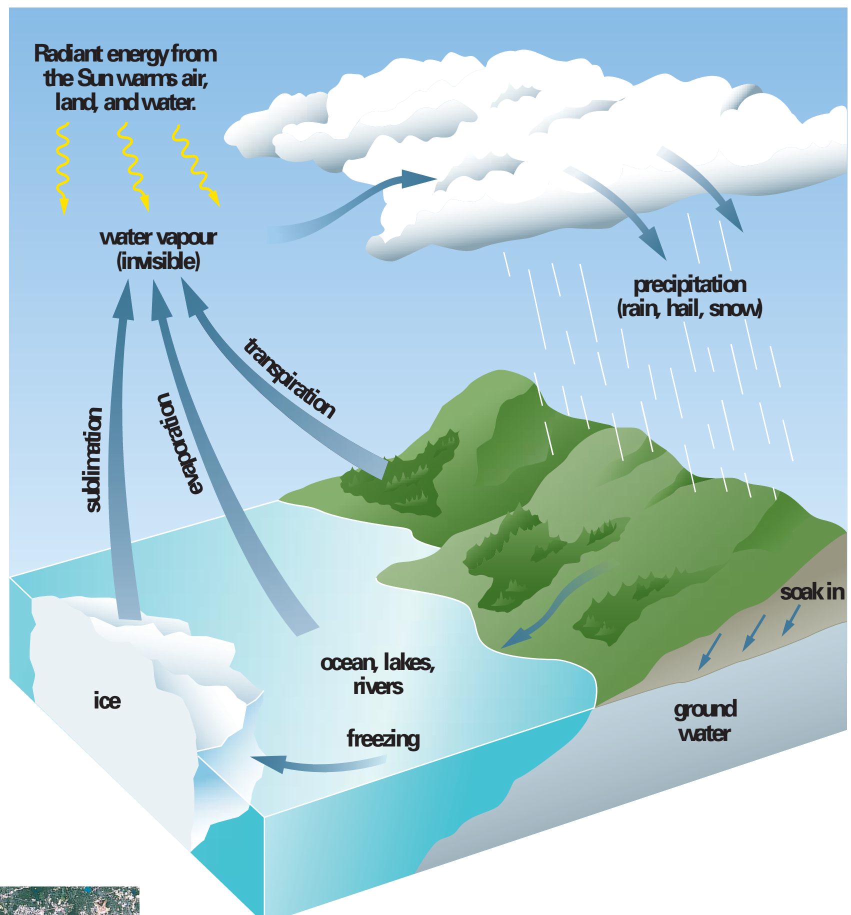

Figure 4

The water cycle

The Hydrosphere and Human Habitat

Fresh water is vital for human survival. In the past, people lived near sources of fresh water, especially rivers and lakes. Today, a large portion of the world's population still lives near water, both fresh water and the oceans (Figure 5). Thus, weather systems on and near large bodies of water greatly affect large numbers of people. And in the future, these effects will be even more far reaching as the population increases.

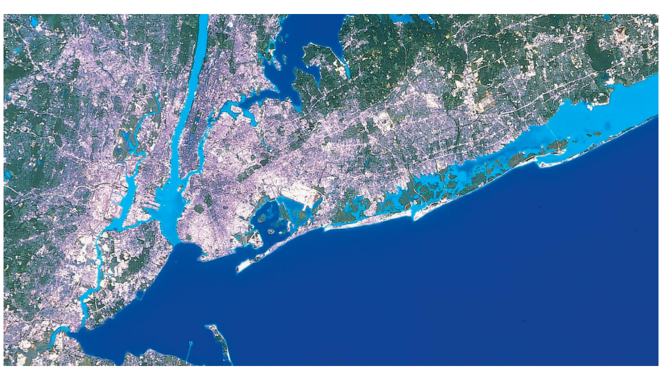

Figure 5

We need water to drink; we also use it as a source of food and for transportation. Shorelines all around the world are becoming crowded with people.

Try This Activity

Evaporating Salt Water

When salt water evaporates, does the vapour carry the salt with it?

Materials: apron, an evaporating dish or saucer, table salt, distilled water, a balance, a stirring rod

¥ Add a small amount of table salt to a dry evaporating dish or saucer, and use a balance to measure the combined mass of the dish and salt.

¥ Add water to the dish and stir the mixture until the salt is completely dissolved.

¥ Place the dish in a safe place and allow the water to evaporate completely. (This may take several days.) Record the time.

¥ Measure the mass of the dish.

¥ Wash your hands.

(a) How much salt was carried off in water vapour?

Understanding Concepts

1. In your own words, write a definition of the term Åhydrosphere.Æ
2. Explain why fresh water is more important to human life than salt water.
3. In a paragraph, explain why it is important to learn about salt water in order to understand weather.
4. A glacier may be thousands of years old, yet it is considered to be ÅfreshÆ water. Explain why.
5. Use the information in Figure 3 to determine the percentage of EarthÈs hydrosphere that is found in
   (a) underground water;
   (b) freshwater lakes;
   (c) the atmosphere.

Making Connections

6. The following famous lines are from the poem The Rime of the Ancient Mariner, by Samuel Taylor Coleridge:
   Water, water, every where,
   And all the boards did shrink;
   Water, water, every where,
   Nor any drop to drink.

   In two or three sentences explain what these words mean.
7. As the worldÈs freshwater supply becomes increasingly limited, people in some countries suggest more schemes to obtain water. One suggestion is to tow icebergs from the North Atlantic Ocean, near Greenland, through the Mediterranean Sea, to the Middle East. Speculate about some advantages and disadvantages of such a scheme.
8. The amount of fresh water available in the world through the water cycle is about 2×10^{16} L per year.
   (a) Calculate approximately how much water this is for each person on the planet. (The worldÈs population is estimated to be 6 billion.)
   (b) If Canada has about 10% of the total amount of fresh water, repeat (a) for our population.
   (c) What do you conclude about the availability of water to Canadians?
9. Bottled mineral water is becoming increasingly popular in Canada. Research and report on the supply and demand of this type of water, both in Canada and countries such as France, which have longer traditions of using bottled water.

Exploring

10. (I) (J) An aquifer is an underground body of water. The Ogallala Aquifer is the largest aquifer in the world. Research this aquifer and describe in a poster how it is used, how long it may last, and other pertinent facts.
11. The Gisborne Lake project proposed the bulk export of fresh water from a lake in southern Newfoundland. However, legislation was introduced to stop it. Research this project and write a brief report that describes what happened. Include your position on the issue.

Challenge

1 How would you ensure that your weather forecasts are appropriate for people with a variety of interests or careers, such as people who fish, farm, grow fruit trees, play soccer, wash high-rise office windows, etc.?

2 What factors related to water are important for you to consider in your community design?

3 Find out where members of your network live. For example, do they live near a large body of water, on the top of a hill, in the centre of a large city?

SKILLS HANDBOOK: (I) (J) Research Skills

Major Ocean Currents

As you have seen, oceans are particularly important in weather dynamics. One reason is that they occupy so much of EarthÈs surface. To find another reason, look at a world map: there is little land mass at the equator, but if you circle the globe at, say, 45¡ north, there is considerable land mass. So there is a vast volume of water at the equator, where the radiation from the Sun is direct. One way in which all this direct energy absorbed by the oceans is spread around the world is by ocean currents.

You might expect countries such as Norway and Iceland, which are as far north as CanadaÈs Arctic region, to have very cold winters. However, their Atlantic harbours remain ice-free all winter because of the Gulf Stream, an Atlantic Ocean current that transports warm water all the way from the Gulf of Mexico, near the equator, to the North Atlantic region. Figure 1 shows the Gulf Stream and several other major ocean currents in the world. The warm ocean currents act like Åconveyer belts,Æ transporting energy (stored in the water) from warmer parts of the world to colder parts. The cold ocean currents from the North Atlantic and Pacific Oceans and the Antarctic circumpolar current flow toward the equator. These cold waters become warmer as they circulate through the equatorial regions of the worldÈs oceans.

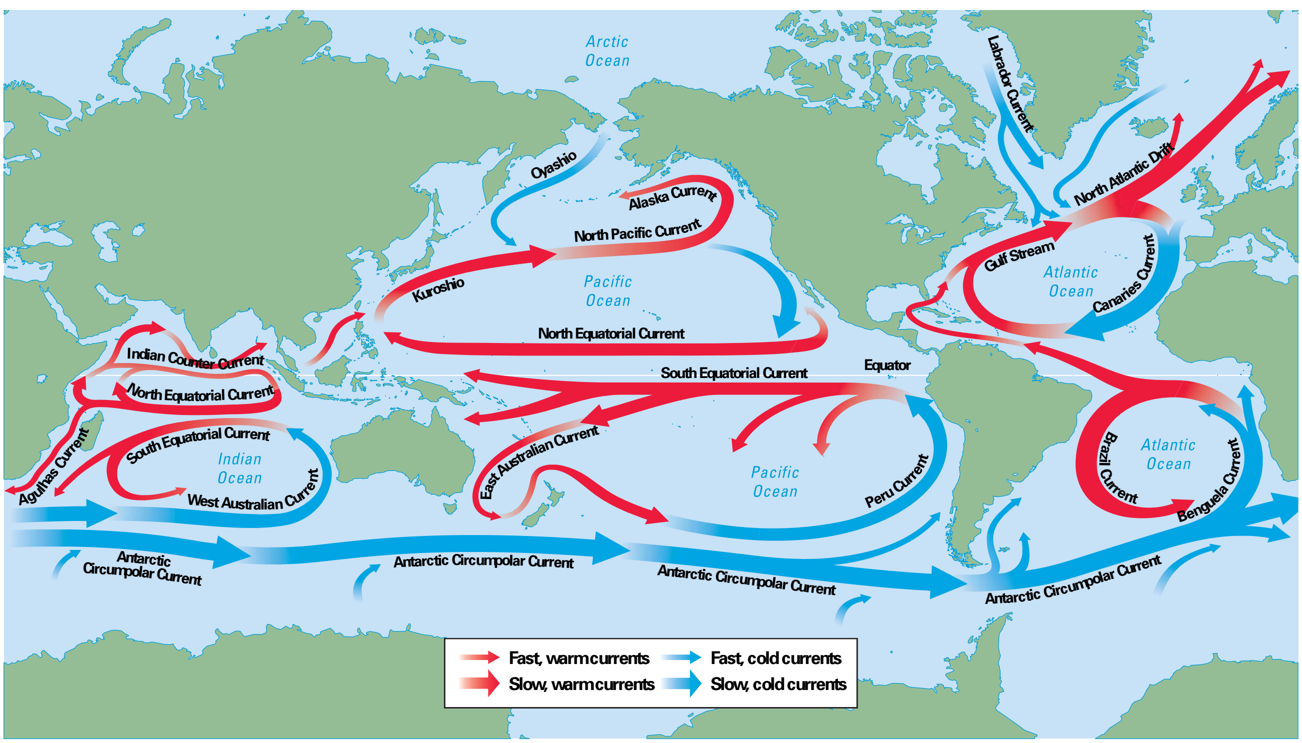

Figure 1

The major warm and cold ocean currents in the world. Compare the directions of the ocean currents with the directions of the major winds in Figure 2 in Section 13.6.

Causes of Ocean Currents

As you study the map of ocean currents in Figure 1, you will begin to notice certain patterns. Each of these patterns can be explained by considering convection currents, winds across the oceans, the influence of Earth's rotation, the shapes of the continents, the heat capacity of water, and the amount of salt in the oceans.

Warm water tends to travel from the equator toward the North or South Pole, and cold water tends to travel in the opposite direction. Solar energy strikes the oceans at the equator directly and therefore more intensely, heating the water and starting convection currents. As the warm, less dense water moves away from the equator, it is replaced by cooler, denser water, as shown in Figure 2. The convection currents are also influenced by the prevailing winds blowing at the surface and the twisting caused by the Coriolis effect.

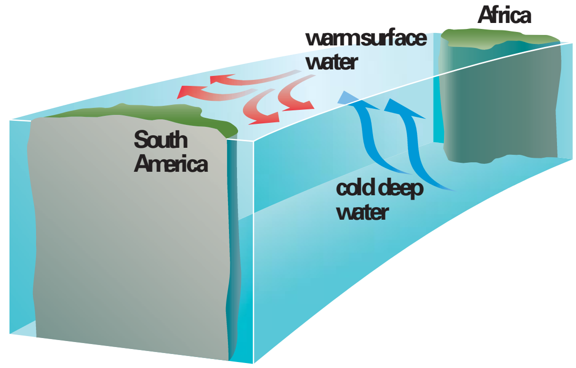

Figure 2

Ocean water near the equator absorbs the direct, intense solar energy. Since warm water is less dense than cold water, the warm water moves northward or southward at the surface, and is replaced by cold water from below, starting a convection current.

Close to a continent, ocean currents are forced to travel along its edge, just like water in a river changes direction if it hits a rock or steep shoreline. Because of Earth's eastward rotation, ocean currents on the west sides of the oceans tend to be narrow and fast moving, travelling at about 6.5 km/h. Currents on the east sides tend to be wider and slower, travelling at about 1.1 km/h. Only one ocean current, the Antarctic Circumpolar Current, travels all the way around the world, with no continents in the way.

The oceans act as huge heat sinks because water has a high capacity to store heat. As water absorbs solar energy, it takes a long time to heat up. However, once it is warm, the water takes a long time to cool down again. These properties have an important effect on both world climate and local weather.

The salt in the water also affects ocean currents. For example, as the warm Gulf Stream flows northward, water evaporates, leaving increasingly saltier water. The saltier water is more dense, so it sinks, creating deep-water currents, and is replaced by warm, less dense water.

Effects of Ocean Currents

The Gulf Stream warming the coasts of Norway and Iceland is just one example of the effect of ocean currents. You will understand all the ocean current effects if you recognize the relationship between air temperature and its ability to hold moisture: the warmer a body of air, the greater its ability to hold moisture.

The ocean current that reaches Peru in western South America is cold, so the air above it is dry. Therefore, the coast of Peru is cool and dry, which helps to create a desert called the Atacama Desert beside the Pacific Ocean. (You have already seen how winds help create the dry conditions.) According to Figure 1, in what other coastal regions in the world could cold ocean currents help produce similar dry effects?

Along the western side of the huge Pacific Ocean, the warm waters evaporate, form clouds, and produce large quantities of precipitation. Which current causes a similar effect in Brazil, which has a large portion of Earth's rain forests?

Did You Know?

Currents that go through narrow channels travel much faster than other currents. The strongest currents in the world are the Nakwakto Rapids, Slingsby Channel, British Columbia, where the current can flow as fast as 30 km/h.

Ocean currents are responsible for coastal regions being cooler in summer and warmer in winter than regions several kilometres inland. Large bodies of water and their currents moderate the climate. For example, the average early-morning January temperature in Ottawa, Ontario, is 30¡C lower than the average early-morning July temperature. But in St. JohnÕs, on the east coast of Newfoundland, that difference is only 18¡C. And Ottawa is farther south than St. JohnÕs! Newfoundland is warmer in winter because of the warm, moist air brought northward by the Gulf Stream.

The high heat capacity of water is one factor that causes seasonal changes to lag behind the daylight hour changes; that is, in the Northern Hemisphere the most daylight hours occur on June 21, yet the hottest months are June, July, and August rather than May, June, and July. This occurs partly because water takes a long time to warm up after the winter. Another factor that contributes to this lag is the flow of energy: in July the energy input in the Northern Hemisphere is greater than the energy output.

A similar lag occurs in winter when the fewest daylight hours occur on December 21, yet the coldest months are December, January, and February, rather than November, December, and January.

Ocean currents also affect the pressure of the air above them. For example, air above warm ocean currents becomes warmer and less dense, forming low-pressure systems. You will learn later how these systems influence weather.

Challenge

1 How could you use record low and high temperatures and other statistics for your region to make your forecasts more interesting?

2 Where will your imaginary community be located? For what conditions will it be designed?

Understanding Concepts

1. Use Figure 1 as a reference to answer these questions:
   (a) In what way are the ocean currents in the Southern Hemisphere Åmirror imagesÆ of those in the Northern Hemisphere?
   (b) Name three fast-moving surface currents and three slow-moving currents.
   (c) On which side of Australia (east or west) would you expect to find deserts? rain forests? Explain why. Use a map of Australia to check your answer.
   (d) In what other regions of the world would you expect to find deserts? Why?
2. The text states that ocean currents act as Åconveyer beltsÆ of energy. Explain what this means.
3. Explain why the name ÅAntarctic Circumpolar CurrentÆ is appropriate.
4. A student who lives on the south coast of New Zealand places a message in a bottle, seals the bottle, and throws it into the coastal waters. About four years later, another student finds the same bottle floating in the ocean on the coast of Iceland. Describe how this is possible. Include the names of the ocean currents as well as the continents that the bottle passed on its route to Iceland.
5. Why is it impossible to have an Arctic Circumpolar Current?
6. The Namib Desert is on the west coast of southern Africa. Explain how this region can be dry, even though it is on the Atlantic Ocean.
7. Explain why the coldest months of the year in the Northern Hemisphere are December, January, and February, even though the fewest daylight hours occur in December.

Making Connections

8. When big ships enter a harbour or channel that is unfamiliar to the captain, a local navigator comes onboard to help. What are some possible hazards the visiting captain may not know about?

Exploring

9. Research how ÅeddiesÆ form when warm and cold ocean (I) (J) currents meet. Why do fishing fleets like to track these slow-moving locations?
10. In the 1947 Kon-Tiki Expedition, six adventurers sailed a raft across the Pacific Ocean. Report on how currents and winds helped the sailors on their journey. Do you think the expedition accomplished its objectives?

SKILLS HANDBOOK: (I) (J) Research Skills