SECTION 3
The Hydrosphere and Biosphere

Life on Earth is restricted to a very narrow layer around the Earth's surface. In this layer, called the *biosphere,* everything that organisms need to survive can be found. One of the requirements of living things is liquid water.

Objectives

- Name the three major processes in the water cycle.
- Describe the properties of ocean water.
- Describe the two types of ocean currents.
- Explain how the ocean regulates Earth's temperature.
- Discuss the factors that confine life to the biosphere.
- Explain the difference between open and closed systems.

Key Terms

water cycle
evaporation
condensation
precipitation
salinity
fresh water
biosphere
closed system
open system

The Hydrosphere and Water Cycle

The hydrosphere includes all of the water on or near the Earth's surface. The hydrosphere includes water in the oceans, lakes, rivers, wetlands, polar ice caps, soil, rock layers beneath Earth's surface, and clouds.

The continuous movement of water into the air, onto land, and then back to water sources is known as the **water cycle,** which is shown in **Figure 17**. **Evaporation** is the process by which liquid water is heated by the sun and then rises into the atmosphere as water vapor. Water continually evaporates from Earth's oceans, lakes, streams, and soil, but the majority of the water evaporates from the oceans. In the process of **condensation,** water vapor forms water droplets on dust particles. These water droplets form clouds, in which the droplets collide, stick together, and create larger, heavier droplets. These larger droplets fall from clouds as rain in the process called **precipitation.** Precipitation may also take the form of snow, sleet, or hail.

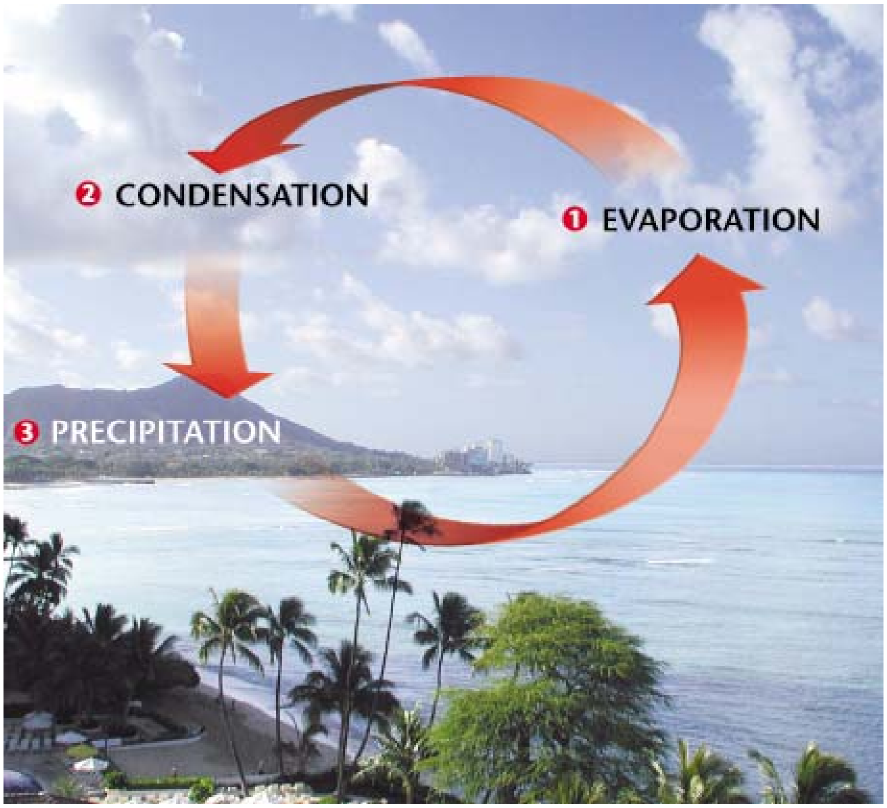


Figure 17 ▶ The major processes of the water cycle include ❶ evaporation, ❷ condensation, and ❸ precipitation.

Connection to Geology

Submarine Volcanoes Geologists estimate that approximately 80 percent of the volcanic activity on Earth takes place on the ocean floor. Most of this activity occurs as magma slowly flows onto the ocean floor where tectonic plates pull away from each other. But enormous undersea volcanoes are also common. Off the coast of Hawaii, a submarine volcano called the *Loihi Seamount* rises 5,185 m from the ocean floor. Loihi is just 915 m below the ocean's surface, and in several thousand years, this volcano may become the next Hawaiian Island.

Earth's Oceans

We talk about the Atlantic Ocean, the Pacific Ocean, the Arctic Ocean, and the Indian Ocean. However, if you look at **Figure 18,** you see that these oceans are all joined. This single, large, interconnected body of water is called the *world ocean*. Its waters cover a little over 70 percent of the Earth's surface. As we will see, the world ocean plays many important roles in regulating our planet's environment.

The largest ocean on Earth is the Pacific Ocean. It covers a surface area of approximately 165,640,000 km^2 and has an average depth of 4,280 m. The deepest point on the ocean floor is in the Pacific Ocean. The point is called the Challenger Deep and is located east of the Philippine Islands at the bottom of the Mariana Trench. The Challenger Deep is 11,033 m below sea level, which is deeper than Mount Everest is tall. Oceanographers often divide the Pacific Ocean into the North Pacific and South Pacific based on the direction of surface current flow in each half of the Pacific Ocean. Surface currents in the Pacific move in a clockwise direction north

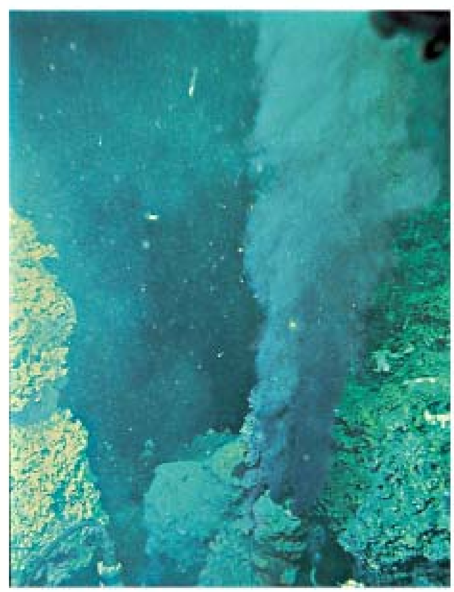
CASE STUDY

Hydrothermal Vents

The light from your tiny research submarine illuminates the desert-like barrenness of the deep-ocean floor. Suddenly, the light catches something totally unexpected—an underwater oasis teeming with sea creatures that no human has laid eyes on before. At the center of this community is a tall chimney-like structure from which a column of black water is rising.

This scene is much like the one which John Corliss and John Edmond witnessed when they discovered the first deep-sea hydrothermal vents and the odd community of creatures that inhabit them. Corliss's and Edmond's discovery was made during a dive in the submarine *Alvin* in early 1977. The dive site was in the eastern Pacific Ocean near the Galápagos Islands. Since the original dive, many more hydrothermal vents have been located on the ocean bottom.

Hydrothermal vents are openings in the ocean floor where super-hot, mineral-rich waters stream into the ocean. Hydrothermal vents form where tectonic plates are separating and where deep fractures are opening in the Earth's crust. Water seeps down into some of these fractures to a depth where it is heated by molten rock and enriched with minerals. The water returns to the ocean floor through other fractures and then pours into the ocean. Water often streams through structures called *chimneys*. Chimneys form when the minerals in the vent water—mostly iron and sulfur—precipitate as the water cools from above 100°C to less than 50°C. The tallest chimney reported to date is 49 m. Vent



▶ Superheated, mineral-rich water streams through a chimney at a hydrothermal vent on the floor of the Pacific Ocean.

of the equator, whereas surface currents flow in a counterclockwise direction south of the equator.

The second largest ocean on Earth is the Atlantic Ocean. It covers a surface area of 81,630,000 km², which is about half the area of the Pacific Ocean. Like the Pacific Ocean, the Atlantic Ocean can be divided into a north and south half based on the directions of surface current flow north and south of the equator.

The Indian Ocean covers a surface area of 73,420,000 km² and is the third-largest ocean on Earth. It has an average depth of 3,890 m.

The smallest ocean is the Arctic Ocean, which covers 14,350,000 km². The Arctic Ocean is unique because much of its surface is covered by floating ice. This ice, which is called *pack ice*, forms when either waves or wind drive together frozen seawater, known as sea ice, into a large mass.

Figure 18 ▶ The Pacific, Atlantic, Indian, and Arctic Oceans are interconnected into a single body of water, the world ocean, which covers 70 percent of Earth's surface.

▶ Over 300 species of organisms have been found in hydrothermal vent communities, including species of tube worms that may grow to a length of 3 m.

water can reach temperatures as high as 400°C.

The pressure at the ocean bottom is tremendous. No sunlight penetrates these depths, and hydrothermal vents spew minerals into their surroundings. Still, at least 300 species of organisms—all new to scientists—live near hydrothermal vents. These organisms include tube worms, giant clams, mussels, shrimp, crabs, sea anemones, and octopuses.

How is life at hydrothermal vents possible? Bacteria that live in vent communities can use hydrogen sulfide escaping from the vents as an energy source. Some animals that live in vent communities consume these bacteria to obtain their energy. Other animals have bacteria living inside their bodies that supply them with energy.

CRITICAL THINKING

1. Applying Processes Some scientists have suggested that life may have originated in or near hydrothermal vents because vent organisms are able to obtain their energy from chemicals in the absence of sunlight. Does this suggestion seem realistic?

2. Making Predictions How might the creatures that live in hydrothermal vent communities be of benefit to humankind in the future?

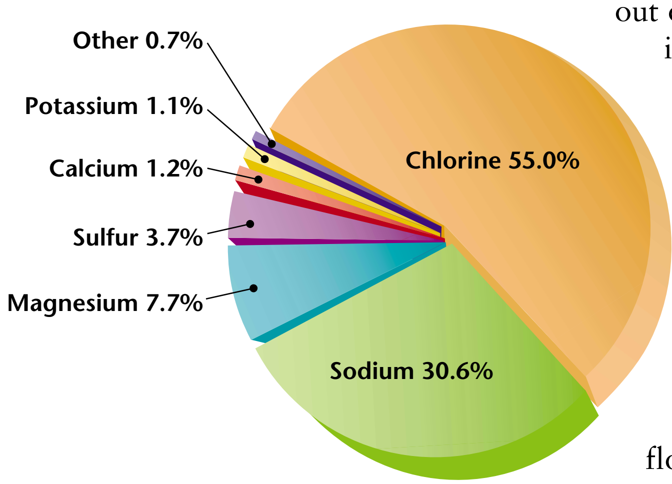


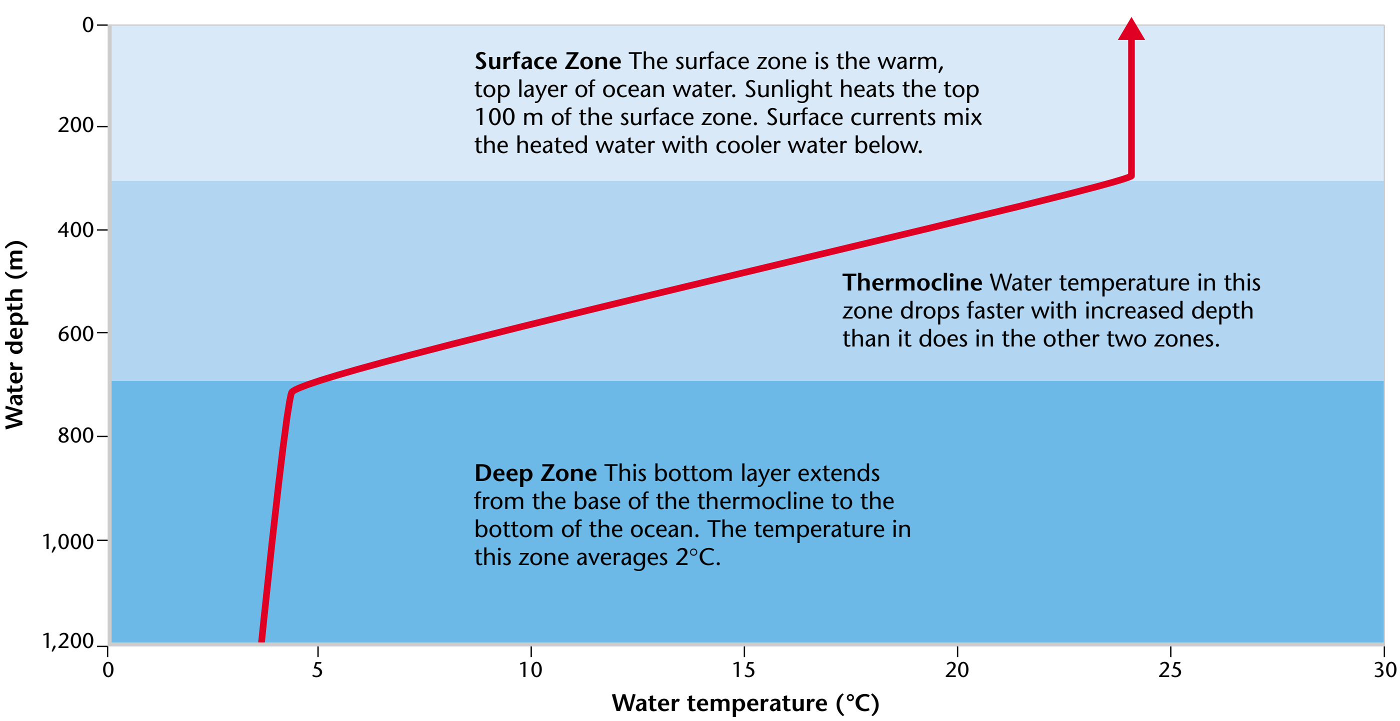
Figure 19 ▶ This pie graph shows the percentages by weight of dissolved solids found in ocean water. Sodium and chlorine, the two elements that form salt, are the most important dissolved solids in ocean water.

Ocean Water The difference between ocean water and fresh water is that ocean water contains more salts. These salts have dissolved out of rocks on land and have been carried down rivers into the ocean over millions of years. Underwater volcanic eruptions also add salts to the ocean.

As you can see in **Figure 19,** most of the salt in the ocean is sodium chloride, the same salt that we sprinkle on food. Sodium chloride, NaCl, is made up of the elements sodium, Na, and chlorine, Cl. The **salinity** of sea water is the total quantity of dissolved salts. The average salinity of sea water is 3.5 percent by weight. The salinity of ocean water is lower in places that get a lot of rain or in places where fresh water flows into the sea. Salinity is higher where water evaporates rapidly and leaves the salts behind.

Temperature Zones **Figure 20** shows the temperature zones of the ocean. The surface of the ocean is warmed by the sun. In contrast, the depths of the ocean, where sunlight never reaches, are very cold and have a temperature only slightly above freezing. Surface waters are stirred up by waves and currents, so the warm surface zone may be as much as 450 m deep. Below the surface zone is the thermocline, which is a layer about 2 km deep where the temperature falls rapidly with depth. If you have ever gone swimming in a deep lake in the summer, you have probably encountered a shallow thermocline. Sun warms the surface of the lake to a comfortable temperature, but if you

Figure 20 ▶ Water in the ocean can be divided into three zones based on temperature.



drop your feet, they fall into cold water that may be only slightly above freezing. The boundary between the warm and cold water is the thermocline.

A Global Temperature Regulator One of the most important functions of the world ocean is to absorb and store energy from sunlight. This capacity of the ocean to absorb and store energy from sunlight regulates temperatures in Earth's atmosphere.

The world ocean absorbs over half the solar radiation that reaches the planet's surface. The ocean both absorbs and releases heat more slowly than land does. As a consequence, the temperature of the atmosphere changes much more slowly than it would if there were no ocean on Earth. If the ocean did not regulate atmospheric and surface temperatures, the temperature would be too extreme for life on Earth to exist.

Local temperatures in different areas of the planet are also regulated by the world ocean. Currents that circulate warm water cause the land areas they flow past to have a more moderate climate. For example, the British Isles are warmed by the waters of the Gulf Stream, which moves warm waters from lower latitudes toward higher latitudes, as in **Figure 21.**

MATHPRACTICE

The Influence of the Gulf Stream The temperature of the British Isles is moderated by the Gulf Stream. Falmouth, England, and Winnipeg, Canada, are located at approximately 50° north latitude. Falmouth, which is located in extreme southwest England near the Atlantic Ocean, has average high temperatures of 18°C in June, 19°C in July, and 19°C in August. Winnipeg, which is located in the interior of North America, has average high temperatures of 22°C in June, 25°C in July, and 23°C in August. What is the difference in average high temperatures in degrees Celsius between Falmouth and Winnipeg?

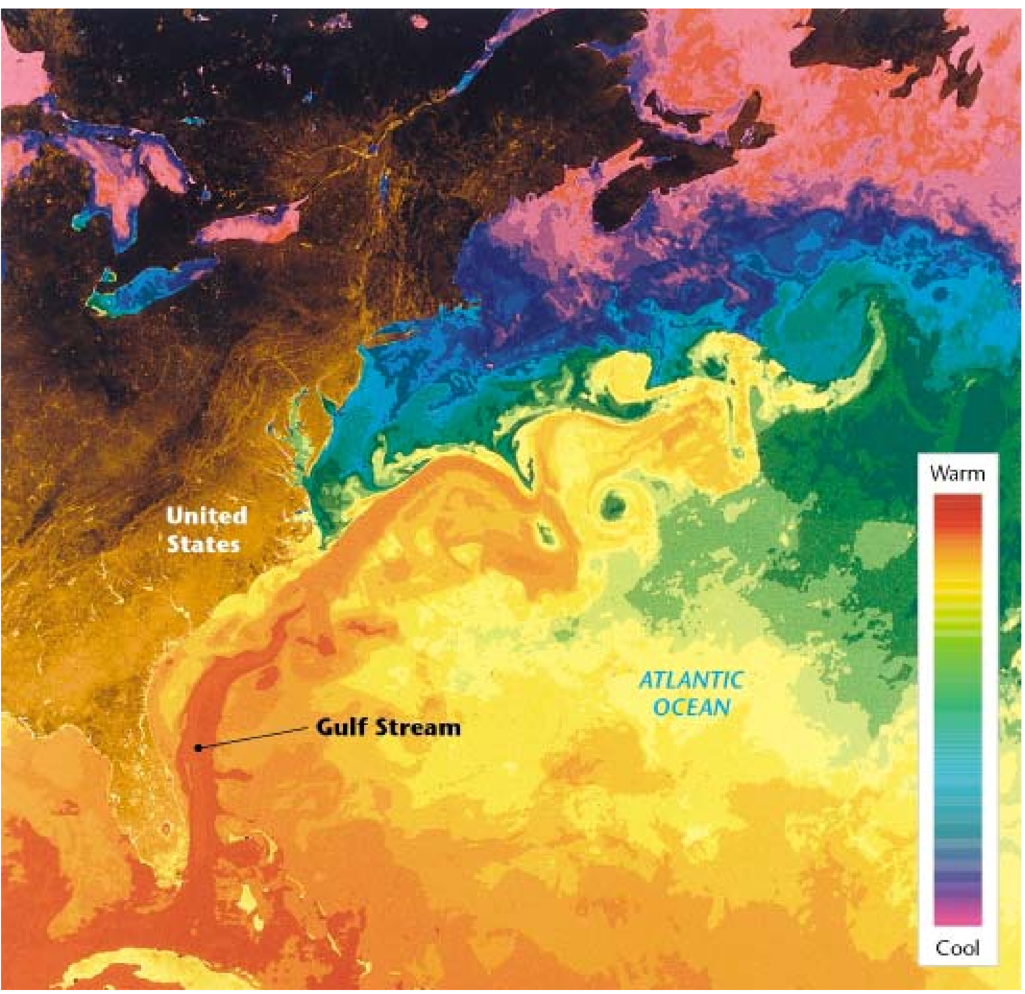


Figure 21 ▶ In this infrared satellite image, the Gulf Stream is moving warm water (shown in red, orange, and yellow) from lower latitudes into higher latitudes. The British Isles are warmed by the waters of the Gulf Stream.

QuickLAB

Make a Hydrothermal Vent

Procedure

1. Fill a **large glass container** or **aquarium** with very **cold water.**
2. Tie one end of a **piece of string** around the neck of a **small bottle.**
3. Fill the small bottle with **hot water,** and add a few drops of **food coloring.**
4. Keep the small bottle upright while you lower it into the glass container until it rests flat on the bottom.

Analysis

1. Did the food coloring indicate that the hot water and cold water mixed?

Ocean Currents Streamlike movements of water that occur at or near the surface of the ocean are called surface currents. Surface currents are wind driven and result from global wind patterns. **Figure 22** shows the major surface currents of the world ocean. Surface currents may be warm-water currents or cold-water currents. Currents of warm water and currents of cold water do not readily mix with one another. Therefore, a warm-water current like the Gulf Stream can flow for hundreds of kilometers through cold water without mixing and losing its heat.

Surface currents can influence the climates of land areas they flow past. As we have seen, the Gulf Stream moderates the climate in the British Isles. The Scilly Isles in England are as far north as Newfoundland in northeast Canada. However, palm trees grow on the Scilly Isles, where it never freezes, whereas Newfoundland has long winters of frost and snow.

Deep currents are streamlike movements of water that flow very slowly along the ocean floor. Deep currents form when the cold, dense water from the poles sinks below warmer, less dense ocean water and flows toward the equator. The densest and coldest ocean water is located off the coast of Antarctica. This cold water sinks to the bottom of the ocean and flows very slowly northward to produce a deep current called the Antarctic Bottom Water. The Antarctic Bottom Water creeps along the ocean floor for thousands of kilometers and reaches a northernmost point of approximately 40° north latitude. It takes several hundred years for water in this deep current to make this trip northward.

Figure 22 ▶ The oceans' surface currents circulate in different directions in each hemisphere.