13.5 Cycling of Matter

VOCABULARY

hydrologic cycle
biogeochemical cycle
nitrogen fixation

KEY CONCEPT **Matter cycles in and out of an ecosystem.**

MAIN IDEAS

- Water cycles through the environment.
- Elements essential for life also cycle through ecosystems.

Connect to Your World

Since life in most ecosystems requires a constant inflow of energy from the Sun, Earth is an open system in terms of energy. However, in terms of matter, such as oxygen and carbon, Earth is a closed system. Today's Earth has roughly the same amount of carbon as it had billions of years ago, meaning that the same carbon atoms that make up your body may once have been part of a tree, or gases spewed by a volcano, or even part of a dinosaur.

MAIN IDEA

Water cycles through the environment.

Matter changes form, but it does not disappear. It can be used over and over again in a continuous cycle. If you crush a rock, for example, it does not vanish. Instead, it turns into sand and other bits of minerals. Although matter may change form over time, the total amount of matter remains the same.

As you learned earlier, a major part of life on Earth is water, which has a cycle of its own. The **hydrologic cycle** (HY-druh-LAHJ-ihk), also known as the water cycle, is the circular pathway of water on Earth from the atmosphere, to the surface, below ground, and back. Part of that pathway involves humans and other organisms, which all have bodies made mostly of water.

As shown in **FIGURE 5.1,** precipitation, such as rain or snow, falls to Earth. Some of this precipitation seeps into the ground, some drops into ponds, streams, lakes, or other waterways, and some forms puddles or other temporary pools. Depending on the type of soil and rocks surrounding it and also on its location, groundwater may empty directly into oceans. Sometimes water flows first into lakes, swamps, or wetlands, but these—along with rivers, streams, and other freshwater sources—also feed into oceans.

In addition, some droplets of water quickly reenter the atmosphere through evaporation. Since oceans cover over 70 percent of Earth's surface, about 85 percent of Earth's evaporation occurs between the oceans and the atmosphere. On land, water vapor is released by plants during transpiration, which is evaporation that occurs between plant leaves and the atmosphere. The cycle is completed as water vapor in the atmosphere condenses and forms clouds, returning water to the surface once again in the form of precipitation.

Analyze **If the total amount of water on Earth does not change, why are there concerns about global freshwater shortages?**

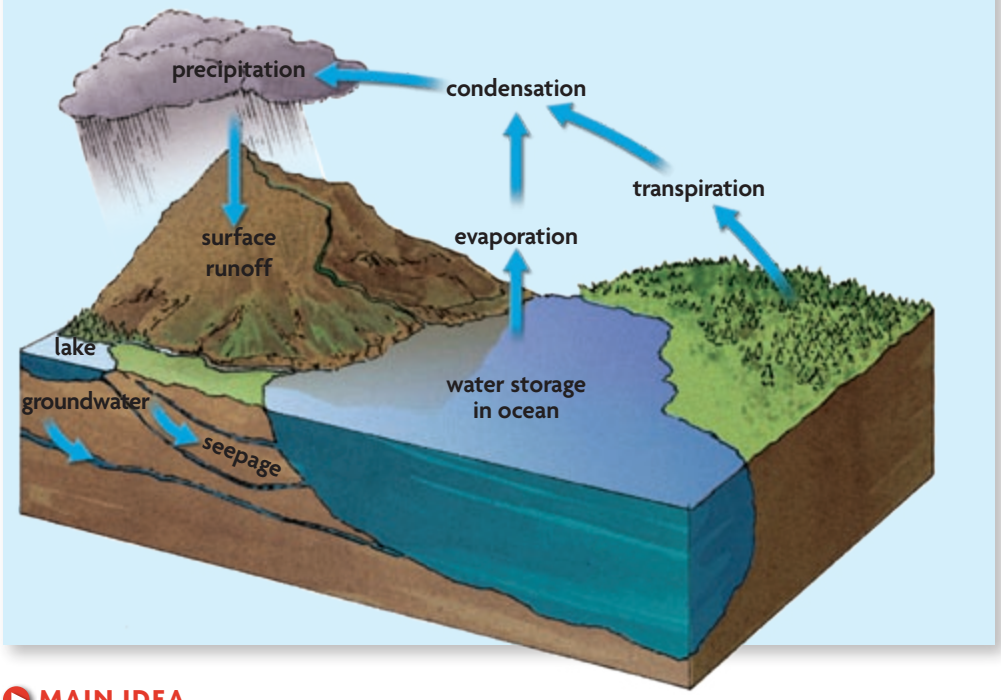
CONNECT TO

PROPERTIES OF WATER

The presence of water is necessary for life on Earth. All organisms depend on the simple structure of the water molecule. As you learned in **Chemistry of Life**, water has several unique properties. Water's high specific heat helps keep cells at the right temperature to carry out life processes.

FIGURE 5.1 Hydrologic Cycle

The hydrologic cycle is the circular pathway of water on Earth.



MAIN IDEA

Elements essential for life also cycle through ecosystems.

Many elements are essential to the structure and function of organisms. Elements are basic chemical substances, such as the oxygen and hydrogen found in the chemical compound of water. Additional elements important to life include carbon, nitrogen, phosphorus, and sulfur. As you learned in Chemistry of Life, oxygen, carbon, nitrogen, and hydrogen make up 96 percent of the mass of the human body. This is just one reason why the cycling of these elements is important. All of these elements cycle through ecosystems, as water does.

A **biogeochemical cycle** (BY-oh-JEE-oh-KEHM-ih-kuhl) is the movement of a particular chemical through the biological and geological, or living and nonliving, parts of an ecosystem. Just as water changes from solid form (ice or snow) to liquid form (rain) or gaseous form (water vapor), other substances may also change state as they move through their cycles.

The Oxygen Cycle

Plants, animals, and most other organisms need oxygen for cellular respiration. As shown in **FIGURE 5.2,** plants release oxygen as a waste product during photosynthesis. In turn, humans and other organisms take in this oxygen and release it as carbon dioxide through respiration. Oxygen is also indirectly transferred through an ecosystem by the cycling of other nutrients, including carbon, nitrogen, and phosphorus.

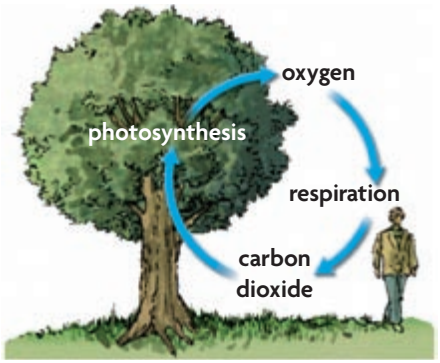


FIGURE 5.2 In the oxygen cycle, oxygen flows into the atmosphere as a byproduct of photosynthesis. Organisms take in this oxygen and release it as carbon dioxide through respiration.

Apply **Explain how deforestation might affect the oxygen cycle.**

Biology VIDEO CLIP
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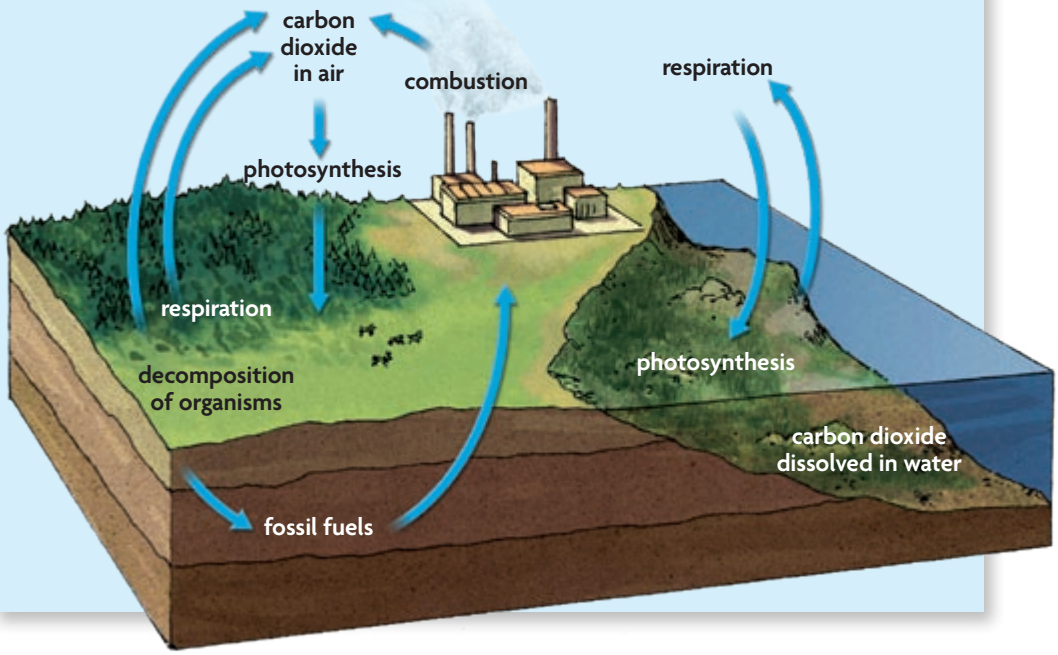
PREMIUM CONTENT
Carbon Cycle

FIGURE 5.3 Carbon Cycle

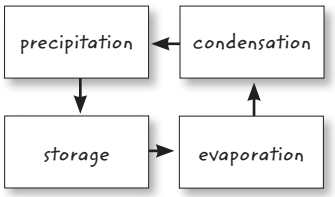
Photosynthesis and respiration account for much of the transformation and movement of carbon.



READING TOOLBOX

TAKING NOTES

For each cycle, draw and label a simple diagram in your notes.



The Carbon Cycle

Carbon is the building block of life—it is key to the structure of all organisms on our planet. It is an essential component of carbohydrates, proteins, fats, and all the other organic molecules that make up your body. Carbon continually flows from the environment to living organisms and back again in the carbon cycle, shown in **FIGURE 5.3.**

Carbon exists in the abiotic world in several forms. Carbon can be found in solid, liquid, and gaseous states. Sources of carbon include

- carbon dioxide (CO_2) gas in the atmosphere
- bicarbonate (HCO_3^-) dissolved in water
- fossil fuels, which are underground deposits of oil, natural gas, and coal
- carbonate rocks, such as limestone
- dead organic matter, such as humus, in the soil

The simplest transfer of carbon occurs between plants and animals. Plants use energy from the sun to convert carbon dioxide from the air into organic material that becomes a part of the plant's structure. The carbon then moves through the biotic world as one organism eats another.

Carbon is returned to the atmosphere as carbon dioxide by respiration or through the decomposition of dead organisms. The burning of fossil fuels and wood, as well as emissions from factories and automobiles, adds to carbon dioxide in the atmosphere. Another source of atmospheric carbon is methane, which is emitted from wetlands, landfills, and livestock.

Not all carbon molecules move freely through the cycle. Areas that store carbon over a long period of time are called carbon sinks. One example is forest land, where large amounts of carbon are stored in the cellulose of wood.

The Nitrogen Cycle

About 78 percent of Earth's atmosphere is made of nitrogen gas. However, most organisms can use nitrogen only in the form of ions such as ammonium (NH_4^+) or nitrate (NO_3^-). As shown in **FIGURE 5.4,** much of the nitrogen cycle takes place underground.

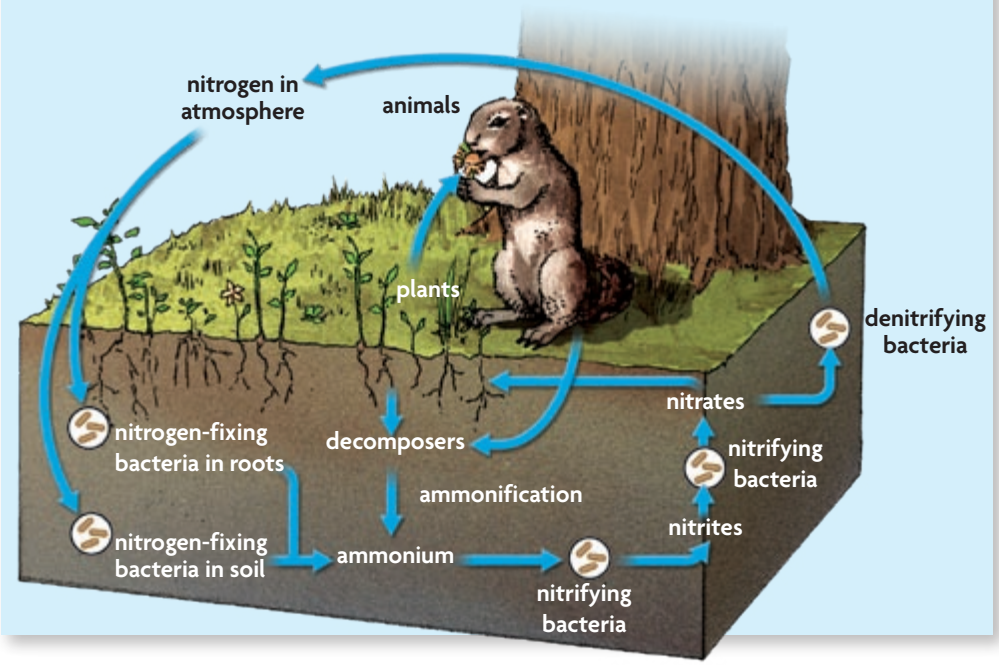
Certain types of bacteria convert gaseous nitrogen into ammonia (NH_3) through a process called **nitrogen fixation.** A few types of cyanobacteria fix nitrogen in aquatic ecosystems. On land, some nitrogen-fixing bacteria live in small outgrowths, called nodules, on the roots of plants such as beans and peas. Other nitrogen-fixing bacteria live freely in the soil. The ammonia released by these bacteria is transformed into ammonium by the addition of hydrogen ions found in acidic soil. Some ammonium is taken up by plants, but most is used by nitrifying bacteria as an energy source. Through the process called nitrification, these bacteria change ammonium into nitrate.

Nitrates released by soil bacteria are taken up by plants, which convert them into organic compounds such as amino acids and proteins. Nitrogen continues along the cycle as animals eat plant or animal matter. When decomposers break down animal excretions or dead animal and plant matter, nitrogen is returned to the soil as ammonium, in a process called ammonification.

Denitrifying bacteria use nitrate as an oxygen source, releasing nitrogen gas into the atmosphere as a waste product. Some nitrogen also enters the soil as a result of atmospheric fixation by lightning. Lightning's energy breaks apart nitrogen molecules in the atmosphere. Nitrogen recombines with oxygen in the air, forming nitrogen oxide. The combination of nitrogen oxide with rainwater forms nitrates, which are absorbed by the soil.

FIGURE 5.4 Nitrogen Cycle

Much of the nitrogen cycle occurs underground, where bacteria transform ammonium into nitrates, which are used by plants to make amino acids.

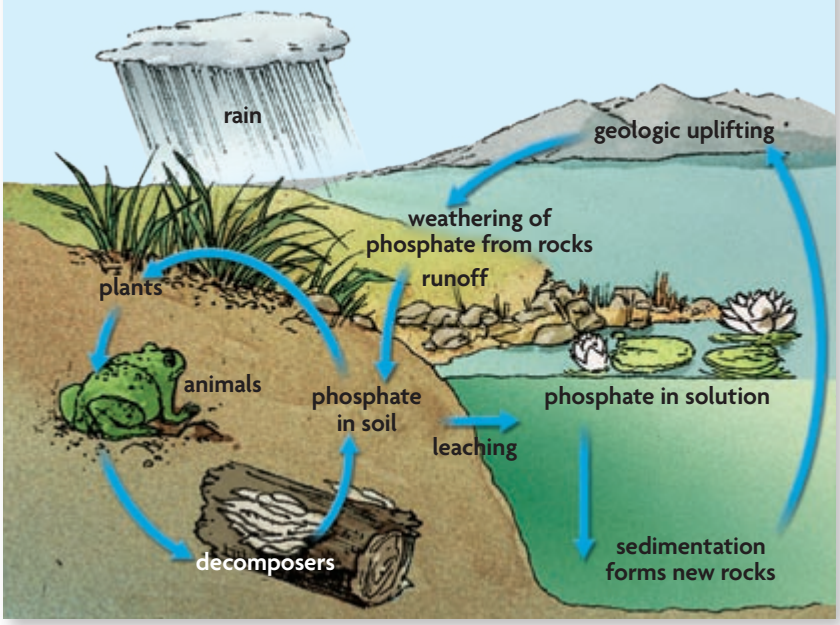


The Phosphorus Cycle

Unlike the other cycles, the phosphorus cycle does not include an atmospheric portion. Instead, most of the cycle takes place at and below ground level, as shown in **FIGURE 5.5.**

FIGURE 5.5 Phosphorus Cycle

The phosphorus cycle occurs on a local, rather than global, scale. Its cycle is limited to water, soil, and ocean sediment.



The phosphorus cycle begins when phosphate is released by the weathering of rocks. Plants and some fungi found near plant roots are able to take up phosphate. Phosphorus moves from producers to consumers through the food web. When the producers and consumers die, decomposers break down the organisms. This process releases phosphorus back into the soil or water for use by producers. Some phosphorus may leach into groundwater from the soil. This groundwater may flow into a lake or other body of water, where the phosphorus becomes locked in sediments at the bottom. Over many thousands of years, these sediments eventually become rock again, and the cycle starts again as phosphate is released by the weathering of these newly formed rocks.

Mining and agricultural runoff also add to the overall amount of phosphorus in the environment. The excessive flow of phosphorus into an aquatic ecosystem from sewage and agricultural runoff can cause significant problems. Phosphorus is a limiting factor for the growth of plants. Large amounts of phosphorus within an aquatic environment can lead to algal blooms. These blooms crowd out other plant species and negatively impact wildlife populations as well.

Summarize Choose one of the biogeochemical cycles, and list the key processes involved in the cycling of the element.

13.5 Formative Assessment

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PREMIUM CONTENT

REVIEWING MAIN IDEAS

1. How does the **hydrologic cycle** move water through the environment?
2. What are four elements that cycle through ecosystems, and why are they important?

CRITICAL THINKING

3. **Apply** Why might farmers plant legumes such as peas to improve the nitrogen levels in their soil?
4. **Synthesize** Explain the importance of decomposers to the overall **biogeochemical cycle**.

CONNECT TO

EVOLUTION

5. How might Earth's biogeochemical cycles help scientists to understand the early history of life on Earth?