SECTION 2
The Cycling of Materials

Objectives

- ▶ List the three stages of the carbon cycle.
- ▶ Describe where fossil fuels are located.
- ▶ Identify one way that humans are affecting the carbon cycle.
- ▶ List the three stages of the nitrogen cycle.
- ▶ Describe the role that nitrogen-fixing bacteria play in the nitrogen cycle.
- ▶ Explain how the excess use of fertilizer can affect the nitrogen and phosphorus cycles.

Key Terms

carbon cycle
nitrogen-fixing bacteria
nitrogen cycle
phosphorus cycle

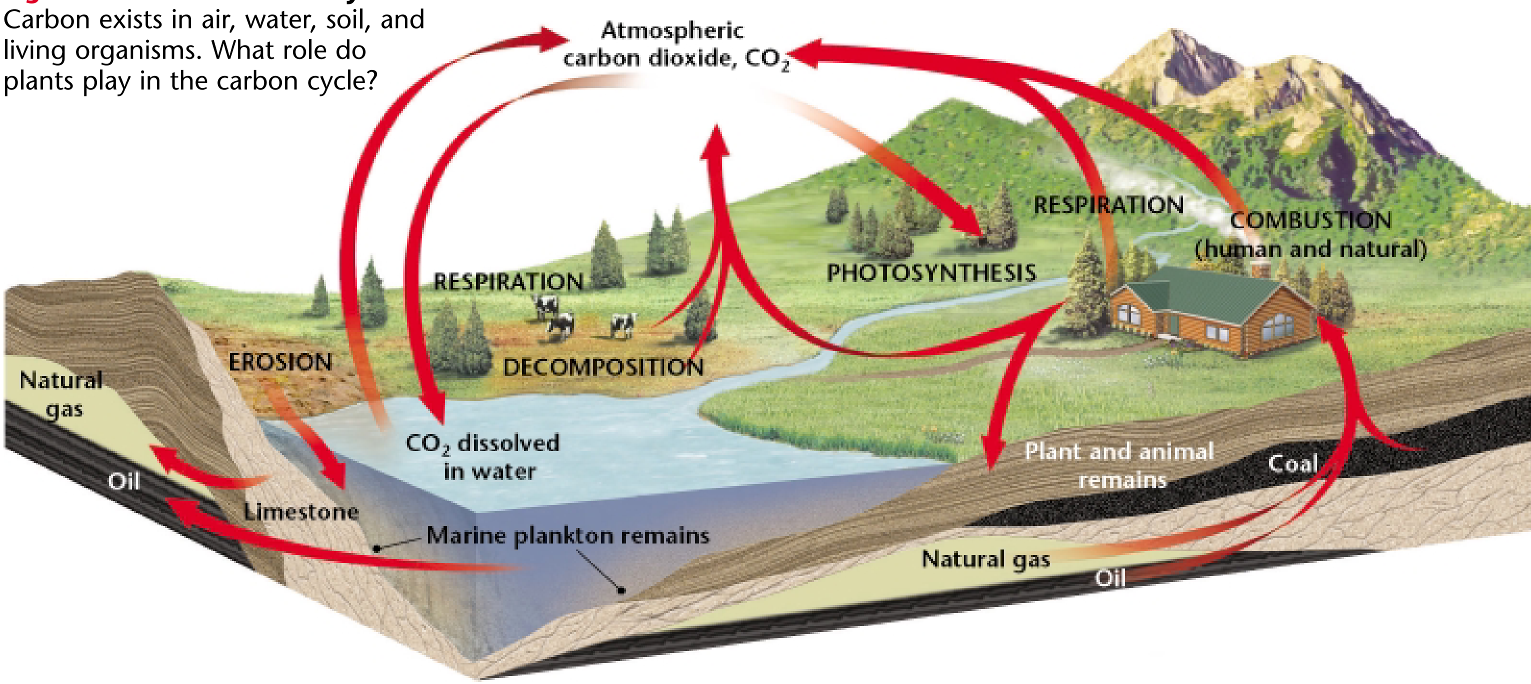
What will happen to the next ballpoint pen you buy? You will probably use it until its ink supply runs out and then throw it away. The plastic and steel the pen is made of will probably never be reused. By contrast, materials in ecosystems are constantly reused. In this section, you will read about three cycles by which materials are reused—the carbon cycle, the nitrogen cycle, and the phosphorus cycle.

The Carbon Cycle

Carbon is an essential component of proteins, fats, and carbohydrates, which make up all organisms. The **carbon cycle** is a process by which carbon is cycled between the atmosphere, land, water, and organisms. As shown in **Figure 10,** carbon enters a short-term cycle in an ecosystem when producers, such as plants, convert carbon dioxide in the atmosphere into carbohydrates during photosynthesis. When consumers eat producers, the consumers obtain carbon from the carbohydrates. As the consumers break down the food during cellular respiration, some of the carbon is released back into the atmosphere as carbon dioxide. Organisms that make their own food through photosynthesis also release carbon dioxide during cellular respiration.

Some carbon enters a long-term cycle. For example, carbon may be converted into *carbonates,* which make up the hard parts of bones and shells. Bones and shells do not break down easily.

Figure 10 ▶ The Carbon Cycle Carbon exists in air, water, soil, and living organisms. What role do plants play in the carbon cycle?



Over millions of years, carbonate deposits produce huge formations of limestone rocks. Limestone is one of the largest *carbon sinks,* or carbon reservoirs, on Earth.

Some carbohydrates in organisms are converted into fats, oils, and other molecules that store energy. The carbon in these molecules may be released into the soil or air after an organism dies. When these molecules are released they can form deposits of coal, oil, and natural gas underground known as *fossil fuels*. Fossil fuels are essentially stored carbon left over from bodies of plants and animals that died millions of years ago.

How Humans Affect the Carbon Cycle When we burn fossil fuels, we release carbon into the atmosphere. The carbon returns to the atmosphere as carbon dioxide. Cars, factories, and power plants rely on these fossil fuels to operate. In the year 2000, vehicles, such as the truck in **Figure 11,** were the source of one-third of all carbon dioxide emitted in the United States. All together, about 6 billion metric tons of carbon a year are released into the atmosphere as carbon dioxide. Natural burning of wood or forest fires combined with the burning of fossil fuels make up this 6 billion metric tons. About half of this carbon dioxide remains in the atmosphere, so over a period of years, the amount of carbon dioxide in the atmosphere has steadily increased.

Increased levels of carbon dioxide may contribute to global warming, which is an overall increase in the temperature of the Earth. What happens to the carbon dioxide that is not absorbed by the atmosphere? Scientists estimate that over a billion metric tons of carbon dioxide dissolves into the ocean, which is a carbon sink. Plants probably absorb the remaining carbon dioxide.

QuickLAB

Make Every Breath Count

Procedure

1. Pour **100 mL** of **water** from a **graduated cylinder** into a **250 mL beaker.** Add several drops of **brom thymol blue** to the beaker of water. Make sure you add enough to make the solution a dark blue color.
2. Exhale through a **straw** into the solution until the solution turns yellow. (CAUTION: Be sure not to inhale or ingest the solution.)
3. Pour the yellow solution into a large **test tube** that contains a **sprig of *Elodea*.**
4. **Stopper** the test tube, and place it in a sunny location.
5. Observe the solution in the test tube after 15 minutes.

Analysis

1. What do you think happened to the carbon dioxide that you exhaled into the solution? What effect do plants, such as the *Elodea,* have on the carbon cycle?

Connection to Biology

The Rise of Carbon Dioxide
In the past 150 years, more than 350 billion tons of carbon have been released into the air in the form of carbon dioxide. The concentration of carbon dioxide today has increased 30 percent since preindustrial times. If the present amount of carbon dioxide emission continues, this concentration will double by 2080. Many scientists speculate that as a result, Earth's temperature may rise by 3°C.

Figure 11 ▶ This truck releases carbon into the atmosphere when it burns fuel to operate.

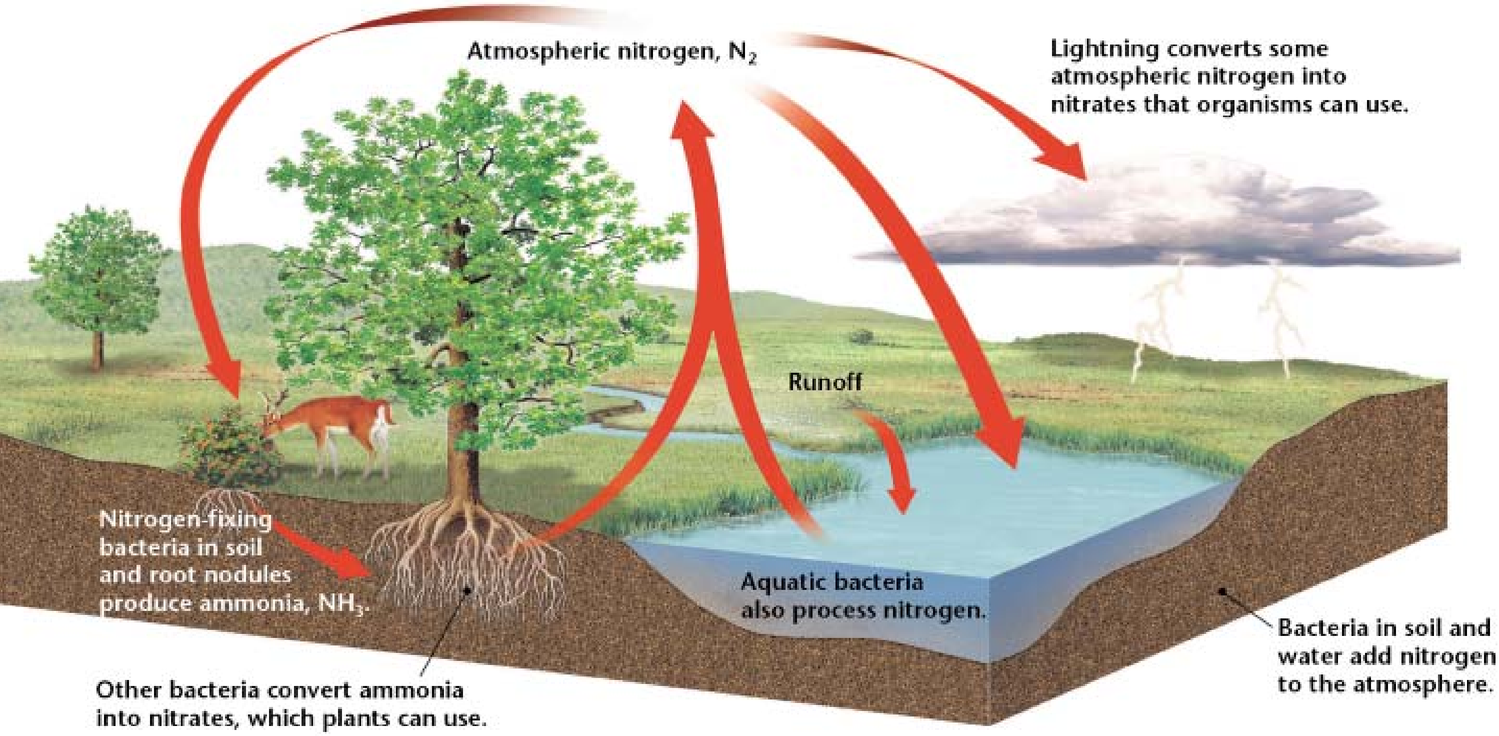


Figure 12 ▶ The Nitrogen Cycle Nitrogen could not be cycled in the atmosphere without nitrogen-fixing bacteria. What role do animals play in the nitrogen cycle?

Figure 13 ▶ The swellings on the roots of this soybean plant are called *nodules*. Nitrogen-fixing bacteria, as shown magnified at right, live inside the nodules of plants.

The Nitrogen Cycle

All organisms need nitrogen to build *proteins*, which are used to build new cells. Nitrogen makes up 78 percent of the gases in the atmosphere. However, most organisms cannot use atmospheric nitrogen. It must be altered, or fixed, before organisms can use it. The only organisms that can fix atmospheric nitrogen into chemical compounds are a few species of bacteria known as **nitrogen-fixing bacteria.** All other organisms depend upon these bacteria to supply nitrogen. Nitrogen-fixing bacteria are a crucial part of the **nitrogen cycle,** a process in which nitrogen is cycled between the atmosphere, bacteria, and other organisms. As shown in **Figure 12,** bacteria take nitrogen gas from the air and transform it into molecules that living things can use.

Nitrogen-fixing bacteria, shown in **Figure 13,** live within nodules on the roots of plants called *legumes*. Legumes include beans, peas, and clover. The bacteria use sugars provided by the legumes to produce nitrogen-containing compounds such as nitrates. The excess nitrogen fixed by the bacteria is released into the soil. In addition, some nitrogen-fixing bacteria live in the soil rather than inside the roots of legumes. Plants that do not have nitrogen-fixing bacteria in their roots get nitrogen from the soil. Animals get nitrogen by eating plants or other animals, both of which are sources of usable nitrogen.

Decomposers and the Nitrogen Cycle In the nitrogen cycle, nitrogen moves between the atmosphere and living things. After nitrogen cycles from the atmosphere to living things, nitrogen is again returned to the atmosphere with the help of bacteria. These decomposers are essential to the nitrogen cycle because they break down wastes, such as urine, dung, leaves, and other decaying plants and animals and return the nitrogen that these wastes and dead organisms contain to the soil. If decomposers did not exist, much of the nitrogen in ecosystems would be stored in wastes, corpses, and other parts of organisms. After decomposers return the nitrogen to the soil, bacteria transform a small amount of the nitrogen into nitrogen gas, which then returns to the atmosphere and completes the nitrogen cycle. So once nitrogen enters an ecosystem, most of it stays within the ecosystem, cycles between organisms and the soil, and is constantly reused.

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The Phosphorus Cycle

Phosphorus is an element that is a part of many molecules that make up the cells of living organisms. For example, phosphorus is an essential material needed to form bones and teeth in animals. Plants get the phosphorus they need from soil and water, while animals get their phosphorus by eating plants or other animals that have eaten plants. The **phosphorus cycle** is the movement of phosphorus from the environment to organisms and then back to the environment. This cycle is slow and does not normally occur in the atmosphere because phosphorus rarely occurs as a gas.

As shown in **Figure 14**, phosphorus may enter soil and water in a few ways. When rocks erode, small amounts of phosphorus dissolve as phosphate in soil and water. Plants absorb phosphates in the soil through their roots. In addition, phosphorus is added to soil and water when excess phosphorus is excreted in waste from organisms and when organisms die and decompose. Some phosphorus also washes off the land and eventually ends up in the ocean. Many phosphate salts are not soluble in water, so they sink to the bottom of the ocean and accumulate as sediment.

Geofact

Minerals in Your Mouth
Phosphorus is the 11th most abundant element in the Earth's crust and occurs naturally as phosphate in the mineral apatite. Apatite can exist in igneous, metamorphic, and sedimentary rocks as well as in your teeth and bones.

Figure 14 ▶ The Phosphorus Cycle Phosphorus moves from phosphate deposits in rock to the land, then to living organisms, and finally to the ocean.

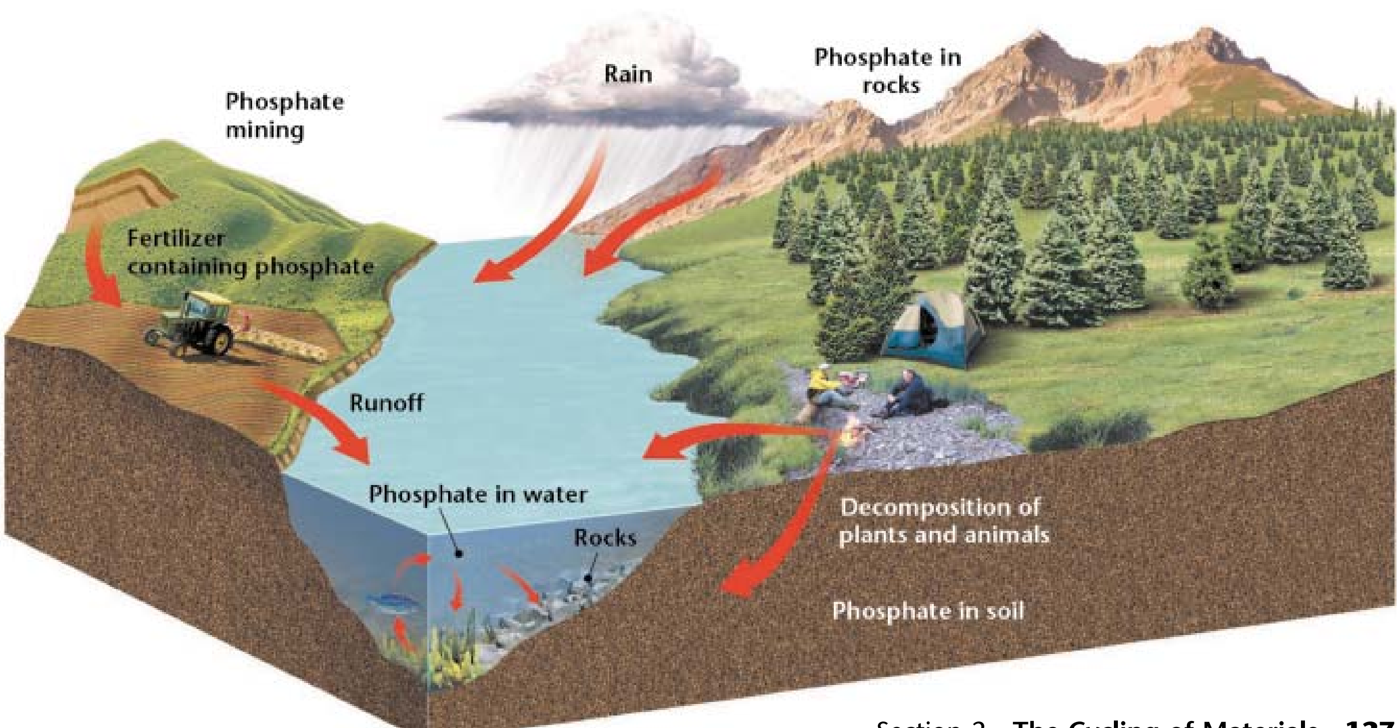

Figure 15 ▶ More than 30 percent of fertilizer may flow with runoff from farmland into nearby waterways. Large amounts of fertilizer in water can cause an excessive growth of algae (below).

Fertilizers and the Nitrogen and Phosphorus Cycles People often apply fertilizers to stimulate and maximize plant growth. Fertilizers contain both nitrogen and phosphorus. The more nitrogen and phosphorus that is available to a plant, the faster and bigger the plant tends to grow. However, if excessive amounts of fertilizer are used, the fertilizer can enter terrestrial and aquatic ecosystems through runoff. Excess nitrogen and phosphorus in an aquatic ecosystem or nearby waterway can cause rapid and overabundant growth of algae, which results in an *algal bloom.* An algal bloom, as shown in **Figure 15,** is a dense, visible patch of algae that occurs near the surface of water. Algal blooms, along with other plants and the bacteria that break down dead algae, can deplete an aquatic ecosystem of important nutrients such as oxygen. Fish and other aquatic organisms need oxygen to survive.

Acid Precipitation We affect the nitrogen cycle every time we burn coal, wood, or oil. When we burn fuel, a large amount of nitric oxide is released into the atmosphere. Nitric oxide is a harmful gas, and when it is released into the air, it can combine with oxygen and water vapor to form nitric acid. Nitric acid can dissolve in rain and snow, which contributes to acid precipitation.

SECTION 2 Review

1. **Describe** the three stages of the carbon cycle.
2. **Describe** how the burning of fossil fuels affects the carbon cycle.
3. **Explain** how the excess use of fertilizer affects the nitrogen cycle and the phosphorus cycle.
4. **Explain** why the phosphorus cycle occurs more slowly than both the carbon cycle and the nitrogen cycle.

CRITICAL THINKING

5. **Making Comparisons** Write a short paragraph that describes the importance of bacteria in the carbon, nitrogen, and phosphorus cycles. What role does bacteria play in each cycle? WRITING SKILLS
6. **Applying Ideas** What is one way that a person can help reduce the level of carbon dioxide in the atmosphere? Can you think of more than one way?