Chapter 18

Ecosystems

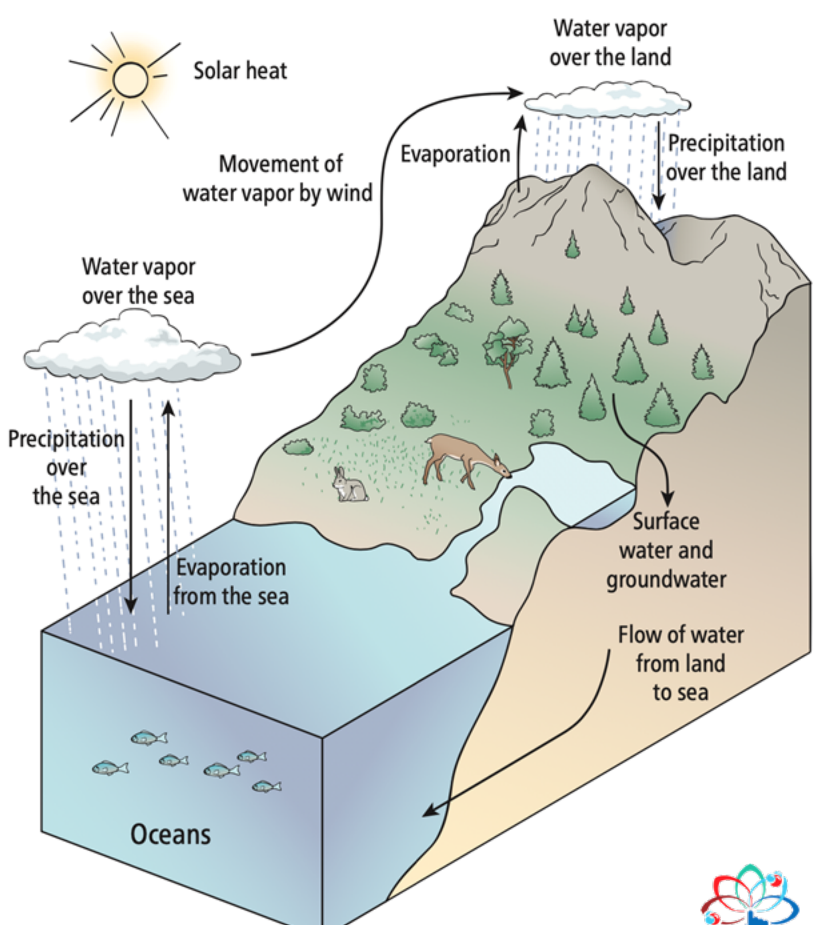
18.3 Biogeochemical Cycles

A water molecule in a cell on your cheek once bobbed on the Indian Ocean. A carbon atom on the skin over your knee once floated in the cold air above Antarctica. A nitrogen atom flowing through your veins was once part of Albert Einstein. Parts of you have been all over the world, in places you have never seen with your own eyes, even in important historical figures! How is this possible?

Living organisms are made up of many substances, including water, carbon, nitrogen, phosphorus, sodium, calcium, sulfur, chlorine, and many others. All these substances move around Earth in a series of **biogeochemical cycles**, going back and forth between the tissues of living organisms and the abiotic world. The word *biogeochemical* emphasizes that substances cycle between living organisms (*bio*) and Earth (*geo*)—specifically, Earth's atmosphere, crust, and waters.

FIGURE 18.9

Water cycles through the oceans, atmosphere, and land. Some water enters the bodies of living organisms.



As atoms and molecules move through their biogeochemical cycles, they pass through a series of *reservoirs*—that is, places where they stay for a period of time, as shown in Figure 18.9. For example, a water molecule may sit in one reservoir, the ocean, until evaporation moves it to another reservoir, the atmosphere. It may then fall as precipitation into a third reservoir, a lake. The average amount of time a molecule spends in each reservoir—for example, the average amount of time a water molecule spends in the ocean before it moves to another reservoir—is known as its *residence time* in that reservoir. Although every substance used by living organisms has a biogeochemical cycle, we will focus on three of the most important: water, carbon, and nitrogen.

Water

All living things need water. About 98 percent of the water on Earth is found in oceans, rivers, and lakes. The rest—about 2 percent—is found in glaciers, in the polar ice caps, in soil—and in living organisms. The global water cycle, shown in Figure 18.9, describes how water moves around Earth. Water evaporates from the oceans into the atmosphere, is moved around the atmosphere by winds, and then falls back to Earth as rain or snow. Water that falls on land flows back to the oceans through rivers, streams, and groundwater.

Water enters the biotic world when it is absorbed or swallowed by organisms. Some of this water may pass up the food chain. The rest is returned to the abiotic environment through processes such as respiration, perspiration, excretion, and elimination. Plants also lose water when it evaporates inside leaves and then escapes through the stomata to the atmosphere. Did you know that every time you exhale, you return water to the atmosphere? If you breathe onto a cool mirror the water vapor in your breath will condense to form a foggy film of liquid water. Thus, with every breath you exhale, you are returning water molecules from the biotic to the abiotic world.

Carbon

Carbon is an essential component of all organic molecules. The carbon cycle is shown in Figure 18.10. Much of the inorganic carbon on Earth exists as carbon dioxide and is found either in the atmosphere or dissolved in ocean waters.

Carbon enters the biotic world during photosynthesis, when plants and other producers use carbon dioxide to make the organic molecule glucose. This carbon becomes available to other organisms as it moves up the food chain. Carbon is returned to the abiotic world during cellular respiration, when organisms break down organic molecules (such as glucose) and release carbon dioxide. Carbon is also returned to the abiotic world through the process of combustion, as occurs during a forest fire.

An important part of Earth's carbon supply is found in fossil fuels such as coal and oil. Both coal and oil are formed over long time periods from the remains of dead organisms. This is why they are called "fossil" fuels. Notably, fossil fuels are generally considered biotic because they arose from living organisms.

Human burning of fossil fuels has released so much carbon into the atmosphere that atmospheric carbon dioxide levels are now higher than they have been for 15 million years. Because atmospheric carbon dioxide traps heat on the planet, Earth has warmed noticeably as a result. This warming of Earth is called *global warming*, which is a major issue facing humanity and appropriately addressed in a chemistry or environmental science course.

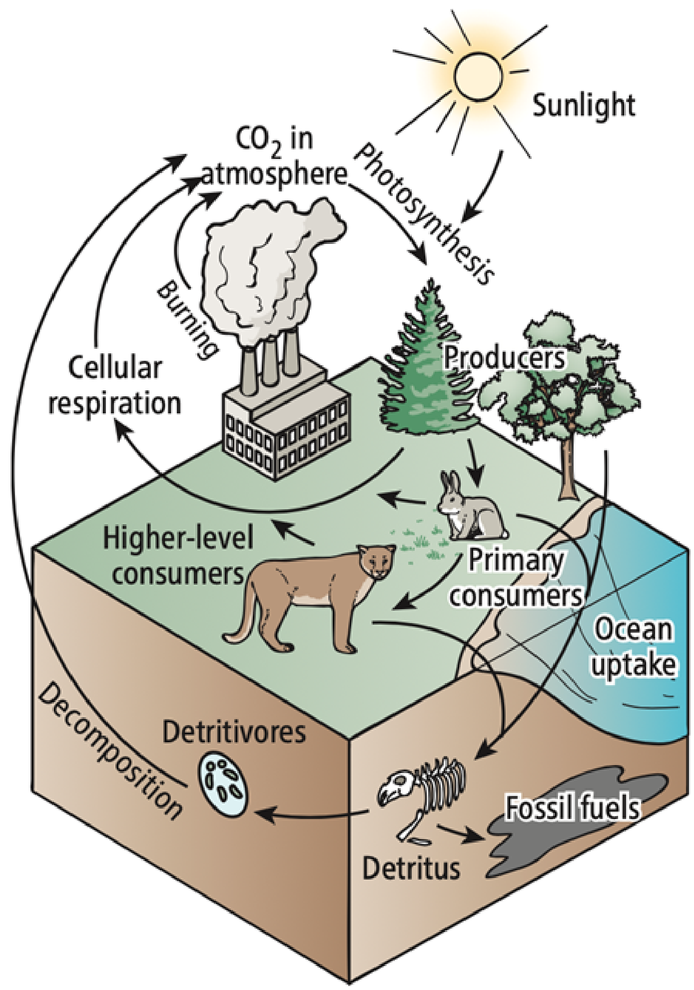


FIGURE 18.10

Carbon is found as carbon dioxide in the atmosphere and oceans. During photosynthesis, producers move carbon into the biotic world. Carbon is returned to the abiotic world as carbon dioxide, a product of cellular respiration.

Nitrogen

Nitrogen is an essential component of amino acids, DNA, and many other organic molecules. The nitrogen cycle is shown in Figure 18.11. Most of Earth's nitrogen exists as nitrogen gas, N_2, in the atmosphere. However, this nitrogen is not a form of nitrogen that most living things can use. Why not? Because N_2 is an amazingly stable molecule, which means it is rather inert and not easy to transform through chemical or biochemical processes. Certain bacteria, however, have evolved to overcome this barrier.

Nitrogen-fixing bacteria in soil convert nitrogen gas, N_2, into ammonium ions, and then *nitrifying bacteria* convert ammonium ions into nitrates. Plants absorb nitrogen primarily in the form of nitrates, although they make some use of ammonium ions as well. Nitrogen then moves from plants up the food chain. Nitrogen returns to the abiotic environment when it is converted back into nitrogen gas by denitrifying bacteria.

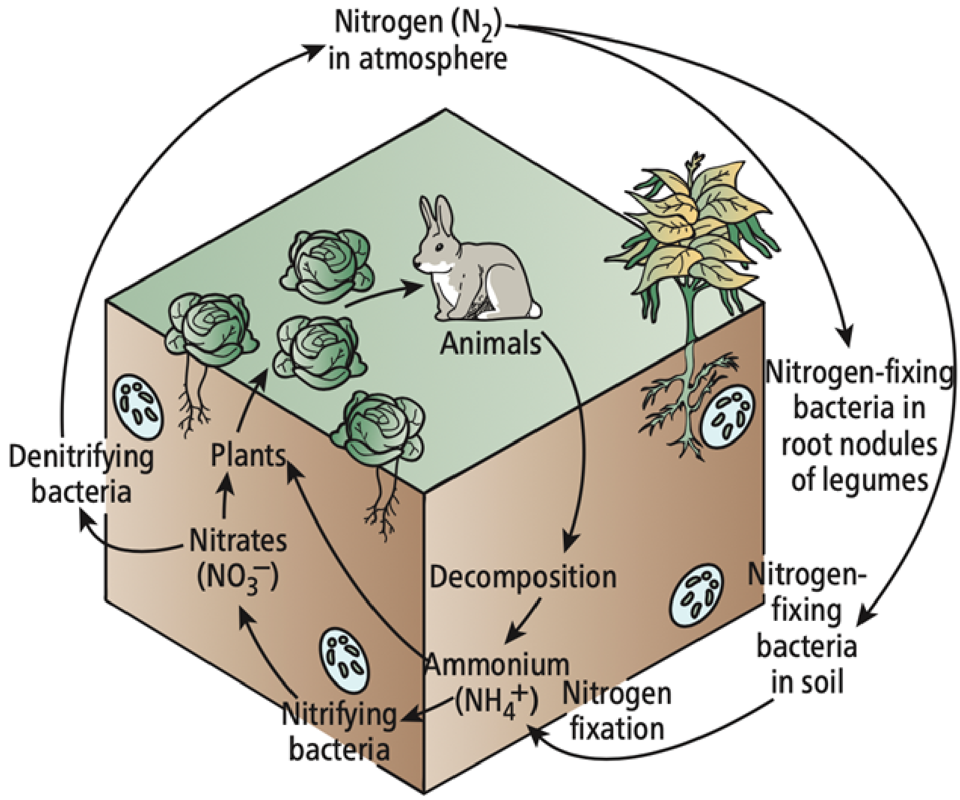


FIGURE 18.11

Nitrogen is found as nitrogen gas in the atmosphere. Bacteria convert atmospheric nitrogen into forms that can be used by living organisms.

Certain plants, including legumes such as peas, beans, clover, and alfalfa, have evolved a mutualistic relationship with nitrogen-fixing bacteria.

These plants shelter the bacteria in special nodules in their roots, and the bacteria provide the plants with nitrogen (Figure 18.12). This is why farmers often grow legumes with other plants:

The excess nitrogen enriches the soil and allows other crops to grow better. These days, however, not all plants rely on bacteria for nitrogen—industrial processes have been invented for making nitrogen-rich fertilizers. This has allowed humans to grow more food and to support larger human populations, but industrial fertilizers also pollute and damage natural environments.

FIGURE 18.12

Legumes house symbiotic nitrogen-fixing bacteria in special root nodules like those shown here.

READING CHECK

What living things do you, as a human, rely on to obtain (a) water, (b) carbon, and (c) nitrogen?

CHECK YOUR ANSWERS

a. You don't have to rely on other living things to obtain water—you can drink it directly!

b. All the carbon in your body comes ultimately from plants and other photosynthesizers. This carbon comes to you through the food you eat.

c. The nitrogen in your body also comes through the food you eat. Nitrogen-fixing bacteria and nitrifying bacteria change nitrogen into a form that plants can use, and then you eat the plants (or the animals that eat the plants).

You can learn more about the water cycle here:

https://www.noaa.gov/education/resource-collections/freshwater/water-cycle

Read about the carbon cycle here:

https://www.noaa.gov/education/resource-collections/climate/carbon-cycle

https://earthobservatory.nasa.gov/features/CarbonCycle

And check out this website on the nitrogen cycle:

https://www.visionlearning.com/en/library/Earth-Science/6/The-Nitrogen-Cycle/98