3–3 Cycles of Matter

TEKS FOCUS: 2A Implement investigative procedures; 9D Flow of matter and energy; 12A Carbon cycle, nitrogen cycle, water cycle; TEKS SUPPORT: 2D Communicate valid conclusions

Guide for Reading

Key Concepts
- How does matter move among the living and nonliving parts of an ecosystem?
- How are nutrients important in living systems?

Vocabulary
biogeochemical cycle
evaporation
transpiration
nutrient
nitrogen fixation
denitrification
primary productivity
limiting nutrient
algal bloom

Reading Strategy: Using Visuals Before you read, preview the cycles shown in **Figures 3–11, 3–13, 3–14,** and **3–15.** Notice how each diagram is similar to or different from the others. As you read, take notes on how each chemical moves through the biosphere.

Energy is crucial to an ecosystem. But all organisms need more than energy to survive. They also need water, minerals, and other life-sustaining compounds. In most organisms, more than 95 percent of the body is made up of just four elements: oxygen, carbon, hydrogen, and nitrogen. Although these four elements are common on Earth, organisms cannot use them unless the elements are in a chemical form that cells can take up.

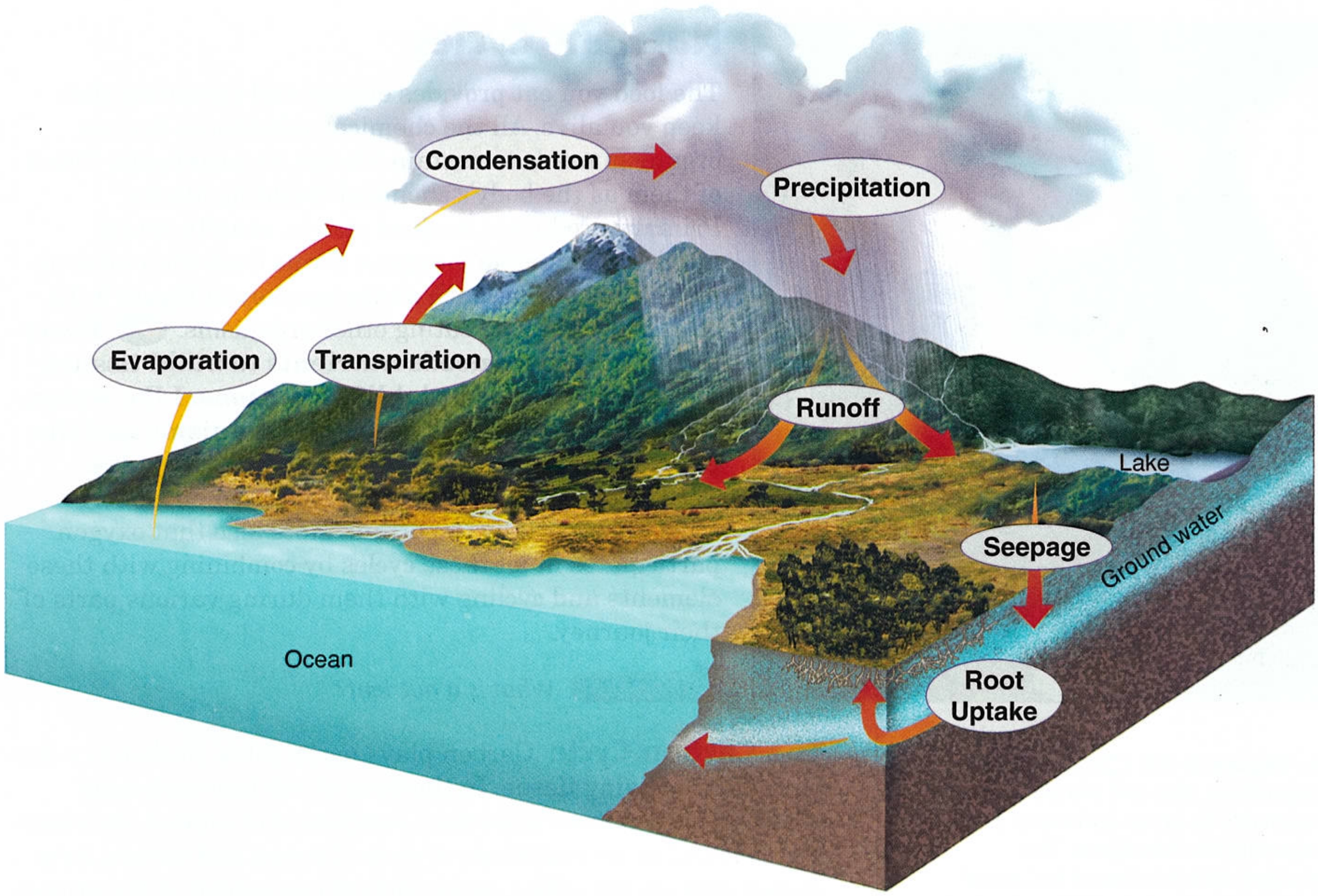
Recycling in the Biosphere

Energy and matter move through the biosphere very differently. **Unlike the one-way flow of energy, matter is recycled within and between ecosystems.** Elements, chemical compounds, and other forms of matter are passed from one organism to another and from one part of the biosphere to another through **biogeochemical cycles.** As the long word suggests, biogeochemical cycles connect *bio*logical, *geo*logical, and *chemi*cal aspects of the biosphere.

Matter can cycle through the biosphere because biological systems do not use up matter, they transform it. The matter is assembled into living tissue or passed out of the body as waste products. Imagine, for a moment, that you are a carbon atom in a molecule of carbon dioxide floating in the air of a wetland like the one in **Figure 3–10.** The leaf of a blueberry bush absorbs you during photosynthesis. You become part of a carbohydrate molecule and are used to make fruit. The fruit is eaten by a caribou, and within a few hours, you are passed out of the animal's body. You are soon swallowed by a dung beetle, then combined into the body tissue of a hungry shrew, which is then eaten by an owl. Finally, you are released into the atmosphere once again when the owl exhales. Then, the cycle starts again.

Simply put, biogeochemical cycles pass the same molecules around again and again within the biosphere. Just think—with every breath you take, you inhale hundreds of thousands of oxygen atoms that might have been inhaled by dinosaurs millions of years ago!

▼ **Figure 3–10** **Matter moves through an ecosystem in biogeochemical cycles.** In this Alaskan wetland, matter is recycled through the air, the shrubs, the pond, and the caribou—as it is used, transformed, moved, and reused.



▲ **Figure 3–11** This diagram shows the main processes involved in the water cycle. Scientists estimate that it can take a single water molecule as long as 4000 years to complete one cycle. **Interpreting Graphics** *What happens to the water that evaporates from oceans and lakes?*

The Water Cycle

All living things require water to survive. Where does all this water come from? It moves between the ocean, atmosphere, and land. As **Figure 3–11** shows, water molecules enter the atmosphere as water vapor, a gas, when they evaporate from the ocean or other bodies of water. The process by which water changes from liquid form to an atmospheric gas is called **evaporation** (ee-vap-uh-RAY-shun). Water can also enter the atmosphere by evaporating from the leaves of plants in the process of **transpiration** (tran-spuh-RAY-shun).

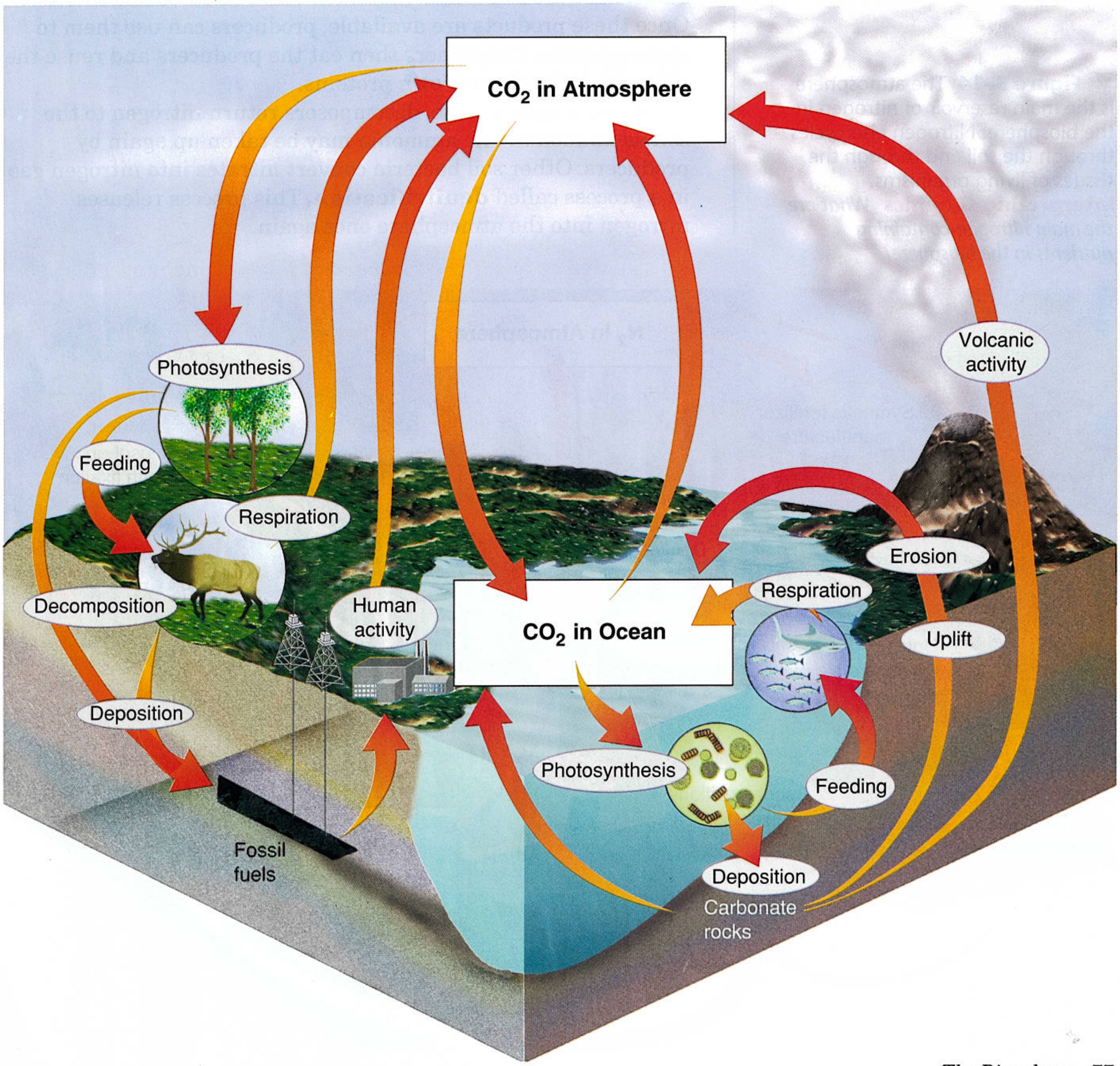
During the day, the sun heats the atmosphere. As the warm, moist air rises, it cools. Eventually, the water vapor condenses into tiny droplets that form clouds. When the droplets become large enough, the water returns to Earth's surface in the form of precipitation—rain, snow, sleet, or hail.

On land, much of the precipitation runs along the surface of the ground until it enters a river or stream that carries the runoff back to an ocean or lake. Rain also seeps into the soil, some of it deeply enough to become ground water. Water in the soil enters plants through the roots, and the water cycle begins anew.

CHECKPOINT *How are evaporation and transpiration related?*

Figure 3–13 shows how these processes move carbon through the biosphere. In the atmosphere, carbon is present as carbon dioxide gas. Carbon dioxide is released into the atmosphere by volcanic activity, by respiration, by human activities such as the burning of fossil fuels and vegetation, and by the decomposition of organic matter. Plants take in carbon dioxide and use the carbon to build carbohydrates during photosynthesis. The carbohydrates are passed along food webs to animals and other consumers. In the ocean, carbon is also found, along with calcium and oxygen, in calcium carbonate, which is formed by many marine organisms. Calcium carbonate can also be formed chemically in certain marine environments. This chalky, carbon-based compound accumulates in marine sediments and in the bones and shells of organisms. Eventually these compounds break down and the carbon returns to the atmosphere.

▼ **Figure 3–13** Carbon is found in several large reservoirs in the biosphere. In the atmosphere, it is found as carbon dioxide gas; in the oceans as dissolved carbon dioxide; on land in organisms, rocks, and soil; and underground as coal, petroleum, and calcium carbonate rock. **Interpreting Graphics** ***What are the main sources of carbon dioxide in the ocean?***

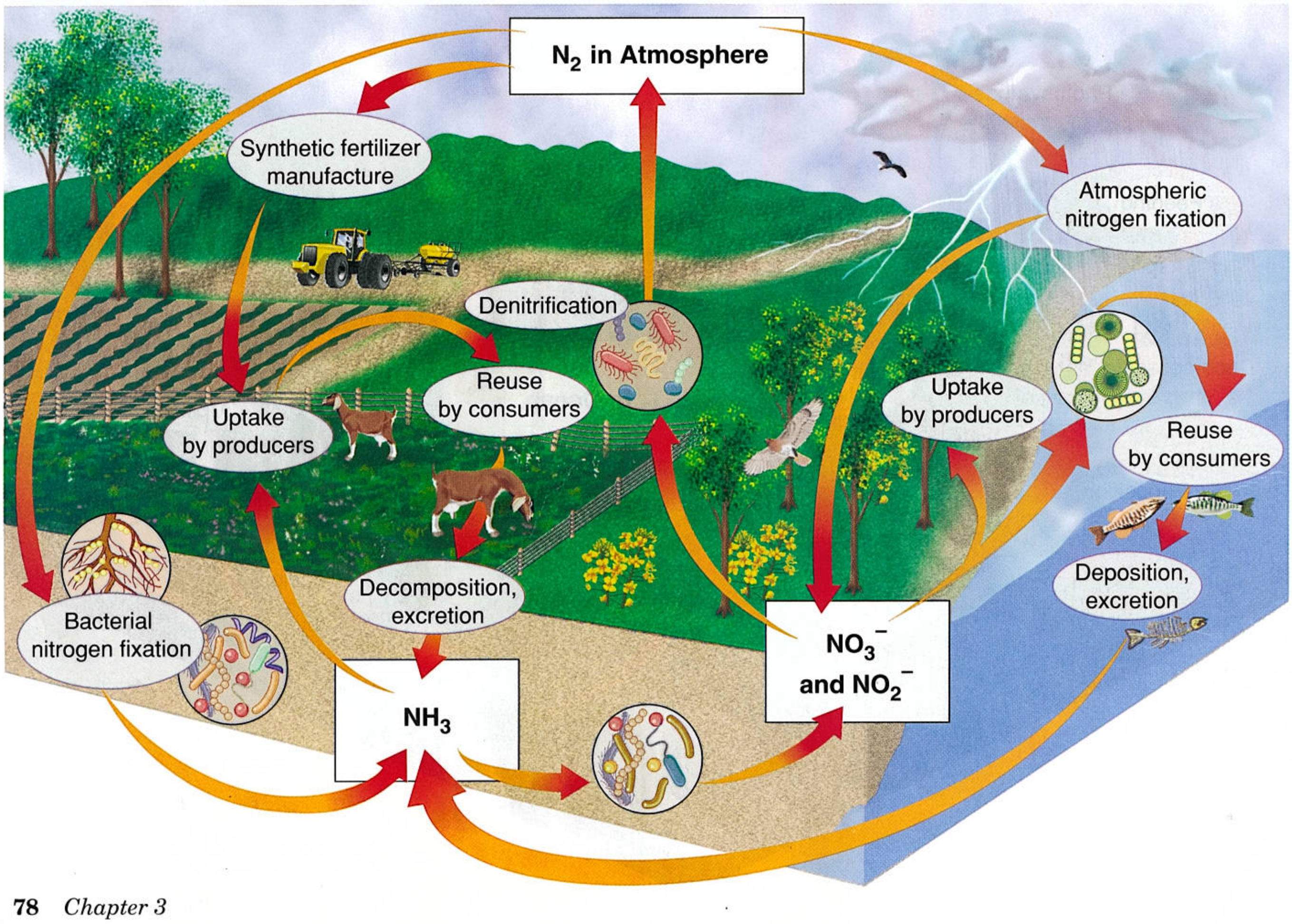


The Nitrogen Cycle All organisms require nitrogen to make amino acids, which in turn are used to build proteins. Many different forms of nitrogen occur naturally in the biosphere. Nitrogen gas (N_2) makes up 78 percent of Earth's atmosphere. Nitrogen-containing substances such as ammonia (NH_3), nitrate ions (NO_3^-), and nitrite ions (NO_2^-) are found in the wastes produced by many organisms and in dead and decaying organic matter. Nitrogen also exists in several forms in the ocean and other large water bodies. Human activity adds nitrogen to the biosphere in the form of nitrate—a major component of plant fertilizers.

Figure 3–14 shows how the different forms of nitrogen cycle through the biosphere. Although nitrogen gas is the most abundant form of nitrogen on Earth, only certain types of bacteria can use this form directly. Such bacteria, which live in the soil and on the roots of plants called legumes, convert nitrogen gas into ammonia in a process known as **nitrogen fixation.** Other bacteria in the soil convert ammonia into nitrates and nitrites. Once these products are available, producers can use them to make proteins. Consumers then eat the producers and reuse the nitrogen to make their own proteins.

When organisms die, decomposers return nitrogen to the soil as ammonia. The ammonia may be taken up again by producers. Other soil bacteria convert nitrates into nitrogen gas in a process called **denitrification.** This process releases nitrogen into the atmosphere once again.

▼ **Figure 3–14** The atmosphere is the main reservoir of nitrogen in the biosphere. Nitrogen also cycles through the soil and through the tissues of living organisms. **Interpreting Graphics** *What are the main nitrogen-containing nutrients in the biosphere?*



Analyzing Data

Farming in the Rye

Sometimes, farmers grow crops of rye and other grasses and then plow them under the soil to decay. This practice helps to increase crop yields of other plants. Farmers may also plow under legumes such as peas, vetch, and lentils. Legumes are plants that have colonies of nitrogen-fixing bacteria living in nodules on the plant roots.

In an effort to determine which practice produces the best crop yields, scientists performed an experiment in Georgia. They grew corn on land that had previously received one of five treatments. Three fields had previously been planted with three different legumes. A fourth field had been planted with rye. The fifth field was left bare before the corn was planted. None of the fields received fertilizer while the corn was growing. The table shows how much corn was produced per hectare of land (kg/ha) in each field. One hectare is equivalent to 10,000 square meters.

Corn Production

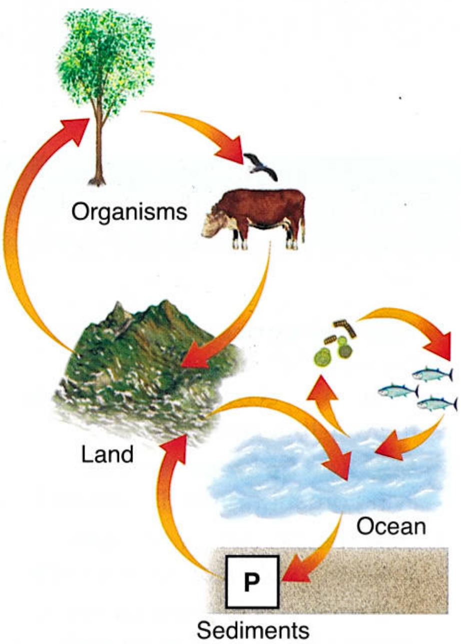
Previous Crop	Average Yield of Corn (kg/ha)
Monantha vetch	2876
Hairy vetch	2870
Austrian peas	3159
Rye	1922
None	1959

1. **Using Tables and Graphs** Use the data in the table to create a bar graph.
2. **Comparing and Contrasting** Compare the effect of growing legumes to that of growing grass on the yield of corn. How do the yields differ from the yield on the field that had received no prior treatment?
3. **Using Tables and Graphs** Which treatment produced the best yield of corn? The worst yield?
4. **Applying Concepts** Based on your knowledge of the nitrogen cycle, how can you explain these results?

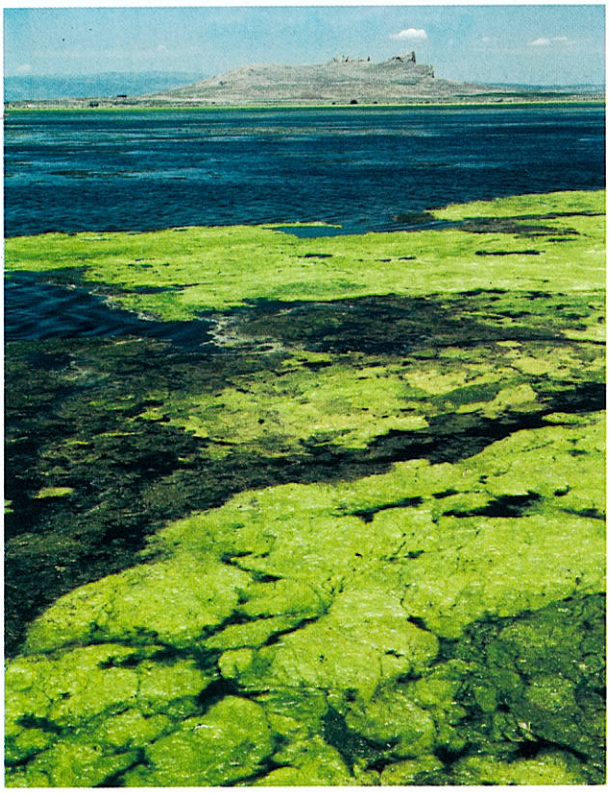
The Phosphorus Cycle Phosphorus is essential to living organisms because it forms part of important life-sustaining molecules such as DNA and RNA. Although phosphorus is of great biological importance, it is not very common in the biosphere. Unlike carbon, oxygen, and nitrogen, phosphorus does not enter the atmosphere. Instead, phosphorus remains mostly on land in rock and soil minerals, and in ocean sediments. There, phosphorus exists in the form of inorganic phosphate. As the rocks and sediments gradually wear down, phosphate is released. On land, some of the phosphate washes into rivers and streams, where it dissolves. The phosphate eventually makes its way to the oceans, where it is used by marine organisms.

As **Figure 3–15** shows, some phosphate stays on land and cycles between organisms and the soil. When plants absorb phosphate from the soil or from water, the plants bind the phosphate into organic compounds. Organic phosphate moves through the food web, from producers to consumers, and to the rest of the ecosystem.

✓ CHECKPOINT *Where is most of the phosphorus stored in the biosphere?*



▶ **Figure 3–15** Phosphorus in the biosphere cycles among the land, ocean sediments, and living organisms. **Interpreting Graphics** *How is phosphorus important to living organisms?*



▲ **Figure 3–16** When an aquatic ecosystem receives a large input of a limiting nutrient, the result is often an increase in the number of producers. Here, an extensive algal bloom covers the shoreline of Tule Lake in California. **Using Analogies** *How is this situation similar to the one that occurs in a fish tank in which the fish have been overfed?*

Nutrient Limitation

Ecologists are often interested in the **primary productivity** of an ecosystem, which is the rate at which organic matter is created by producers. One factor that controls the primary productivity of an ecosystem is the amount of available nutrients. If a nutrient is in short supply, it will limit an organism's growth. When an ecosystem is limited by a single nutrient that is scarce or cycles very slowly, this substance is called a **limiting nutrient.**

Because they are well aware of this phenomenon, farmers apply fertilizers to their crops to boost their productivity. Fertilizers usually contain three important nutrients—nitrogen, phosphorus, and potassium. These nutrients help plants grow larger and more quickly than they would in unfertilized soil.

The open oceans of the world can be considered nutrient-poor environments compared to the land. Sea water contains at most only 0.00005 percent nitrogen, or 1/10,000 of the amount typically found in soil. In the ocean and other saltwater environments, nitrogen is often the limiting nutrient. In some areas of the ocean, however, silica or even iron can be the limiting nutrient. In streams, lakes, and freshwater environments, phosphorus is typically the limiting nutrient.

When an aquatic ecosystem receives a large input of a limiting nutrient—for example, runoff from heavily fertilized fields—the result is often an immediate increase in the amount of algae and other producers. This result is called an **algal bloom.** Why do algal blooms occur? There are more nutrients available, so the producers can grow and reproduce more quickly. If there are not enough consumers to eat the excess algae, conditions can become so favorable for growth that algae cover the surface of the water. Algal blooms, like the one shown in **Figure 3–16,** can sometimes disrupt the equilibrium of an ecosystem.

3–3 Section Assessment

1. **Key Concept** How does the way that matter flows through an ecosystem differ from the way that energy flows?
2. **Key Concept** Why do living organisms need nutrients?
3. Describe the path of nitrogen through its biogeochemical cycle.
4. Explain how a nutrient can be a limiting factor in an ecosystem.
5. **Critical Thinking Predicting** Based on your knowledge of the carbon cycle, what do you think might happen if vast areas of forests are cleared?
6. **Critical Thinking Applying Concepts** Summarize the role of algal blooms in disrupting the equilibrium in an aquatic ecosystem.

TAKS *Tune-up*

Science 3 Bio TEKS 9D

Making a Cycle Diagram
Create a cycle diagram to trace the flow of matter in the carbon cycle. Include the following labels: *Photosynthesis, Feeding, Respiration, Decomposition, Deposition, CO_2 in Atmosphere,* and *Fossil Fuels.* Limit the diagram to what occurs between land, air, rocks, and soil.