Section 3–3

1 FOCUS

Objectives

3.3.1 ***Describe*** how matter cycles among the living and nonliving parts of an ecosystem.

3.3.2 ***Explain*** why nutrients are important in living systems.

3.3.3 ***Describe*** how the availability of nutrients affects the productivity of ecosystems.

Guide for Reading

Vocabulary Preview

Figure 3–11, page 75, introduces seven terms. Two of the terms, *evaporation* and *transpiration,* are explicitly defined in the text. The meanings of the remaining five terms—*condensation, precipitation, runoff, seepage,* and *uptake*—can be inferred from their context. As students read about the water cycle on page 75, have them look for sentences that relate to the terms and copy them on a sheet of paper. Finally, using the sentences they copied as a basis, students can extrapolate a "formal" definition for each term. Have students share their definitions in a class discussion.

Reading Strategy

Have students make their own simplified cycle diagrams of the water cycle, carbon cycle, nitrogen cycle, and phosphorus cycle.

2 INSTRUCT

Recycling in the Biosphere

Build Science Skills

Inferring After students have read Recycling in the Biosphere, point out the sentence that begins *You are soon swallowed by a dung beetle . . .* Ask: **How can a molecule that's swallowed by a dung beetle "combine into"—or become part of—the body tissue of a tree shrew and then an owl?** *(The tree shrew takes in the molecule when it eats the dung beetle, and then an owl takes in the molecule when it eats the tree shrew.)* L2

3–3 Cycles of Matter

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.

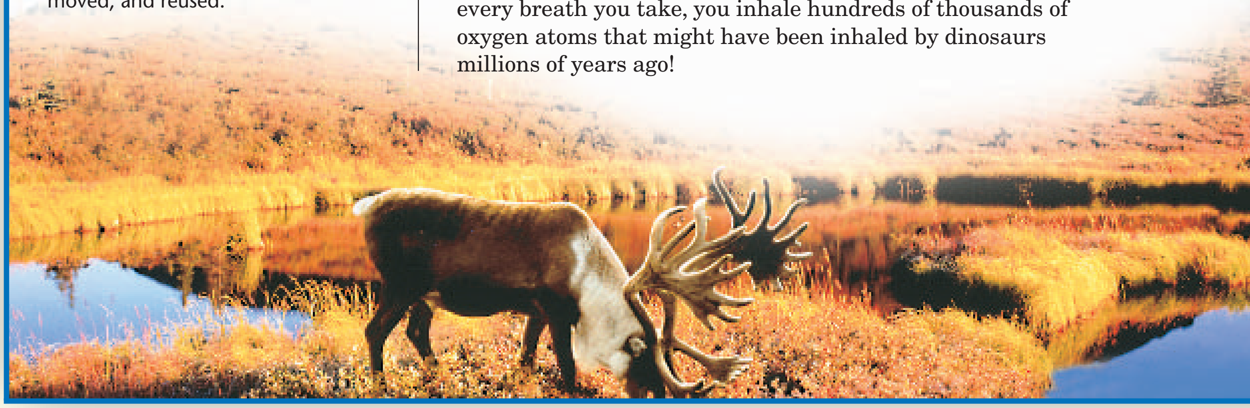
Energy is crucial to an ecosystem. But all organisms need more than energy to survive. They also need water, minerals, and other life-sustaining compounds. In most organisms, more than 95 percent of the body is made up of just four elements: oxygen, carbon, hydrogen, and nitrogen. Although these four 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.

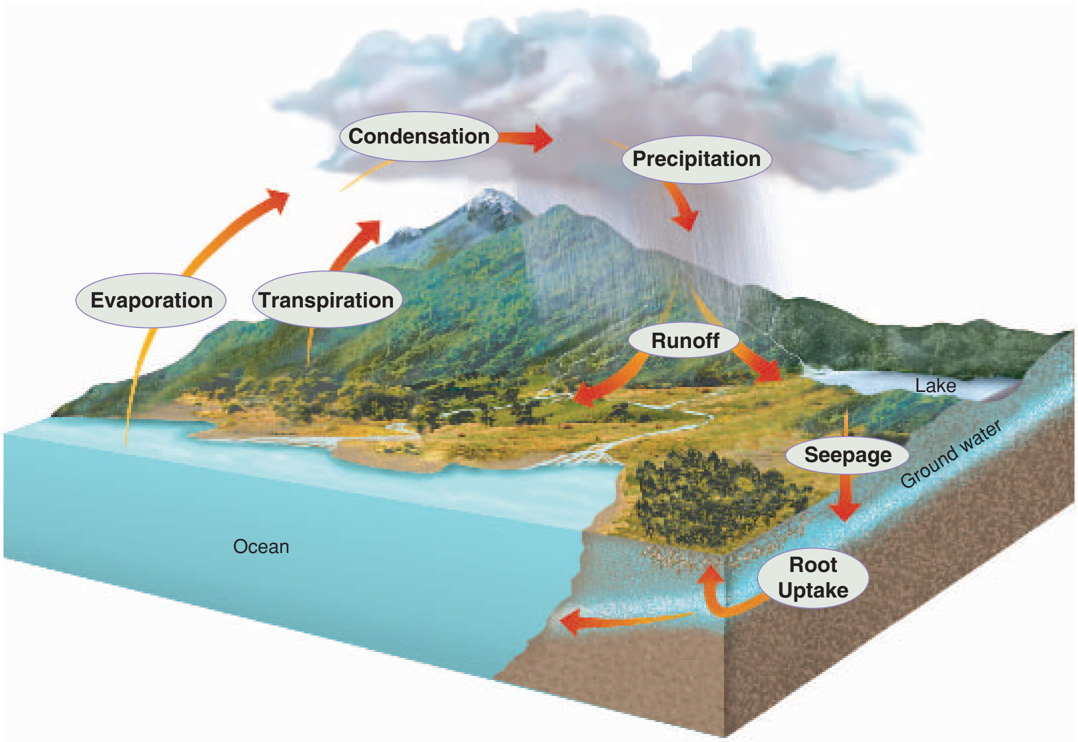
TIME SAVER — SECTION RESOURCES

Print:

- ***Laboratory Manual A,*** Chapter 3 Lab
- ***Laboratory Manual B,*** Chapter 3 Lab
- ***Teaching Resources,*** Lesson Plan 3–3, Adapted Section Summary 3–3, Adapted Worksheets 3–3, Section Summary 3–3, Worksheets 3–3, Section Review 3–3, Enrichment
- ***Reading and Study Workbook A,*** Section 3–3
- ***Adapted Reading and Study Workbook B,*** Section 3–3
- ***Biotechnology Manual,*** Issue 4
- ***Lab Worksheets,*** Chapter 3 Exploration

Technology:

- ***BioDetectives DVD,*** *Pfiesteria:* A Killer in the Water
- ***iText,*** Section 3–3
- ***Transparencies Plus,*** Section 3–3



▲ **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?*

Go Online active art
For: Water Cycle activity
Visit: PHSchool.com
Web Code: cbp-2033

Go Online active art
For: Water Cycle activity
Visit: PHSchool.com
Web Code: cbe-2033
Students can examine how water moves through the water cycle.

The Water Cycle

Use Visuals

Figure 3–11 After students have studied the diagram and read the caption, have them recall what they learned about water in Chapter 2. Remind them that water is the single most abundant compound in most living things. Then, ask: **What are two ways that water can enter the atmosphere?** *(Evaporation and transpiration)* **What process moves water through the cycle from the air to the ground?** *(Precipitation)* **What are two routes by which water might make its way to the ocean?** *(Through runoff and through seepage into ground water and eventual flow into the ocean)* L1 L2

Build Science Skills

Comparing and Contrasting Emphasize that transpiration by plants releases water vapor, a gas, into the air, not liquid water. Ask: **What process in humans and other mammals also releases water vapor into the air?** *(Respiration)* **How are transpiration in plants and respiration in mammals different?** *(Sample answer: Mammals have specialized organs that are involved in respiration—the lungs, diaphragm, bronchial tubes, and so forth—but plants do not have "breathing" organs.)* L2

UNIVERSAL ACCESS

Less Proficient Readers
Some students might be unfamiliar with the terms used in Figure 3–11. Call on students at random to read aloud each sentence or set of sentences in the text that describes one of the processes in the water cycle. For example, the first two sentences in the second paragraph on page 75 describe condensation. After the text explanation for each process is read aloud, have students find that step in the cycle in Figure 3–11 and describe it in their own words. L1 L2

Advanced Learners
Encourage students who need an extra challenge to investigate further one of the biogeochemical cycles discussed in this section. You might assign one student to do further research on each of the four cycles discussed. Students can find more information on these cycles in higher-level biology texts as well as in earth science texts. Have students prepare a presentation to the class, complete with visual aids. L3

Answers to . . .

CHECKPOINT *Evaporation is part of the process of transpiration.*

Figure 3–11 *The water vapor rises into the atmosphere and then cools and condenses to form clouds.*

3–3 (continued)

Nutrient Cycles

Make Connections

Health Science For each pair of students, provide an empty vitamin container with its nutrition label intact. Try to provide a mix of vitamins for adults, for young children, and for infants. You may want to ask students in advance to bring in containers from home. Ask: **What types of information are given on the nutrition label?** *(The serving size, the total number of servings in the container, the specific nutrients in the pills or drops, the amount of each nutrient in one serving, and the percentage of daily value each amount represents.)* **What do you think a "daily value" is?** *(How much of a nutrient a person should take in each day)* **What does "percentage of daily value" mean?** *(How much of the daily value is in one serving of the vitamin)* Ask students if they recognize the names of any of the nutrients listed on the label and whether they know the nutrients' common dietary sources and their functions in maintaining good health. Depending on the extent of students' knowledge, you may want to suggest that they research this information and share their findings in posters or brief oral presentations. L2 L3

Go Online NSTA SCiLINKS

Download a worksheet on cycles of matter for students to complete, and find additional teacher support from NSTA SciLinks.

▲ **Figure 3–12 Like all living organisms, the owl monkey needs nutrients to grow and carry out essential life functions.** This monkey, which is found in Central and South America, obtains most of its nutrients by eating plants.

Go Online NSTA SCiLINKS

For: Links on cycles of matter
Visit: www.SciLinks.org
Web Code: cbn-2033

Nutrient Cycles

The food you eat provides energy and chemicals that keep you alive. All the chemical substances that an organism needs to sustain life are its **nutrients.** Think of them as the body's chemical "building blocks." Primary producers, such as plants, usually obtain nutrients in simple inorganic forms from their environment. Consumers, such as the monkey in **Figure 3–12,** obtain nutrients by eating other organisms. **Every living organism needs nutrients to build tissues and carry out essential life functions. Like water, nutrients are passed between organisms and the environment through biogeochemical cycles.**

The carbon cycle, nitrogen cycle, and phosphorus cycle are especially important. Note also that oxygen participates in all these cycles by combining with these elements and cycling with them during various parts of their journey.

CHECKPOINT *What is a nutrient?*

The Carbon Cycle Carbon plays many roles. Carbon is a key ingredient of living tissue. In the form of calcium carbonate ($CaCO_3$), carbon is an important component of animal skeletons and is found in several kinds of rocks. Carbon and oxygen form carbon dioxide gas (CO_2), an important component of the atmosphere. Carbon dioxide is taken in by plants during photosynthesis and is given off by both plants and animals during respiration. Four main types of processes move carbon through its cycle:

- Biological processes, such as photosynthesis, respiration, and decomposition, take up and release carbon and oxygen.
- Geochemical processes, such as erosion and volcanic activity, release carbon dioxide to the atmosphere and oceans.
- Mixed biogeochemical processes, such as the burial and decomposition of dead organisms and their conversion under pressure into coal and petroleum (fossil fuels), store carbon underground.
- Human activities, such as mining, cutting and burning forests, and burning fossil fuels, release carbon dioxide into the atmosphere.

Scientists identified these processes decades ago, but they are still actively investigating them. For example, how much carbon moves through each part of the cycle? How do other parts of the carbon cycle respond to changes in atmospheric carbon dioxide? How much carbon dioxide can the ocean absorb? Later in this unit, you will learn why answers to these questions are so important.

BIO INSIGHTS — FACTS AND FIGURES

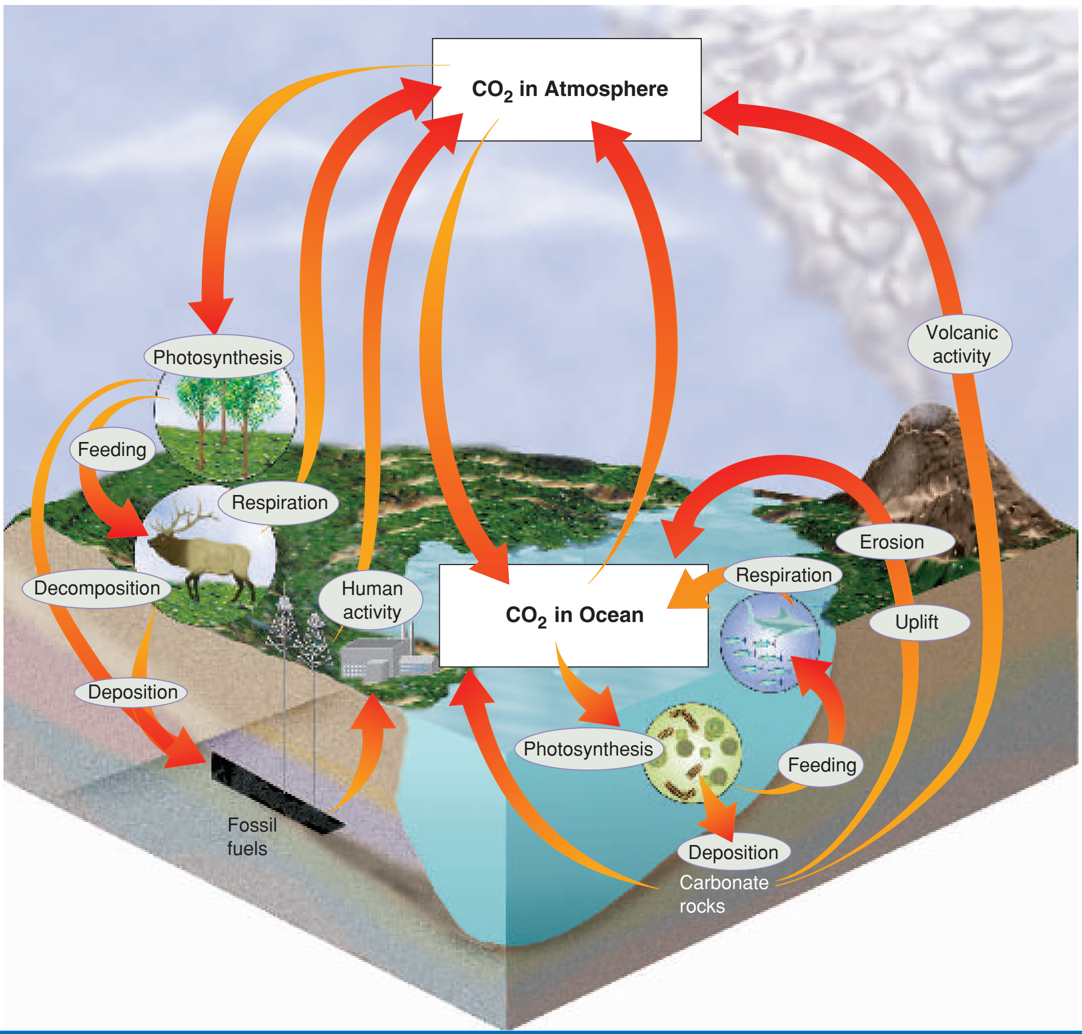
The rain in Spain, and elsewhere

Huge quantities of water cycle between Earth's surface and atmosphere. Hydrologists estimate that about 390,000 cubic kilometers of water evaporate from Earth's surface and enter the atmosphere each year.

Considering all forms of precipitation, about 77 percent falls on oceans and about 23 percent on land. However, this same proportion does not hold true for water that evaporates from Earth's surface: 84 percent of the water in the atmosphere comes from oceans and only 16 percent from land. The reason for the difference in proportions is simple: about a third of the precipitation that falls on land runs off into streams and rivers and is carried to oceans.

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?***



Use Visuals

Figure 3–13 Call on different students in turn to "translate" the diagram's pictures, labels, and arrows into complete, descriptive sentences. For example, the circled picture of trees, the arrows, and the *Photosynthesis* label on the left side of the diagram can be expressed as, "During photosynthesis, plants take in carbon dioxide from the atmosphere and release oxygen." The circled picture of the elk with two arrows can be translated as, "During respiration, animals take in oxygen given off by plants and release carbon dioxide into the atmosphere," and, "When animals die and decompose, carbon is released into the soil." Continue until all the processes in both pathways have been described this way. L2

BIO INSIGHTS

FACTS AND FIGURES

The carbon pool

Scientists estimate the biosphere's total carbon pool to be approximately 49,000 metric gigatons. (1 metric gigaton equals 10^9 metric tons.) Of that total, 71 percent is contained in Earth's oceans, mainly in the form of carbonate and bicarbonate ions. Fossil carbon comprises 22 percent of the total pool. An additional 3 percent is contained in dead organic matter and phytoplankton, and another 3 percent is held in terrestrial ecosystems. The remaining 1 percent is held in the atmosphere, circulated, and used in photosynthesis.

The carbon that is contained in organic molecules—such as the wood in trees—may not be recycled back to the abiotic environment for several hundred years or even longer. Carbon compounds found in coal that formed from ancient trees, for example, are the products of photosynthesis that occurred millions of years ago.

Answers to . . .

CHECKPOINT *Any chemical substance that an organism needs to sustain life*

Figure 3–13 *Respiration by ocean animals, precipitation containing dissolved carbon dioxide, erosion of carbonate rocks formed from the skeletons of ocean organisms such as corals*

3–3 (continued)

Make Connections

Chemistry Write the chemical formulas for atmospheric nitrogen (N_2), ammonia (NH_3), the nitrate ion (NO_3^-), and the nitrite ion (NO_2^-) on the board. Ask students: **Which element is symbolized by each letter in these formulas?** *(N is the symbol for nitrogen; H for hydrogen; and O for oxygen.)* **What do the small numbers mean?** *(The small numbers tell how many atoms of the element are in one molecule or ion of the substance.)* **What atoms make up one molecule of atmospheric nitrogen?** *(Two atoms of nitrogen)* **One molecule of ammonia?** *(One atom of nitrogen and three atoms of hydrogen)* **The nitrate ion?** *(One atom of nitrogen and three atoms of oxygen)* **The nitrite ion?** *(One atom of nitrogen and two atoms of oxygen)* L1 L2

Build Science Skills

Using Models To reinforce students' understanding of the nitrogen cycle, have them make models of the four chemical formulas of the different forms of nitrogen. Provide a variety of materials, and let each student choose the type of model to make. For example, two-dimensional models could be made with circles cut from colored construction paper and glued to a larger sheet. Three-dimensional models could be made with clay balls of different colors held together with toothpicks. Students can use their models as they study the nitrogen cycle in Figure 3–14. L1 L2

Use Visuals

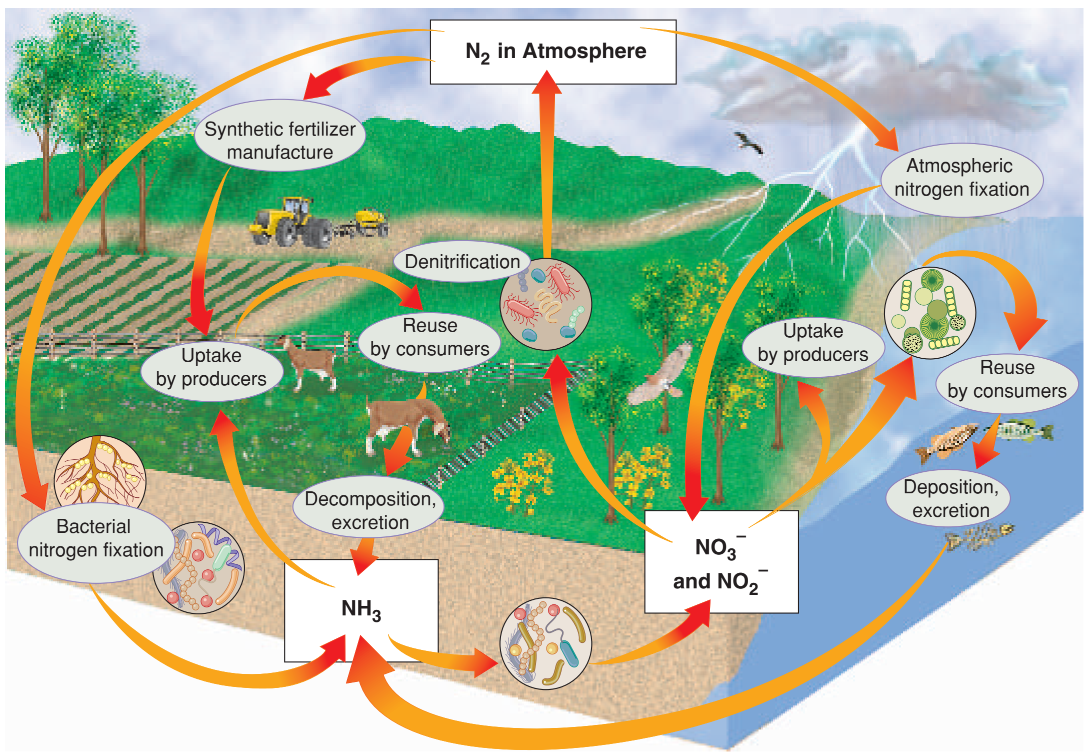
Figure 3–14 The "translation" procedure described for use with Figure 3–13 would also work well with this diagram. For example, the part of the diagram that illustrates nitrogen fixation by bacteria could be described in the following way: "In nitrogen fixation, bacteria in the soil and on plant roots change atmospheric nitrogen into ammonia." L2

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?***



BIO INSIGHTS

FACTS AND FIGURES

The scarcity of nitrogen
Although about 80 percent of the air surrounding Earth is nitrogen gas (N_2), usable forms of the element are scarce in ecosystems. The reason for this is that the two atoms in atmospheric nitrogen are held together by triple covalent bonds that only lightning, volcanic action, and certain bacteria can break. In addition, the ammonia, nitrite, and nitrate formed by nitrifying bacteria are very susceptible to leaching and runoff, which carry away nitrogen dissolved in the water.

Nitrifying bacteria use nitrogenase, an enzyme, to break the covalent bonds in N_2 molecules. Nitrogenase functions only when it is isolated from oxygen. On land, nitrogen-fixing bacteria accomplish this by living inside oxygen-excluding nodules or layers of insulating slime on plant roots. In aquatic ecosystems, cyanobacteria—the primary nitrogen-fixers—have specialized cells called heterocysts that exclude oxygen.

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?*

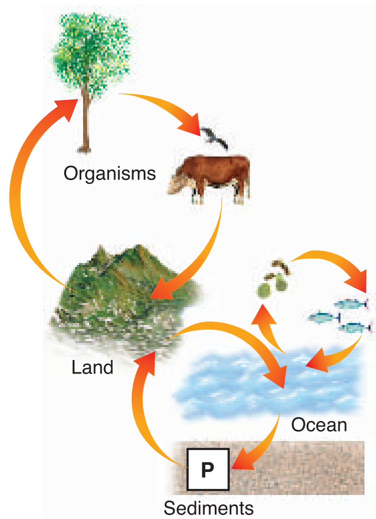


Figure 3–15 Phosphorus in the biosphere cycles among the land, ocean sediments, and living organisms. **Interpreting Graphics** *How is phosphorus important to living organisms?*

Analyzing Data

Help students understand the experiment procedure by asking: **Why was the fifth field left bare?** *(It was the control in the experiment. If the corn in the fifth field grew as well as or better than the corn in any of the other fields, the researchers would know that the previous year's plantings in those other fields did not increase corn productivity.)* L2

Answers

1. Students could plot plant names on the vertical axis and yields on the horizontal axis; use different increments for the yield axis; and/or arrange the crops in sequence from highest to lowest yield or from lowest to highest.

2. Growing legumes the previous year significantly increased the crop yields. Growing rye did not increase yields. In fact, the bare field's yield was slightly higher than the field planted with rye.

3. The legumes—particularly the Austrian peas—produced the highest yields. Rye produced the lowest yield.

4. The corn plants benefited greatly when the soil was enriched with nitrogen fixed by legumes the previous year.

Build Science Skills

Comparing and Contrasting
Point out the terms *inorganic* and *organic* in the description of the phosphorus cycle. Encourage students to consult science dictionaries and chemistry textbooks to determine the difference between organic and inorganic compounds and report their findings to the rest of the class. L2 L3

BIO INSIGHTS — FACTS AND FIGURES

What makes a compound organic?
Organic compounds are often defined simply as compounds that contain carbon. However, not all carbon-containing compounds are considered organic. Carbon dioxide and hydrocarbons such as methane and propane are prime examples of carbon compounds that are not organic. A more precise definition of an organic compound is: a compound that contains carbon and is constructed in living cells.

A carbon atom has four electrons in its outer shell—but the shell is capable of holding eight electrons. For this reason, a carbon atom can form covalent bonds with as many as four atoms of other elements. Carbon atoms are usually joined together in a ring or chain that forms a stable "backbone" for building molecules. Such structures are not present in simple inorganic compounds such as carbon dioxide.

Answers to . . .

CHECKPOINT *In rock and soil minerals and in ocean sediments*

Figure 3–14 *Ammonia, nitrate, and nitrite*

Figure 3–15 *Phosphorus forms part of life-sustaining molecules such as RNA and DNA.*

3–3 (continued)

Nutrient Limitation

Build Science Skills

Making Judgments Call attention to the paragraph about farmers' use of fertilizers. Ask: **How might the use of fertilizers harm ecosystems nearby?** *(Runoff from the fields could carry fertilizers to bodies of water and cause algal blooms there.)* Have students discuss the pros and cons of fertilizer use. Then, let two teams debate the issue. L2 L3

3 ASSESS

Evaluate Understanding

Make one photocopy of Figure 3–11 (the water cycle), Figure 3–13 (the carbon cycle), and Figure 3–14 (the nitrogen cycle). Cover the diagrams' labels with white tape, and then use these "masters" to make a set of copies for students to add labels.

Reteach

Have each student write a brief description of each cycle discussed in the section referring to Figures 3–11, 3–13, 3–14, and 3–15. Let students share their work in a class discussion and correct any errors or omissions in one another's descriptions.

Thinking Visually

Students' flowcharts may vary. Each flowchart, though, should mention and describe the processes included in Figure 3–13. A good flowchart might incorporate the flow of energy, and carbon, through a food chain.

Interactive Textbook

If your class subscribes to the iText, use it to review the Key Concepts in Section 3–3.

Answer to . . .

Figure 3–16 *Bacteria in a lake consume dead algae and deplete oxygen in the lake just as excess food in a fish tank is consumed by bacteria that deplete oxygen in the water.*

▲ **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. Seawater 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.

Thinking Visually

Making a Flowchart
Use a flowchart to trace the flow of energy in the carbon cycle. *Hint*: You may wish to refer to **Figure 3–13,** especially to the labels Photosynthesis, Feeding, Respiration, and Decomposition. Also, you may want to refer to **Figure 3–7** in Section 3–2 for a description of energy flow in an ecosystem.

3–3 Section Assessment

1. Unlike the one-way flow of energy, matter is recycled within and between ecosystems.
2. To build tissues and carry out life functions.
3. Students should summarize the steps in the nitrogen cycle as shown in Figure 3–14. A good response should describe the different forms of nitrogen as well as explain bacterial nitrogen fixation and denitrification.
4. If a nutrient is in short supply, it will limit an organism's growth.
5. If vast areas of forest were cleared, less carbon dioxide would be removed from the atmosphere by plants.
6. When an aquatic ecosystem receives a large input of a limiting nutrient, the result is often an algal bloom. Algal blooms can sometimes disrupt the equilibrium of an ecosystem by producing more algae than consumers can eat.