3.4

Cycling of Matter and Energy in Ecosystems

Oceans cycle energy and matter through the water cycle.

CAN YOU SOLVE IT?

The curious-looking buildings shown in Figure 1 are part of a research facility located in Arizona called Biosphere 2. The tightly sealed glass and steel structure currently serves as a place where scientists study Earth's ecosystems to better understand carbon and oxygen cycles, coral reef health, water recycling, and more.

Gather Evidence As you explore the lesson, gather evidence to explain the relationship between the cycling of matter and the transfer of energy through ecosystems.

FIGURE 1: Biosphere 2 is a research facility located in Arizona.

On September 26, 1991, eight research scientists began a two-year adventure living in Biosphere 2. The researchers, known as "biospherians," were completely sealed off from the outside environment to simulate living in a closed ecosystem. But the results of the experiment were unexpected. The biospherians had to cope with inadequate food, decreasing oxygen levels, and increasing carbon dioxide levels. The imbalances resulted in many plants and animals dying, providing evidence that ecosystems are much more complex and dynamic than originally thought.

Predict Why do you think researchers had problems with low oxygen levels and increasing carbon dioxide levels in Biosphere 2? How would you solve this problem?

Matter Cycles Through Ecosystems

Earth is an open system in terms of energy, as it gains energy from the sun. In contrast, Earth is a closed system in terms of matter. All of the matter on Earth has more or less been here for billions of years. Matter and energy cannot be created or destroyed, only transformed into other forms.

Predict Matter and energy move through ecosystems between different organisms. Where does this matter come from and how does it travel through an ecosystem or through Earth's spheres?

Energy and Matter in the Earth System

The Earth system includes all of the matter, energy, processes, and cycles within Earth's boundary with space. Energy from the sun drives the cycling of matter in Earth's spheres and in the many ecosystems within those spheres. Producers use only about one percent of the sun's energy that enters Earth's atmosphere.

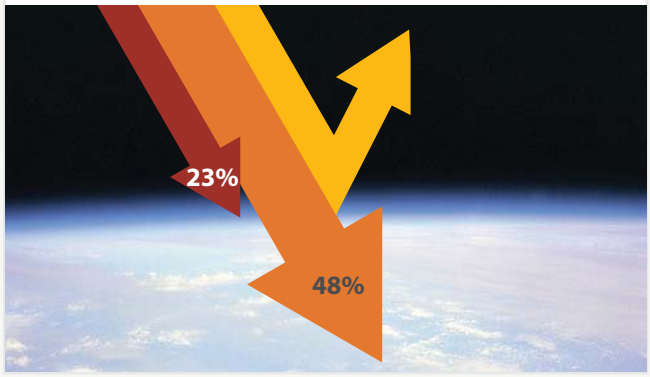
Math Connection

Solar Radiation

When solar radiation enters Earth's atmosphere, about 23 percent is absorbed in the atmosphere and about 48 percent is absorbed at the surface.

Collaborate With a partner discuss these questions: If energy is conserved, what percent of the solar energy should be reflected back into space? How do you think Earth's ecosystems would be different if more or less solar radiation was reflected by the atmosphere?

FIGURE 2: Earth's atmosphere absorbs and reflects energy.



Like energy, matter in the Earth system cycles within and among Earths' spheres: the atmosphere, geosphere, hydrosphere, and biosphere. A relatively small amount of matter is lost into space from the very top of the atmosphere, but scientists generally think of the Earth system as closed in terms of matter.

Matter also changes form as it cycles through the Earth system, but like energy, it cannot be destroyed. For example, organisms metabolize food using chemical reactions. These reactions break bonds and form new chemical bonds among the same atoms to make new substances. The organism can use these new substances for growth and cell processes. Some matter is excreted as waste, which is recycled in the environment. The total amount of matter in the system remains unchanged.

FIGURE 3: The Earth system is closed.

Using food webs and pyramid models, you can see matter cycles through different trophic levels in an ecosystem. As one organism consumes another, that matter is transferred into higher trophic levels. When organisms die, their matter is cycled back through lower trophic levels. In this way, no new matter is created, but matter continually moves through and between ecosystems, as illustrated in Figure 3.

The Water Cycle

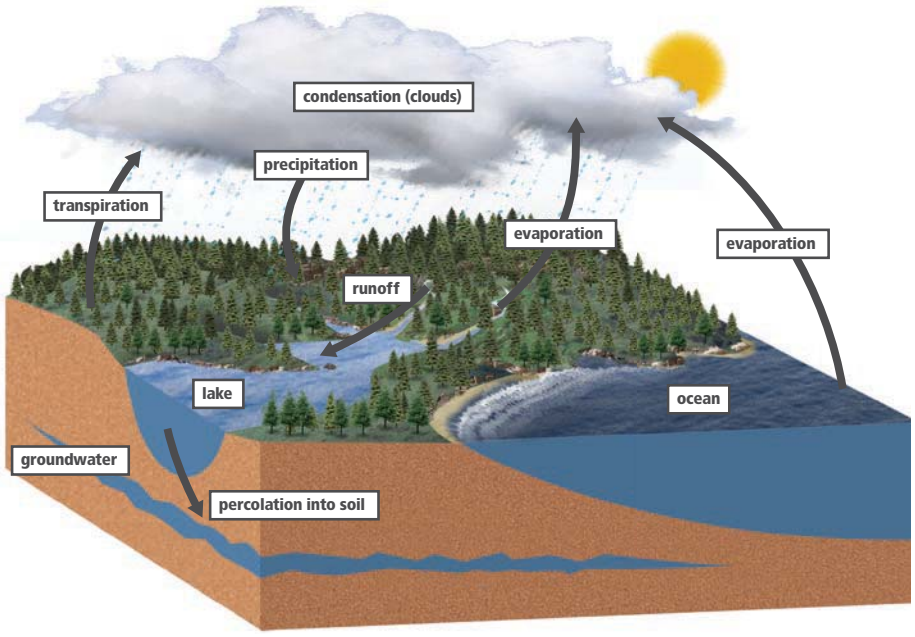
Scientists model specific chemical cycles in order to better understand the cycling of matter in the Earth system. The hydrologic cycle, also known as the water cycle, is the circular pathway of water on Earth from the atmosphere, to the surface, below ground, and back into the atmosphere.

As shown in Figure 4, within the hydrologic cycle, water moves by different processes between reservoirs, such as oceans or lakes. Reservoirs are any location where cycling matter is stored. Water molecules might be stored in a reservoir for a long period of time, such as in a glacier, or for shorter periods of time, such as in a cloud. Evaporation and precipitation are examples of processes that move water between reservoirs.

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

FIGURE 4: The hydrologic cycle transfers water molecules between reservoirs.

Explore Online



In the hydrologic cycle, heat from the sun causes water to evaporate from reservoirs such as the ocean and to evaporate from plant leaves through transpiration. As water rises into the atmosphere it cools and condenses into clouds. Water then falls back to Earth in the form of precipitation, such as rain, snow, or hail. Precipitation seeps in the ground or flows into streams or rivers. Water ends up in a reservoir where it is stored until the process starts again.

Explain Choose two reservoirs in the diagram and, for each location, explain how water cycles through the system.

Biogeochemical Cycles

Many elements are essential for the functioning and growth of organisms. These elements include oxygen, hydrogen, carbon, nitrogen, and phosphorus. Just like water, these elements cycle through the Earth system, ecosystems, and organisms.

A biogeochemical cycle is the movement of a particular chemical through the biotic and abiotic components of an ecosystem. The sun and heat from within Earth provide energy that drives these cycles. Like the hydrologic cycle, the matter in biogeochemical cycles flows between reservoirs where it is stored for a period of time. In contrast to the water cycle, bonds are broken, and atoms are rearranged into new molecules in biogeochemical cycles. The main biogeochemical cycles are the oxygen cycle, the carbon cycle, the nitrogen cycle, and the phosphorus cycle.

Explore Online

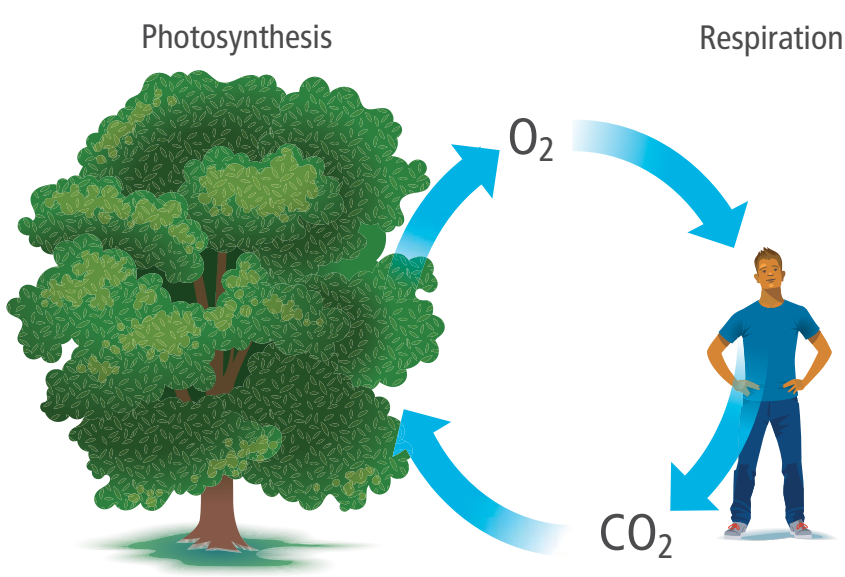
Hands-On Activity

Winter Water Chemistry
Model summer and winter lake conditions to determine how surface ice affects the water chemistry of a lake.

The Oxygen Cycle

Oxygen (O_2) is released into the atmosphere as a product of photosynthesis. The atmosphere serves as a reservoir for oxygen until it is taken in by an organism for use in cellular respiration. Humans, and other organisms, also take in oxygen as part of respiration, or breathing.

FIGURE 5: The oxygen cycle is driven by photosynthesis and cellular respiration.



Collaborate With a partner, discuss how a drought caused by a decrease in precipitation might affect the oxygen cycle. Use evidence from previous lessons to support your answer.

Some of the oxygen is incorporated into compounds that remain in the organism. Thus the organism becomes a reservoir for the oxygen. Carbon dioxide (CO_2) is released back into the atmosphere as a byproduct of cellular respiration. Carbon dioxide is then taken up by plants and used for photosynthesis, and oxygen is released back into the atmosphere. Each cycle on Earth interacts with other cycles. For example, the water cycle interacts with the oxygen cycle, because water is necessary for photosynthesis.

Gather Evidence In the Biosphere 2 project, oxygen concentration decreased over time and carbon dioxide reached dangerous levels. Describe a possible solution to this problem, and explain how it relates to processes in the oxygen cycle.

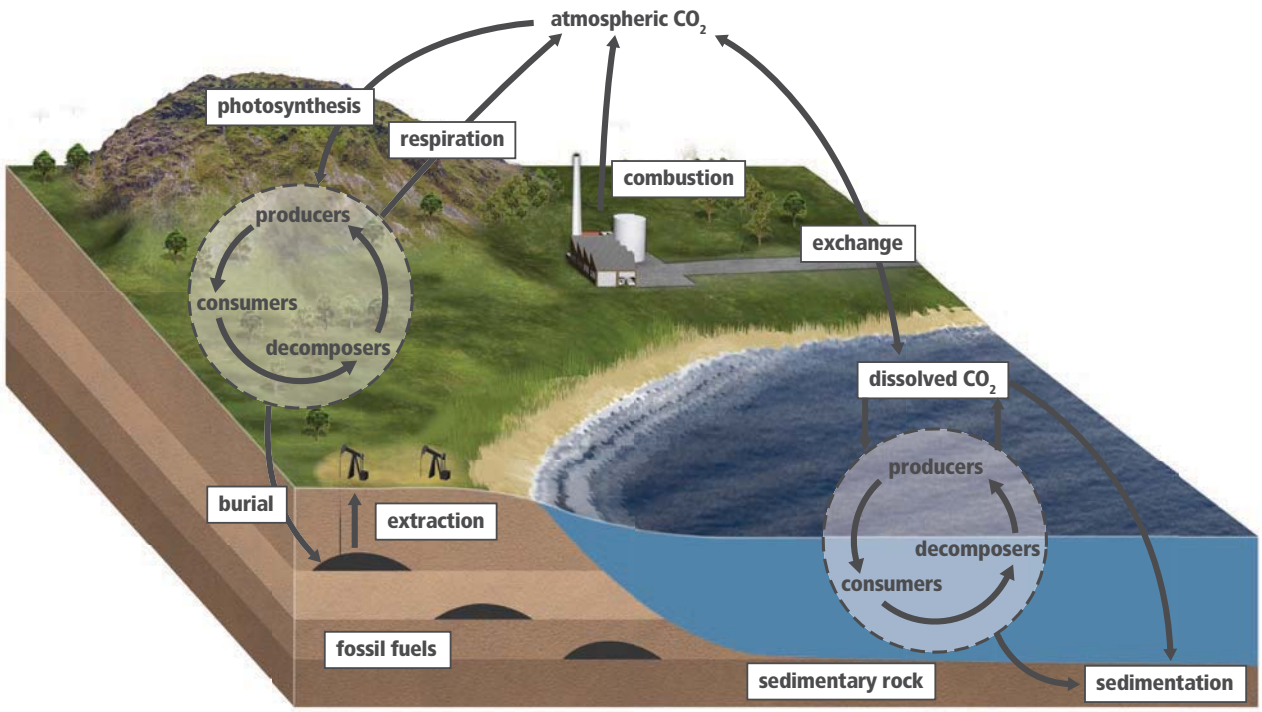
The Carbon Cycle

Gather Evidence Without humans, could carbon in these reservoirs be accessed?

Carbon is present in most chemical compounds that make up living things. Carbon is also stored in abiotic components of the Earth system. For example, CO_2 in the atmosphere, fossil fuels such as oil and coal, dead matter in the soil, and chemical compounds in rocks are carbon reservoirs.

FIGURE 6: Processes such as photosynthesis and combustion drive the cycling of carbon.

Explore Online



Producers remove CO_2 from the atmosphere through photosynthesis. Photosynthetic organisms incorporate the carbon into carbohydrates to store in their tissues. When consumers eat producers, they obtain the carbon, storing some of it in their tissues and releasing some back into the atmosphere through cellular respiration. When the consumers die, decomposers break down the organic matter and release carbon back into the atmosphere through cellular respiration. Carbon is also released into the soil.

Some of the carbon in the organic matter may become fossilized. Under certain conditions, the burial process stores that carbon in Earth's crust where, over millions of years, it becomes fossil fuel. Since the 1800s, humans have extracted this carbon and combusted it, releasing large amounts of carbon back into the atmosphere.

Carbon dioxide diffuses into the ocean from the atmosphere. Oceans are carbon sinks that absorb and hold large amounts of carbon. Carbon enters the aquatic biotic cycle when algae and phytoplankton convert it during photosynthesis. Some dissolved CO_2 is used in the processes of sedimentation and burial to form different types of sedimentary rock. These processes are very slow, taking millions of years, but they form extremely large carbon reservoirs.

Explore Online

Hands-On Activity

Lungs of the Planet
Why are rain forests called the "Lungs of the Planet"? Investigate with Dr. Mike and Dr. Oberbauer to determine if this claim is valid by measuring rates of photosynthesis of rain forest plant life.

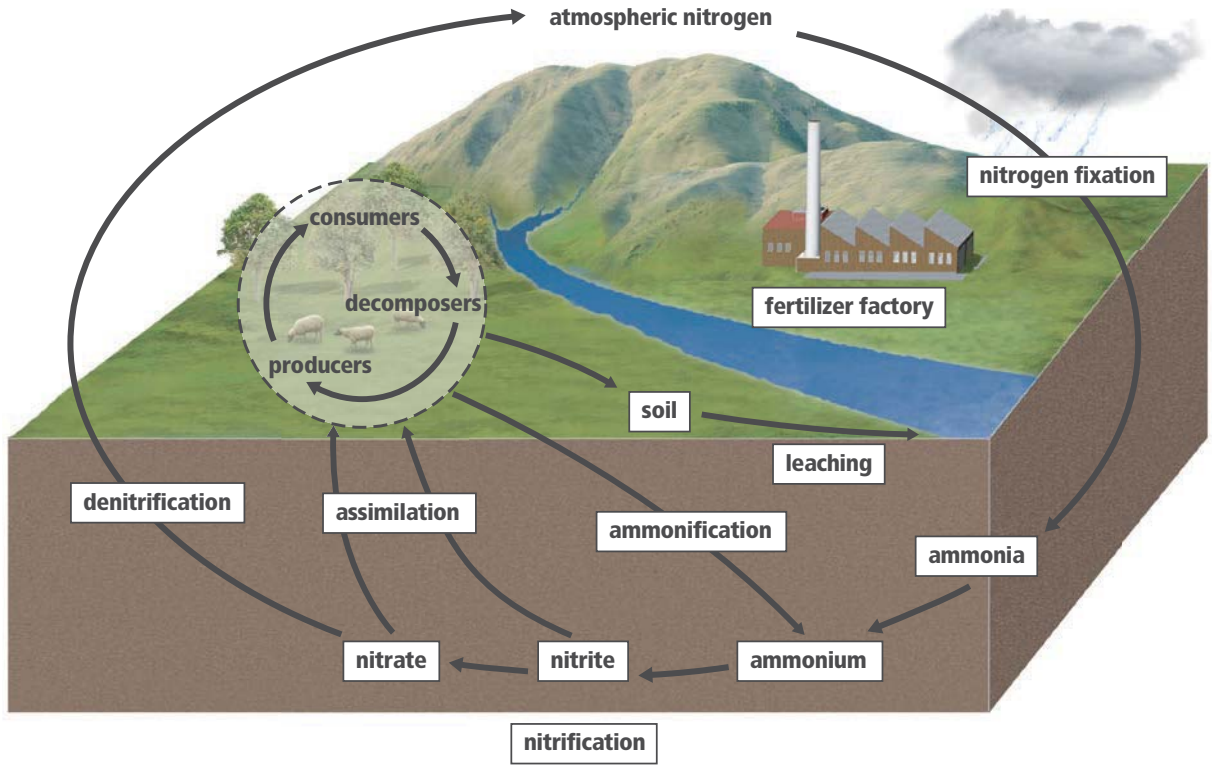
Model Make a model illustrating the roles of photosynthesis and cellular respiration in the cycling of carbon among Earth's spheres. Be sure to include the inputs and outputs for both processes in your model.

The Nitrogen Cycle

About 78% of Earth's atmosphere is composed of nitrogen gas (N_2). However, most organisms are not able to use nitrogen in this form to build organic molecules. The nitrogen must be fixed, or incorporated into other molecules that organisms can use. Bacteria, which are involved in many steps of the nitrogen cycle, fix nitrogen into ammonia, nitrite, nitrate, and other chemicals that organisms can use. As shown in Figure 7, much of the nitrogen cycle takes place below ground.

FIGURE 7: The nitrogen cycle is made up of many processes that move nitrogen from the atmosphere to the biosphere and back again.

Explore Online



Certain types of bacteria convert gaseous nitrogen into ammonia (NH_3) through a process called nitrogen fixation. Some of these bacteria are aerobic, which means they use oxygen. Other bacteria are anaerobic, which means they do not use oxygen. In aquatic ecosystems, this task is performed by a few types of cyanobacteria. Some nitrogen-fixing bacteria on land 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 (NH_4^+) 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. These bacteria change ammonium into nitrate (NO_3^-) through a process called nitrification.

Nitrates released by soil bacteria are taken up by plants through assimilation, which converts 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 back into the atmosphere as a waste product via denitrification.

Scale, Proportion, and Quantity

Bacteria are microscopic organisms, but they are essential to life on Earth. Using evidence from the nitrogen cycle, explain how the microscopic fixation of nitrogen can have such a large impact on life.

Explore Online

Hands-On Lab

Nitrogen Fixation Investigate the role of nitrogen-fixing bacteria by observing prepared slides of legume root nodules.

Nitrogen fixation can occur through biological processes carried out by special types of bacteria, but it can also occur through industrial processes such as the production of fertilizer. Some nitrogen also enters the soil as a result of atmospheric fixation by lightning. Energy from lightning breaks apart nitrogen molecules in the atmosphere. Nitrogen recombines with oxygen in the air, forming nitrogen monoxide. The combination of nitrogen monoxide with rainwater forms nitrates, which are absorbed by the soil. Nitrates in the soil may be moved by water, eventually settling at the bottom of lakes, swamps, and oceans in a process called leaching.

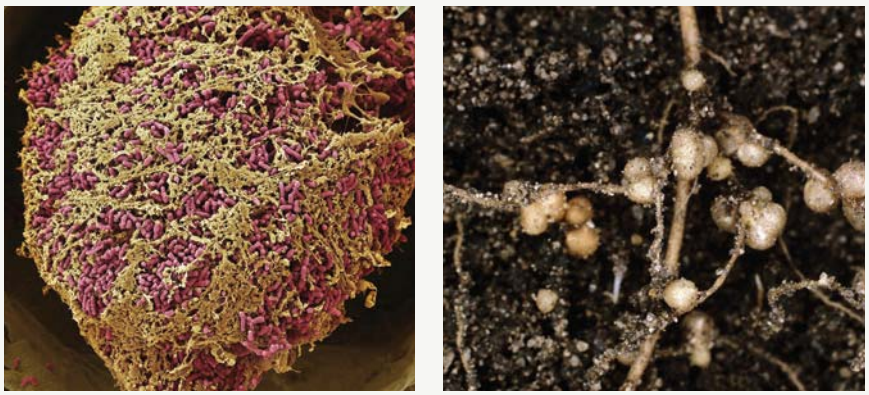
Analyze Organisms in a fish tank can become unhealthy if too much ammonium from their waste builds up in the water. Explain why it is beneficial to add bacteria and plants to a fish tank. Use evidence from the nitrogen cycle model to support your claim.

Energy and Matter

Rhizobia Bacteria

Gather Evidence Legumes are often planted and harvested as crops. When this happens, the plants are not left to decompose into the soil. How does removing the legumes from the ecosystem affect the nitrogen cycle?

FIGURE 8: Nitrogen-fixing bacteria live in a pea plant nodule.



a Rhizobia bacteria (colored SEM)

b Pea plant nodules

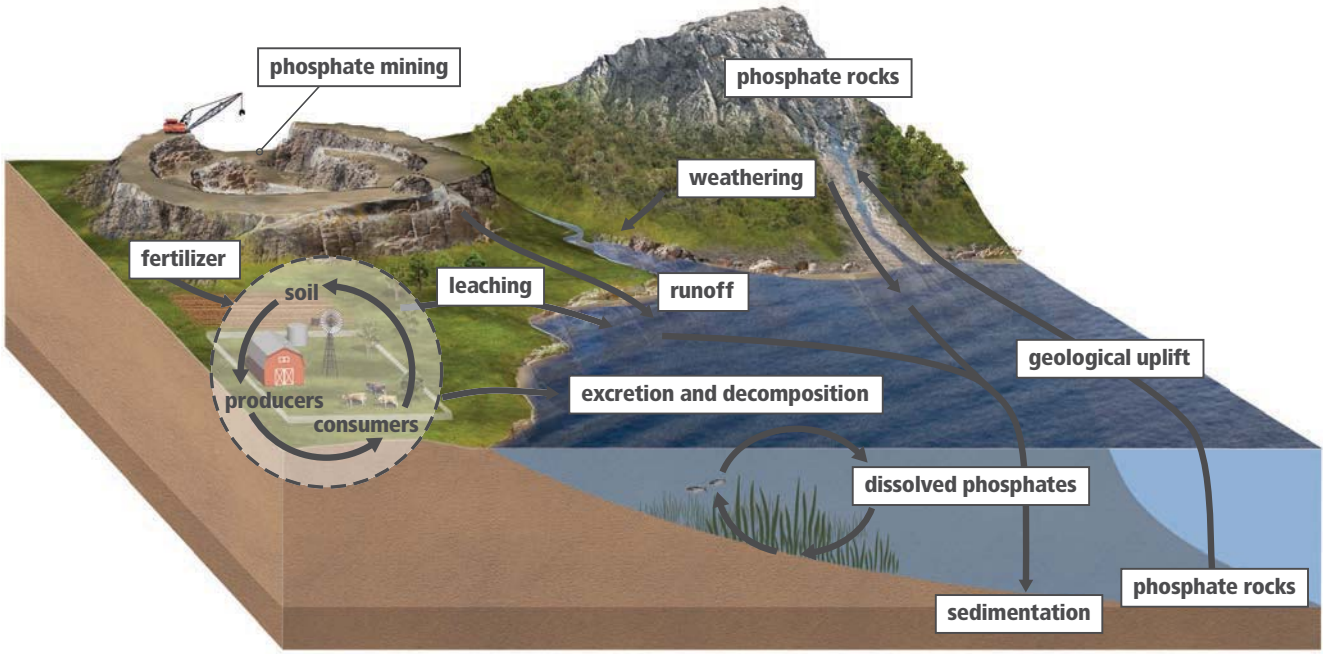
Nitrogen-fixing bacteria live symbiotically, or in close relationship, with certain types of plants, particularly those in the legume family. Rhizobia bacteria live in the nodules on the roots of legumes, as shown in Figure 8. The plant provides essential nutrients to the bacteria and, in return, the bacteria fix nitrogen into ammonia, which the plant absorbs. Most of the ammonia made by the bacteria is kept by the plant and very little is released into the soil until the plant dies. Then, decomposers convert the ammonia molecules into other nitrogen compounds and release some of that nitrogen back into the atmosphere as nitrogen gas.

The Phosphorus Cycle

Phosphorus is an important element for living things. It is a component of phosphate groups in ATP, DNA, and phospholipids in cell membranes. Phosphorus occurs in the form of phosphate salts found in ocean sediments and rocks. Geologic processes expose these rocks, and water and wind break them down, making them available to plants and animals.

FIGURE 9: The phosphorus cycle interacts with the rock cycle through processes such as geologic uplift and weathering.

Explore Online



Analyze Which of Earth's spheres is not part of the phosphorus cycle?

As shown in Figure 9, weathering of phosphate rocks by rain releases phosphate compounds in soil and water. On land, plants can take up phosphate compounds from the soil and consumers gain phosphorus by eating the producers. Decomposers then return phosphorus to the soil and water when they break down the organic matter and wastes of the producers and consumers.

Water can transport phosphorus to aquatic ecosystems through runoff and leaching. Phosphorus compounds dissolve into phosphates where they can be taken up by algae and then consumed by other aquatic organisms. Some dissolved phosphates settle at the bottom of oceans in a process called sedimentation, becoming phosphate rocks over millions of years.

Certain geologic processes expose the phosphate rocks at the bottom of the ocean to the atmosphere. The rocks then undergo weathering, releasing phosphate compounds back into the ecosystem, and continuing the phosphorus cycle. Humans also introduce phosphates into the ecosystem by mining them to make fertilizers and cleaners. Excess phosphates from human activities can enter aquatic ecosystems through runoff and leaching. Very little phosphate is naturally available in most bodies of water and any increases can lead to significant changes in the ecosystem.

Collaborate
Discuss this question with a partner: When the water at Biosphere 2 became polluted with too many nutrients, researchers treated the water by running it over mats of algae. Why did they do this, and how does this action relate to the nitrogen and phosphorus cycles?

Explain How do the hydrologic cycle and the different biogeochemical cycles relate to one another? How can a change in one cycle affect all of the other cycles?

Human Impact on Earth's Cycles

FIGURE 10: Easter Island

Easter Island, located in the southeastern Pacific Ocean, was first inhabited between 400 CE and 700 CE. The human colony grew quickly over the next 1000 years, cutting down the forests for lumber and for building boats. The forests were cleared faster than they could grow back, and eventually the island was left with no trees. Without trees, there was no wood for shelter or boats, the soil washed away, and habitat for the island's animal populations was lost. With no food and the island resources nearly gone, the Easter Islanders disappeared. Today, a small population of people live on the island. The stone monuments placed by the first inhabitants, shown in Figure 10, are a major tourist attraction.

Predict What effect did the human population have on Easter Island? How did they change the island's natural cycling of matter and energy?

Gather Evidence
As you read, record evidence to support or refute the idea that atoms are rearranged in biogeochemical cycles.

Air Pollution

Without human activity, the cycling of carbon, phosphorus, and nitrogen in the Earth system would be in a relatively steady state. Each year humans add synthetic chemicals and materials to Earth, and many of these chemicals cannot be integrated into normal ecosystem functions. The harmful effect of these pollutants can be immediate or delayed, but these effects may add up over time and can disrupt ecosystem functions.

FIGURE 11: Engine combustion contributes to air pollution.

The most common air pollution comes from the waste products produced by burning fossil fuels, such as gasoline and oil that contain carbon, nitrogen, and phosphorus. Burning fossil fuels releases carbon dioxide, methane, nitrous oxide, and other chemicals that pollute the air. Smog is a type of air pollution caused by the interaction of sunlight with pollutants produced by fossil fuel emissions. The nitrogen dioxide in smog reacts with oxygen to produce ozone, O_3. The ozone produced by reactions of nitrogen dioxide and oxygen tends to stay close to the ground, where it can be harmful to human health and ecosystem functions. However, ozone also exists naturally in the upper atmosphere. There, it acts as a shield protecting Earth's biosphere against harmful ultraviolet rays found in sunlight.

Algal Blooms

The production of fertilizers and detergents through industrial nitrogen fixation and phosphate mining has increased greatly over the last few decades. When these fertilizers are added to food crops or lawns, rain causes excess nitrogen and phosphorus to run off into nearby streams or lakes. The addition of nitrogen to an ecosystem alters the nutrient balance, which can lead to increases in producers such as algae, causing what is known as an algal bloom.

Algal blooms affect the overall health of an ecosystem, and in the case of aquatic ecosystems, deplete oxygen through a process called eutrophication. When algae die, decomposers break down their bodies, consuming oxygen in the process. The lack of oxygen harms aquatic organisms, and can even lead to major die-off events.

Cause and Effect

FIGURE 12: Eutrophication harms aquatic ecosystems.

Excess Fertilizer

In many cities, residents over-fertilize their lawns. The excess nitrogen and phosphorus are washed into lakes, streams, and ponds and can lead to eutrophication, as shown in Figure 12. Some cities make efforts to educate their citizens about how to test their soil so they apply just the right amount of nutrients when fertilizing their lawns.

Model Make a model describing how over-fertilizing leads to eutrophication. Then use your model to suggest one possible solution to this problem.

Climate Change

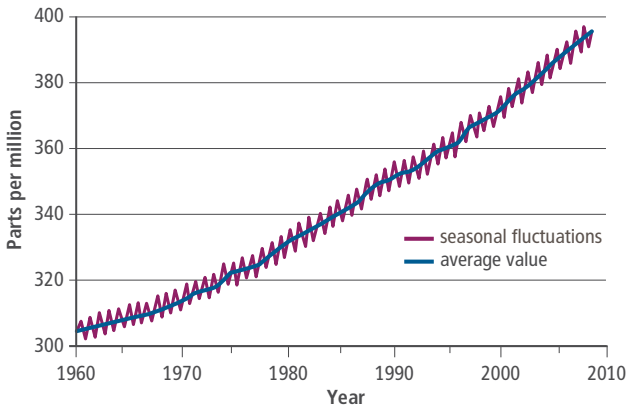
Carbon dioxide emissions released from the burning of fossil fuels have led to a substantial increase in atmospheric CO_2, as shown in Figure 13. The rate at which carbon dioxide enters the atmosphere as a result of human activities is much faster than the rate at which it is removed by other processes. Combusting fossil fuels and clear-cutting forests are two examples of human activities that lead to increased carbon dioxide levels in Earth's atmosphere.

Analyze As carbon dioxide is added to the atmosphere, more carbon dioxide also enters the ocean through diffusion. Carbon dioxide reacts with water to produce carbonic acid, which lowers the pH of the water. What effects do you think this might have on marine life?

Carbon dioxide is one of several greenhouse gases. These gases act in a similar manner to a greenhouse for growing plants: They allow sunlight to pass through and provide energy for plant growth, but keep infrared radiation, or heat, from escaping. Increasing the amount of carbon dioxide in the atmosphere has been linked to increasing global temperatures, which has a devastating effect on ecosystems. Some species have already been observed moving into new areas because the changes in the climate make it difficult for these species to continue living in their natural range. Increased carbon dioxide concentrations have also caused the polar ice caps to shrink and sea levels to rise as a result.

Atmospheric CO_2 at Mauna Loa Observatory

FIGURE 13: Atmospheric carbon dioxide levels have risen substantially since 1960.



Source: Scripps Institution of Oceanography, NOAA Earth System Research Laboratory

Explain Many scientists worry that the influence humans have on the biogeochemical and hydrologic cycles will cause lasting damage to Earth. Make a list of the activities you perform in a day that may impact one of these cycles. Explain how you are interacting with the cycle and how that could be affecting your local ecosystem. What can you do to decrease your impact?

Guided Research

Evaluating Solutions to Human Impacts

Scientists and engineers are working to develop solutions to human impacts on the hydrologic and biogeochemical cycles. Burning fossil fuels for energy has one of the largest impacts on these cycles. Finding alternatives to fossil fuel energy is key to decreasing human impact and making lasting changes.

Currently engineers and scientists are investigating solar, wind, water, biological, and geothermal energies as potential alternatives to fossil fuels. You may have already heard of wind and solar farms. Scientists must ask many questions when they consider implementing new energy sources such as these, including:

- **Costs** - Is the solution cost effective? Can a similar solution be reached in a less costly manner without losing quality?
- **Safety** - Is the solution safe for humans and other living things?
- **Reliability** - Is the solution going to hold up over time in the given conditions? Will it need large amounts of upkeep to be maintained over time?
- **Aesthetics -** Does the solution add to or detract from the natural visual beauty of the area?
- **Social and cultural impacts** - How does the solution impact human societies and cultures? Are there any concerns about these impacts?

FIGURE 14: These wind turbines capture energy from the wind and convert it to electricity. Wind energy is an alternative to energy from fossil fuels.

- **Environmental impacts** - How does the solution impact the environment? Are there any concerns about these impacts?
- **Meeting criteria** - Does the solution solve the problem and meet the needs of those who will use the new energy source?
- **Evidence to support the solution** - How well does the evidence provided support the claims that are being made about this solution and how it will work?

Language Arts Connection

Choose an alternative energy source and research how it impacts the biogeochemical and hydrologic cycles or how it reduces human impact on these cycles. Write a blog entry detailing your research. Explain how the alternative energy source will work for human populations in terms of its trade-offs, such as cost, reliability, and impact on society and the environment. Gather evidence from multiple sources and describe specific evidence from each source.

LUNGS OF THE PLANET | NITROGEN FIXATION | WINTER WATER CHEMISTRY

Go online to choose one of these other paths.

Lesson Self-Check

CAN YOU SOLVE IT?

FIGURE 15: Biosphere 2

The Biosphere 2 research center was originally built with five separate ecosystems: rain forest, ocean, wetlands, grassland, and desert. Scientists thought that by replicating Earth's ecosystems they would be able to make a self-sustaining ecosystem in which humans could live and grow their own food. Almost immediately, however, Biosphere 2 began suffering from a lack of oxygen and increased carbon dioxide concentrations.

Explain Refer to the notes in your Evidence Notebook to explain how matter changes form as it flows within the Biosphere 2 system. Use this information to help you answer the following questions:

1. How do matter and energy change form as they cycle through ecosystems and Earth's spheres?
2. Why do you think researchers had problems with low oxygen in Biosphere 2?
3. How would you solve this problem?

The Biosphere 2 experiment never recovered. The scientists built CO_2 scrubbers to try to remove excess carbon dioxide from the air and eventually had to pump in oxygen to stay alive. The ecosystems inside Biosphere 2 suffered and never flourished as scientists had hoped they would. The original purpose of the experiment failed: A group of people could not survive in a self-sustained system. However, scientists did learn that Earth's ecosystems are extremely complex and there is much the scientific community has yet to learn. Today researchers use Biosphere 2 as a place to study Earth's ecosystems to better understand carbon and oxygen cycles, water recycling, and more.

CHECKPOINTS

Check Your Understanding

1. The steps of the carbon cycle are described below. Place the steps in the correct order.

- **a.** Animals and plants release carbon dioxide and water as a result of cellular respiration.
- **b.** Carbon dioxide is released by plants and animals and moves into the biosphere.
- **c.** Plants use water and carbon dioxide from the atmosphere to make sugar and oxygen through the process of photosynthesis.
- **d.** Animals and plants use sugar and oxygen for the process of cellular respiration.
- **e.** Cellular respiration transforms sugar and oxygen into carbon dioxide and water.

2. Which statement describes a difference between the nitrogen and carbon cycles?

- **a.** The carbon cycle involves only plants.
- **b.** The nitrogen cycle requires a process called fixation that is carried out by certain bacteria.
- **c.** The carbon cycle requires that temperatures be above 27 °C (80 °F).
- **d.** The nitrogen cycle occurs entirely in the ocean.

3. What are the potential effects of introducing too much nitrogen and phosphorus into an aquatic ecosystem? Select all correct answers.

- **a.** Fish populations would increase.
- **b.** Aquatic organisms would die off.
- **c.** Water would become clearer.
- **d.** Algae would grow out of control.
- **e.** Oxygen levels would increase.

4. Which of the following things are common to all of the biogeochemical cycles? Select all correct answers.

- **a.** reservoirs and processes
- **b.** an atmospheric component
- **c.** photosynthesis and respiration
- **d.** living things as a reservoir
- **e.** the sun as a source of energy
- **f.** can be affected by human activities

5. Complete the sentence by filling in the correct substance in each blank.

In the carbon cycle, the role of photosynthesis is to take in _____, and the role of cellular respiration is to give off _____.

6. Recently, some areas in the United States have seen an increase in trees due to reforestation efforts. Draw a "before" and "after" model to show how the carbon cycle might be altered after a large-scale reforestation effort.

7. Draw a diagram of the water cycle, labeling each process. Add arrows and labels to show how energy drives the cycle and is transferred through it.

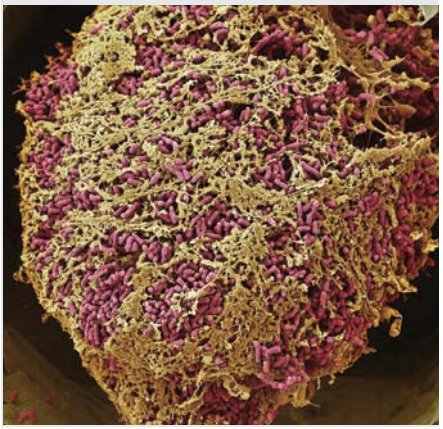
FIGURE 16: Biosphere model

8. How is matter changing form in the biosphere model shown in Figure 16? How many different types of matter cycles do you think are being shown in the model?

9. There is evidence that the increasing carbon dioxide levels in the atmosphere are affecting phytoplankton, which are tiny photosynthetic organisms in the ocean. Explain how the carbon cycle might be affected if phytoplankton were to decrease in number.

10. Decomposers are an important part of many biogeochemical cycles. Some carry out aerobic respiration and some use anaerobic respiration as they break down organic matter. Explain why decomposers are so crucial for the cycling of matter in ecosystems. Cite specific examples to support your answer.

FIGURE 17: Rhizobia bacteria



11. Explain the crucial role bacteria, such as those shown in Figure 17, play in the nitrogen cycle. What would happen to the nitrogen cycle if the bacteria were no longer present?

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

13. Develop a model that explains how energy from Earth drives the biogeochemical cycles.

MAKE YOUR OWN STUDY GUIDE

In your Evidence Notebook, design a study guide that supports the main ideas from this lesson:

Biogeochemical cycles are processes that move matter through and among Earth's spheres. These cycles can be impacted by human activity.

Remember to include the following information in your study guide:

- Use examples that model main ideas.
- Record explanations for the phenomena you investigated.
- Use evidence to support your explanations. Your support can include drawings, data, graphs, laboratory conclusions, and other evidence recorded throughout the lesson.

Consider how matter and energy transform, but are not destroyed, as they move through and among ecosystems and Earth's spheres.