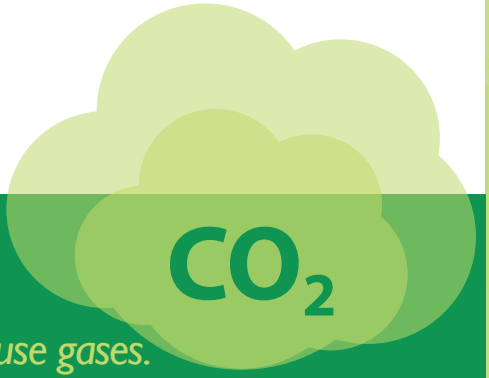
SECTION 3

Carbon Sequestration

Forests can be managed to reduce atmospheric greenhouse gases.



CARBON, OFTEN CALLED THE BUILDING BLOCK OF LIFE, continuously cycles through all plants, animals, soils, rocks, oceans, and the ***atmosphere***. Carbon is found everywhere on Earth, and it undergoes chemical reactions and changes forms as it moves. For example, carbon

- resides in the atmosphere as ***carbon dioxide*** (CO_2);
- is formed into diamonds, one of the hardest substances on earth, and graphite, the soft lead in a pencil;
- provides the structure of plants as cellulose and lignin;
- is stored in starches and sugars that can be broken down to provide organisms with energy for cellular functions;
- resides in every living plant and animal, in the soil, and in the oceans;
- becomes calcium carbonate to form coral reefs and marine animal shells; and
- transforms to calcite in ***limestone***.

In addition, fossilized carbon or ***fossil fuels***, such as coal, oil, and natural gas, are burned as fuel to power the human world. Fossil fuels are used for many activities, such as operating machinery, turning on lights, and flying airplanes. Fossilized carbon is also commonly used to make the fertilizer that helps us grow food efficiently, plastics that keep hospital supplies sterile, and even the packaging that keeps vegetables fresh.

Carbon naturally cycles through biological, physical, and geological ***systems***. However, humans have been altering these systems by adding more carbon to the atmosphere in various ways, most notably through extraction and use of fossil fuels for energy. Atmospheric carbon dioxide has been gradually increasing since the Industrial Revolution (roughly 1760 to 1840), when people began burning fossil fuels in great quantities. In addition, ***deforestation*** increases carbon dioxide levels in the atmosphere, as this action changes landscapes that sequester and store carbon into landscapes that sequester far less carbon, such as agricultural lands or urban developments. As atmospheric carbon increases, most scientists agree that the average global temperature will also increase (U.S. GCRP, 2009). This happens because carbon dioxide, along with other ***greenhouse gases,*** such as methane, nitrous oxide, and water vapor, trap heat in Earth's atmosphere. This process is known as the ***greenhouse effect.*** See the Background section for **Activity 2: Clearing the Air** for more information on climate change science.

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One strategy to reduce carbon dioxide in the atmosphere is to plant and grow more trees so they can sequester and store carbon.

Oceans can also be affected by increased levels of atmospheric carbon because these large bodies of water continuously exchange carbon with the atmosphere. As the amount of carbon in the atmosphere increases, the amount of carbon dissolved in the oceans increases. This causes the ***pH*** of the water to become more acidic. Continued ***ocean acidification*** can affect the health of marine organisms. In particular, organisms that build shells or skeletons containing calcium carbonate, such as coral reefs, clams, and oysters, may be negatively impacted because decreases in ocean water pH will mean that there is less carbonate available for these organisms to build their hard body parts.

As all systems on Earth interact and influence one another, scientists around the globe are researching the potential impacts of a changing average global temperature and ocean water pH. These impacts can be diverse and may involve changes in ***weather*** patterns, sea levels, ***ecosystems***, and plant and animal populations. Strategies to cope with these changes (***adaptation*** strategies) are important. In addition, experts, engineers, policymakers, and communities are working to develop strategies to *reduce* carbon dioxide in the atmosphere (***mitigation*** strategies). Some mitigation strategies include planting and growing more trees to capture more carbon, keeping carbon stored in wood products, capturing carbon and pumping it into the ground, reducing our dependence on fossil fuels, and increasing energy efficiency.

ACTIVITY 7: Carbon on the Move provides an introduction to the ***carbon cycle***, with an emphasis on the role of forests in the cycle. The first portion of the activity focuses on the pools and fluxes of the biological carbon cycle. This is followed by group work and class discussion that include the geological carbon cycle.

Understanding how biological, geological, and atmospheric systems interact through the carbon cycle is a key component to understanding climate change.

ACTIVITY 8: Counting Carbon provides students with an understanding of the role that forests can play in reducing atmospheric carbon dioxide. Students measure trees near their school and calculate the amount of carbon stored in each tree. Students then calculate the amount of carbon being sequestered per year by different land uses in their state. They also compare the amount of carbon that is emitted in their state to the amount of carbon that can be sequestered and consider the implications of the difference.

Potential Areas of Confusion

There are several topics in this section that may be sources of confusion for students based on their existing knowledge, assumptions, or prior experiences. You may be able to use questions to uncover these points of confusion and steer students toward the clarifications provided in the table.

Assumption or Confusion	More Adequate Conception
Plants release oxygen, not carbon dioxide. Or if they do release carbon dioxide, they only respire in the dark.	Plants capture carbon dioxide from the atmosphere during the day, store it in sugar molecules, and then continually break down those sugar molecules to create energy in the form of a chemical compound called ***ATP (adenosine triphosphate).*** ATP is then used to build and maintain complex structures such as cellulose, lignin, bark, and leaves from the simple sugars made in ***photosynthesis.*** The process of metabolizing sugars ***(respiration)*** releases carbon, which returns to the atmosphere as carbon dioxide. This occurs throughout the day and night.
Animals need oxygen, and plants need carbon dioxide.	Plants require carbon dioxide, but they also need oxygen during the process of respiration. Generally, plants release more oxygen as a byproduct of photosynthesis than the amount they use to respire. Woody plants in particular use more carbon dioxide than they release.
Gases are not matter or they don't have mass.	Anything that has matter has mass. Frozen, compressed carbon dioxide is called dry ice and has mass. Gases have mass, too, just less than solids or liquids (by volume) because the molecules are farther apart.
The food broken down for energy leaves an animal's body entirely through its urine and feces.	Much of the substance of food leaves the animal as exhaled carbon dioxide, which is a byproduct of energy-producing cellular respiration.
Respiration produces energy, rather than converting energy.	Respiration converts energy from one form to another.
Energy is used up during biological processes.	Energy cycles. "Used" energy becomes waste heat.
Gases such as carbon dioxide lack sufficient mass to lead to the development of biomass in plants. Plants get mass from the soil.	Plants create biomass from a gas (CO_2) and water (H_2O) by removing carbon and oxygen from carbon dioxide, and hydrogen from water, and then bonding these atoms together to make sugars and cellulose.
Carbon and carbon dioxide are the same thing.	Carbon is an element. When one molecule of carbon combines with two molecules of oxygen, the chemical compound carbon dioxide is formed. At standard temperature and pressure (STP), carbon dioxide is a gas typically found in Earth's atmosphere. Carbon dioxide can also exist as a liquid or solid.

(Table adapted from Hartley, Wilke, Schramm, D'Avanzo, & Anderson, 2011)

The activities in Section 3 help students understand how forests can reduce atmospheric greenhouse gases through carbon sequestration.

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Key Concepts in This Section

- Carbon naturally cycles through biological, physical, and geological systems.
- Humans are altering the natural carbon cycle by adding more carbon to the atmosphere, primarily through fossil fuel combustion.
- Increased levels of atmospheric carbon dioxide will impact other systems, including oceans and forests.
- Trees absorb carbon dioxide from the atmosphere during the process of photosynthesis. About half of this carbon is stored or "sequestered" in the tree's growing roots, trunk, branches, and leaves.
- Southern pine forests are a particularly effective landscape for sequestering carbon because of the trees' fast growth rates.
- There is not enough land available on Earth for forests to sequester all the carbon dioxide that we emit through industry, transportation, and other activities. To reduce atmospheric carbon, we might consider solutions such as reducing consumption and using low-carbon energy sources.

References Cited

Hartley, L. M., Wilke, B. J., Schramm, J. W., D'Avanzo, C., & Anderson, C. W. (2011). College students understanding of the carbon cycle: contrasting principle-based and informal reasoning, *BioScience, 61,* 65–75.

U.S. Global Climate Research Program (U.S. GCRP). (2009). *Global climate change impacts in the US.* Washington, DC: Cambridge University Press. Retrieved from http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf