Carbon Cycle Poster

GRADE LEVEL	4^{th} -$12^{th;}$ Standards for 4^{th}, 5^{th}, 6^{th}, 8^{th}, 9^{th} – 12^{th}
SUBJECTS	Earth Sciences, Developing and Using Models
DURATION	Activity: 40 minutes
SETTING	Classroom

Objectives

Students will be able to:

1. illustrate the carbon flows that occur between the biosphere, hydrosphere, atmosphere and lithosphere.
2. illustrate and explain how humans alter carbon flows between the four spheres
3. identify human alterations of carbon flows that contribute to global climate change.

Materials

- poster or butcher paper
- construction paper in four different colors to represent the different spheres (we suggest blue to represent hydrosphere, green to represent biosphere, yellow to represent atmosphere, and brown to represent lithosphere)
- scotch tape
- scissors
- colored pencils, crayons, or markers
- *Carbon Flow Arrows*
- *Human Alteration Arrows*
- *Carbon Cycle Poster Human Alteration Cards*
- *Carbon Cycle Poster Human Alteration Answers*

Scientific Terms for Students

carbon: an element that can be found in all living things
diffusion: mixing of particles of liquid, gases, or solids from one place to another (from higher concentration to lower concentration)

Earth's spheres
atmosphere: the gases surrounding the Earth
biosphere: the parts of the land, sea and atmosphere in which life exists
hydrosphere: all of the Earth's water, including surface water (water in oceans, lakes, and rivers), groundwater (water in soil and beneath the earth's surface), snowcover, ice, and water in the atmosphere, including water vapor
lithosphere: rocky outer layer of the Earth

Plants and their processes
photosynthesis: the process by which plants use carbon dioxide and energy from the sun to build sugar
respiration: the processes by which plant and animal cells break down sugar, which results in carbon dioxide

Geologic processes
erosion: wearing away and movement of rock and sediment, often by water, wind, glaciers, and waves
sediment: material, such as stones or sand, deposited by water, wind, or glaciers
sedimentation: the process of laying down sediments and forming sedimentary rocks
weathering: processes by which rocks exposed to the weather change and break down

Background for Educators

Carbon Cycle

Carbon is an extremely common element on earth and can be found in all four major spheres of the planet: biosphere, atmosphere, hydrosphere, and lithosphere. Carbon is part of both the living and non-living parts of the planet, as a component in organisms, atmospheric gases, water, and rocks. The carbon contained in any of the planet's spheres does not remain there forever. Instead, it moves from one sphere to another in an ongoing process known as the carbon cycle. The carbon cycle is extremely important on earth as it influences crucial life processes such as photosynthesis and respiration, contributes to fossil fuel formation, and impacts the earth's climate.

Besides the relatively small additions of carbon from meteorites, the amount of carbon on the planet is stable. But, the amount of carbon in any given sphere of the planet can increase or decrease depending on the fluctuations of the carbon cycle. The cycle can be thought of in terms of reservoirs (places where carbon is stored) and flows (the movement between reservoirs). The atmosphere, the biosphere, the hydrosphere, and the lithosphere are the reservoirs and the processes by which carbon moves from one reservoir to another are the flows. Although carbon is extremely common on earth, pure carbon is not common. Rather, carbon is usually bound to other elements in compounds. Thus, when carbon moves or cycles, it is usually doing so within compounds, such as carbon dioxide and methane.

The many processes that move carbon from one place to another happen on different time scales. Some of them happen on short time scales, such as photosynthesis, which moves carbon from the atmosphere into the biosphere as plants extract carbon dioxide from the atmosphere. Some carbon cycle processes happen over much longer time scales. For example, in the ocean, organisms with calcium carbonate skeletons and shells die and some of their remains, those that don't decompose, sink towards the ocean floor. Upon reaching the ocean floor, the carbon that was stored in their bodies becomes part of the carbon-rich sediment and is eventually carried along, via plate tectonic movement, to subduction zones where it is converted into metamorphic rock. These two examples show the extreme variety of processes that take place in the carbon cycle.

In general, the short-term carbon cycle encompasses photosynthesis and respiration. On land, there is a flow of carbon from the atmosphere to plants with photosynthesis and then a flow back to the atmosphere with plant and animal respiration and decomposition. For aquatic plants, photosynthesis involves taking carbon dioxide dissolved in the water around them and respiration and decomposition put carbon dioxide back into the water. In addition to moving

between plants and the atmosphere or the water, carbon dioxide is also constantly moving between the atmosphere and water via diffusion. The long-term carbon cycle encompasses more of the lithospheric processes. It involves the weathering and erosion of carbon-containing rocks, the accumulation of carbon-rich plant and animal material in sediments, and the slow movement of those sediments through the rock cycle.

The entire carbon cycle is composed of even more specific flows between the atmosphere, biosphere, hydrosphere, and lithosphere than those discussed here. Although there are more specific details involved in the earth's complicated carbon cycle, this version highlights some of the most important components and will teach students the overall concept that carbon is limited and moves through the different spheres of the planet. For more detailed carbon cycle information investigate the resources and references listed at the end of the lesson plan.

Human Alterations

There are natural fluctuations in the carbon cycle, but humans have been changing the carbon flows on earth at an unnatural rate. The major human-induced changes in the carbon cycle result in increased carbon dioxide (CO_2) and methane (CH_4) in the atmosphere. The largest source of this change is burning fossil fuels, but other actions such as deforestation, cement manufacturing, cattle farming, and rice farming also contribute to this change in the carbon cycle.

Humans use fossil fuels such as oil, coal, and natural gas for a variety of purposes including powering our vehicles, producing electricity, heating and cooling our buildings, and producing goods such as plastics. Fossil fuels are formed over millions of years from buried plant and animal material that undergoes dramatic changes due to temperature and pressures at depth. In general, coal is derived from terrestrial plant material, while oil and natural gas are derived primarily from microscopic marine plants and animals. When we burn these fossil fuels, we take carbon that has been stored underground for a very long time and put it into the atmosphere.

Deforestation causes carbon to be released into the atmosphere for a number of reasons. First, trees that are cut are often burned, which immediately releases the carbon stored in the trees into the atmosphere. Second, deforestation impacts both the temperature and stability of the soil. Since soils contain a significant amount of carbon, changes that affect the soil can affect the carbon stored in the soil. Deforestation results in more soil erosion because trees are no longer there to stabilize the soil. Eroded soil and the carbon it contains often end up in rivers and streams and eventually in the oceans, bringing carbon from the land into the hydrosphere. Soils in deforested areas are not only eroded because of the lack of trees, but they are also often tilled for agriculture. Tillage turns over the soil, releasing carbon dioxide gas contained in the soil to the atmosphere. After deforestation, soil temperatures increase because the soil is no longer covered by foliage. A rise in soil temperature causes the rate of bacterial decomposition to increase, which results in increased carbon release to the atmosphere.

The process of manufacturing cement releases carbon dioxide gas to the atmosphere. To make cement, calcium carbonate is heated in a kiln to produce lime and carbon dioxide. The lime is incorporated with other materials to make the cement, but the carbon dioxide is released to the atmosphere. In the United States, this process releases approximately 7 to 10 million metric tons

of carbon per year. Although not one of the very top contributors to carbon dioxide emissions, cement manufacturing is still a significant and growing source of carbon emissions worldwide.

Cattle farming and rice farming both release methane gas to the atmosphere. Flooded rice paddies are considered one of the highest releasers of methane. When rice paddies are flooded, the underwater organic matter undergoes decomposition and methane is released. This also occurs in natural wetlands. Cattle farming also contributes significantly to methane emissions. Cattle belches and flatulence release methane because bacteria in the animals' guts break down food and convert some of it to methane gas. Both cattle and rice farming are on the rise worldwide and thus these sources of greenhouse gases are becoming more and more of a concern. Methane emissions are also especially concerning because methane is a much stronger greenhouse gas than carbon dioxide, meaning that each molecule of methane warms the earth substantially more than each molecule of carbon dioxide.

Climate Change

Because carbon dioxide (CO_2) and methane (CH_4) are greenhouse gases that help to control the temperature of the planet, human-induced increases in atmospheric carbon levels are resulting in a host of climatic changes on our planet. These changes include temperature increases, rising sea level, changes in rainfall patterns, increased storms, and organism extinctions. An understanding of the carbon cycle is especially important at this time in human history because of the dramatic and consequential alterations we are making to the cycle.

People are currently taking many different actions, attempting to slow climate change. They are attempting to both lessen the amount of carbon that is emitted to the atmosphere and to take carbon out of the atmosphere and store it elsewhere. Some of the ways to decrease the amount of carbon emitted to the atmosphere include driving less, using energy efficient appliances, switching to solar and wind power, and capturing carbon from power plants and other stationary sources and pumping it underground for storage. This is called carbon capture and storage or carbon sequestration and people have been using this technique in oil fields for a long time. Scientists are currently researching carbon capture and storage methods to try to determine whether this technique can be used on a large scale to help slow climate change. Mitigating climate change by actually taking carbon out of the atmosphere can be accomplished with several different methods. Simply planting more trees takes carbon out of the atmosphere, because plants take carbon from the atmosphere to perform photosynthesis. Other methods for taking carbon dioxide out of the atmosphere include capturing carbon dioxide gas and converting it back into usable fuel. This is an ongoing research topic and although there are currently many viable options for decreasing the amount of carbon in the atmosphere, the future may hold other possibilities as well.

Teacher Prep

1. Collect supplies, cutting poster paper for each group of four.
2. Draw the color key on the board for the 4 spheres.
3. Print out and cut arrows and alteration cards.

Introduction

Discuss what the words "biosphere, lithosphere, hydrosphere, and atmosphere" mean. We suggest guiding students in dissecting the words: Bio means life, litho means rock, hydro means water, and atmos is Greek for vapor. Sphere refers to a part or parts of the planet.

- The biosphere is composed of the parts of the planet that contain life.
- The lithosphere is composed of the parts of the planet that contain rocks and sediments.
- The hydrosphere is composed of the parts of the planet with water
- The atmosphere is composed of the parts of the planet with vapor or gases.

Teach the carbon cycle. We suggest using the **Carbon Cycle Role-Play** activity, but a lecture format will work too.

Making the Carbon Cycle Poster

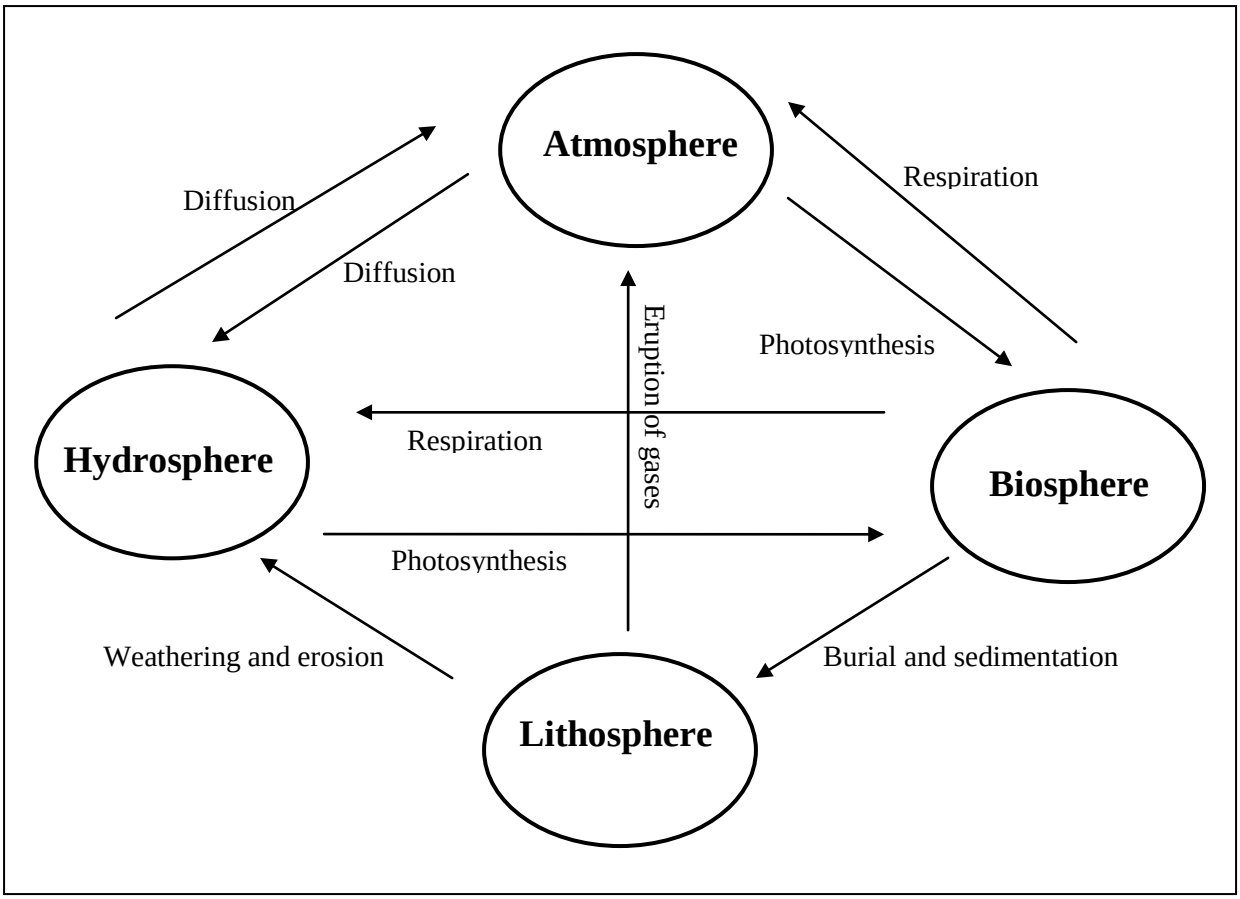
1. Break students up into groups of four and distribute poster paper to each. Explain that their task will be to work together to design a carbon cycle poster which illustrates how the carbon moves between the four different spheres.

2. Have each group help cut out and label the spheres.
   - Give each group four pieces of construction paper, each a different color. Referencing your color key, tell students that each piece of paper will represent one of the four spheres: biosphere, atmosphere, hydrosphere, and lithosphere.
   - Have each student choose one piece of paper and cut a large circle from it. Then, have students write the the name of the sphere on their circle and draw something that represents that sphere (e.g., leaves, clouds, drops, mountains).

3. Have each group create a diagram by taping the spheres and the arrows onto the poster in such a way as to explain how carbon flows through the four spheres.
   - Give each group of students a set of **9 Carbon Flow Arrows**, but don't distribute the human alteration arrows yet. Tell students that these arrows show how carbon moves from one sphere to another.
   - If needed, go over some of the vocabulary on the arrows with the students.
   - Tell students that their task is to place the arrows between the appropriate spheres. Emphasize that the arrows should face the appropriate direction on their posters.

   Teacher Tip: Check for understanding by glancing at posters as they work, and guide students as appropriate. Focus on having them explain their reasoning, referring to prior experience, such as with the **Carbon Cycle Role-Play**.

4. After students have finished connecting their spheres with the arrows, bring everyone together as a class to compare their systems and explain their thinking. You can make a diagram on the board (see example) if it helps to clarify misunderstandings.



5. Discuss how these posters model the system, and what ideas might be clear or missing from this diagram (e.g., carbon is sometimes a solid, liquid, or gas; the quantity of carbon moved through each arrow is not expressed).

   Assessment Boundary: If you are working towards Performance Expectations 5-LS2-1 or MS-LS2-3 or HS-LS2-5 regarding *developing a model to describe the movement of matter among living and non-living parts of an ecosystem*, remember that students are *not* expected to demonstrate understanding of molecular movement or describe the process using chemical reactions.

   Assessment Boundary: If you are working towards Performance Expectations 5-ESS2-1 or MS-ESS2-1 or HS-ESS2-6 regarding *developing a model to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact*, remember that 5th graders only need to explain the interactions of two systems at a time. The emphasis for middle school is on the geologic process of the rock cycle, and the emphasis in high school is on how biogeochemical cycles that include the cycling of carbon through the ocean, atmosphere, soil, and biosphere (including humans), provide the foundation for living organisms.

Tracing Human Impact

1. Give each group a **Human Alteration Card**. Hand out the **Human Alteration Arrow Sheets** and tell students to cut out the arrow and to write their specific human alteration on the arrow.

2. Tell students to place the human alteration arrow on their poster to reflect how the alteration would move carbon from sphere to sphere. Some of these are tricky, so tell students it is okay if they don't know the answer for sure because you will go over it as a class.

3. Have each group present their human alteration and how they think it impacts the carbon cycle to the rest of the class. Use the **Human Alteration Answer**s to check student work and to guide the class in discussion.

4. After each group presents, make sure to discuss how the initial impact of a human alteration to the carbon cycle might be a flux from one sphere to another sphere, represented by the big arrow, but that that initial flux might cause other movements in the cycle too. It is a carbon cycle after all; what moves into one sphere will eventually move into other spheres. Emphasize that the cycle moves at different speeds and that some movements between spheres happen relatively quickly while others take a really long time.

5. Take this opportunity to tell your students that scientists are still studying the carbon cycle and do not completely understand how all of the details work. For example, as humans release more carbon into the atmosphere, some of it is taken up by the oceans, but scientists are not sure exactly how much carbon the ocean takes up from the atmosphere.

6. Discuss which of these human alterations have impacts on the climate (all of them). Six of them put carbon into the atmosphere, where it is a component of greenhouse gases and alters the climate by absorbing and re-radiating heat. One of them takes carbon from the atmosphere and puts in into tree growth and one takes carbon from the lithosphere, but instead of releasing it to the atmosphere, it is injected back into the lithosphere. These last two alterations, planting trees and capturing carbon emissions and storing them underground, are examples of ways that humans are trying to fight climate change and reduce carbon emissions.

Wrap-Up

Discuss the following questions with your students:

- Are humans adding more carbon to the carbon cycle? *(No, humans are changing the amount of carbon in certain spheres, but are not changing the overall amount of carbon on the plant.)*

- What are humans doing to change the carbon cycle? *(Burning fossil fuels, farming cattle, farming rice, deforesting, manufacturing cement)*

- Why are these human alterations to the carbon cycle a problem? *(They are increasing the amount of carbon dioxide and methane in the atmosphere, both of which are greenhouse gases. An increase in greenhouse gases leads to global climate change, which has many effects including rising sea levels, rising temperatures, increased storms, changes in rainfall, organism extinctions…)*

- What can humans do to decrease the amount of carbon being released into the atmosphere? *(Burn fewer fossil fuels by driving less, take public transportation, buy local foods, turn the lights off, plant trees, support renewable energy sources like wind and solar, capture carbon at power plants and store it underground)*

References

Mackenzie, F.T. (2003). *Our Changing Planet: An Introduction to Earth Science and Global Environmental Change.* Upper Saddle River, NJ: Prentice Hall.

Tarbuck, E.J., & Lutgens, F.K. (2002). *Earth: An Introduction to Physical Geology.* Upper Saddle River, NJ: Prentice Hall.

Correlated California State Content Standards

Grade Four

Life Sciences

2c. Students know decomposers, including many fungi, insects, and microorganisms, recycle matter from dead plants and animals.

Earth Sciences

5a. Students know some changes in the earth are due to slow processes, such as erosion, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.

Grade Five

Life Sciences

2f. Students know plants use carbon dioxide (CO_2) and energy from sunlight to build molecules of sugar and release oxygen.

2g. Students know plant and animal cells break down sugar to obtain energy, a process resulting in carbon dioxide (CO_2) and water (respiration).

Grade Six

Life Sciences

5a. Students know energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis and then from organism to organism through food webs.
5b. Students know that matter is transferred over time from one organism to others in the food web and between organisms and the physical environment.

Grade Eight

Life Sciences

6a. Students know carbon, because of its ability to combine in many ways with itself and other elements, has a central role in the chemistry of living organisms.

Grades Nine Through Twelve

Earth Sciences

7a. Students know the carbon cycle of photosynthesis and respiration and the nitrogen cycle.
7b. Students know the global carbon cycle: the different physical and chemical forms of carbon in the atmosphere, oceans, biomass, fossil fuels, and the movement of carbon among these reservoirs.

Next Generation Science Standards

The items listed below indicate how the **Carbon Cycle Unit—**composed of the lessons **What Contains Carbon?**, **Carbon Cycle Role-play**, and **Carbon Cycle Poster—**supports the three dimensions of the Next Generation Science Standards (http://www.nextgenscience.org/).

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and using models **3-5:** Develop a model using an example to describe a scientific principle. **6-8:** Develop and use a model to describe phenomena. **9-12:** Develop a model based on evidence to illustrate the relationships between systems or between components of a system.	**5-ESS2-A: Earth Materials and Systems** Earth's major systems are the geosphere (solid and molten rock, soil, and sediments), the hydrosphere (water and ice), the atmosphere (air), and the biosphere (living things, including humans). These systems interact in multiple ways to affect Earth's surface materials and processes. **5-LS2-B: Cycles of Matter and Energy Transfer in Ecosystems** Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. **MS-ESS-A: Earth's Materials and Systems** All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. **MS-LS2-B: Cycle of Matter and Energy Transfer in Ecosystems** Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. **HS-ESS2-D: Weather and Climate** Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. **HS-LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.	**Systems and system models** **5:** A system can be described in terms of its components and their interactions. **6-8:** Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. **9-12:** Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Related Performance Expectations

Remember, performance expectations are not a set of instructional or assessment tasks. They are statements of what students should be able to do after instruction. This activity or unit is just one of many that could help prepare your students to perform the following hypothetical tasks that demonstrate their understanding:

5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
http://www.nextgenscience.org/5ess2-earth-systems

5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.
http://www.nextgenscience.org/5ls2-ecosystems-interactions-energy-dynamics

MS-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
http://www.nextgenscience.org/msess2-earth-systems

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
http://www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics

HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.
http://www.nextgenscience.org/hsess2-earth-systems

HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
http://www.nextgenscience.org/hsls2-ecosystems-interactions-energy-dynamics