Lesson: Carbon Cycle Poster

GRADE LEVEL	3rd -12th, California Content Standards for 4th, 5th, 6th, 8th, and 9th-12th
SUBJECTS	Life Sciences, Earth Sciences
DURATION	Activity: 40 minutes
SETTING	Classroom

Objectives

In this activity, students will:

1. learn that carbon is in all four of the earth's major spheres: biosphere, hydrosphere, atmosphere, and lithosphere.
2. understand that carbon moves/cycles from one sphere to another.
3. understand how humans influence the carbon cycle and contribute to global climate change.

Materials

poster or butcher paper
four colors of construction paper (we suggest blue, green, yellow, and brown)
scotch tape
scissors
colored pencils, crayons, or markers
Carbon Flow Arrows
Carbon Cycle Poster Alteration Cards
Carbon Cycle Poster Alteration Answers

Vocabulary

- carbon: a naturally abundant, nonmetallic element that occurs in all organic compounds and can be found in all known forms of life
- biogeochemistry: the study of the relationship between the geochemistry of a region and the animal and plant life in that region, including the circulation of elements such as carbon and nitrogen between the environment and the cells of living organisms
- lithosphere: rigid, rocky outer layer of the earth
- 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
- atmosphere: the mixture of gases surrounding the earth, held in place by gravity
- biosphere: the parts of the land, sea, and atmosphere in which organisms are able to live

Teacher Background

Note: If you have already read the teacher background for the "Carbon Cycle Demonstration," you can move directly to the Human Alterations section of this teacher background.

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.

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.

Activity

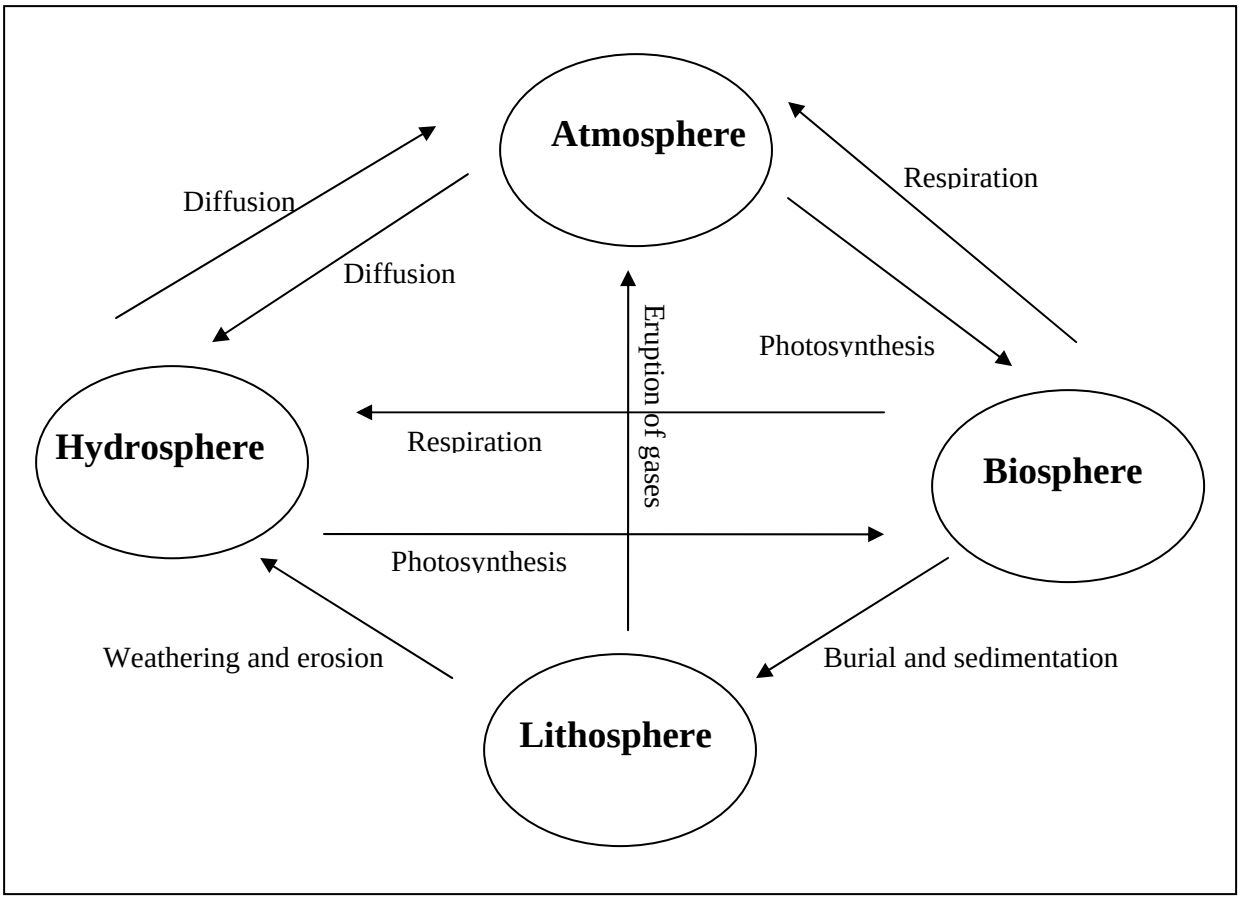
Introduction

- Write the words “biosphere, lithosphere, hydrosphere, and atmosphere” on the board.
- Ask students if they know what these words mean. Guide 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. So, 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 and the atmosphere is composed of the parts of the planet with vapor or gases.
- Write the word “biogeochemistry” on the board.
- Guide students in dissecting the word into “bio”, “geo” and “chemistry.”
- Write the definitions of these three terms on the board: bio means life, geo means land or earth, and chemistry is the study of the composition, structure and properties, of substances and the reactions that they undergo.
- Tell students that the whole word is all three of these things combined. Biogeochemistry is not the study of just one thing, but is the study of how our planet’s spheres interact, how things can move from the biosphere, the living things,

to the geosphere or lithosphere, which contains non-living things like rocks and sediments. The carbon cycle is one of the planet's biogeochemical cycles because carbon moves between both the living organisms and the non-living rocks and sediments.

Procedure

1. Teach the carbon cycle. We suggest using the "Carbon Cycle Demonstration" activity, but a lecture format will work too.
2. Break students up into groups of four. Tell students that they will now put together their own carbon cycle posters.
3. Each group creates a carbon cycle poster.
    - Give each group four pieces of construction paper, each a different color.
    - Tell students that each piece of paper will represent one of the four spheres: biosphere, atmosphere, hydrosphere, and lithosphere. Tell students or decide as a class which color represents which sphere.
    - Have each student choose one piece of paper and cut a large circle from it. Then, have students write their sphere on their circle and draw something that represents that sphere. For example, leaves for the biosphere, clouds for the atmosphere, drops of water for the hydrosphere, and a mountain for the lithosphere.
4. Tell students to tape the four circles onto their poster, making sure that they are spread apart.
5. 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.
6. If needed, go over some of the vocabulary on the arrows with the students.
    - Respiration: plant and animal cells break down sugar, which results in carbon dioxide
    - Photosynthesis: plants use carbon dioxide and energy from the sun to build sugar
    - Diffusion: a process that moves particles, such as atoms or molecules, from one place to another (from higher concentration to lower concentration)
    - Sedimentation: process of laying down sediments and forming sedimentary rocks
    - Weathering: processes by which rocks exposed to the weather change and break down
    - Erosion: wearing away and movement of rock and sediment, often by water, wind, glaciers, and waves
7. Tell students that their task is to place the arrows between the appropriate spheres and facing the appropriate direction on their posters.
8. After students have finished connecting their spheres with the arrows, bring everyone together as a class and make a poster together so that the students can see the answers. See the diagram below.



9. Explain to students that their posters show some of the most important processes that move carbon from one place to another.
10. Have students get back into their groups and give each group a human alteration card.
11. 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.
12. 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.
13. Have each group present their human alteration and how they think it impacts the carbon cycle to the rest of the class. Use the Carbon Cycle Poster Alteration Answers to check student work and to guide the class in discussion.
14. 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 and what moves into one sphere will eventually move into other spheres. Make sure to emphasize that the cycle moves at different speeds and that some movements between spheres happen relatively quickly while others take a really long time.

15. 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.
16. Discuss which of these human alterations have impacts on the climate. They all have impacts on the climate. 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)*

Assessment: Check accuracy of student posters.

Resources

NASA, earth observatory. *The carbon cycle*. Retrieved on January 14, 2008 from http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle2.html

Houghton, R. (2007). *Understanding the global carbon cycle*. Retrieved on March 26, 2008 from http://www.whrc.org/carbon/index.htm

References

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

NASA, earth observatory. *The carbon cycle.* Retrieved on January 14, 2008 from http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle2.html

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
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
Biology/Life Sciences: Ecology

6b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.
6d. Students know how water, carbon, and nitrogen cycle between abiotic resources and organic matter in the ecosystem and how oxygen cycles through photosynthesis and respiration.

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.
7c. Students know the movement of matter among reservoirs is driven by Earth's internal and external sources of energy.

Carbon Cycle Alterations

Deforestation in the Amazon

When humans cut down trees and burn them, the carbon that was stored in the trees is released.

Planting New Trees

As newly planted trees grow, they take in more carbon dioxide to perform photosynthesis.

Burning Fossil Fuels in Automobiles

When humans burn fossil fuels, which take millions of years to form, the carbon in the fossil fuels is released.

Farming Cattle

When cattle release gas from their digestive system, they release methane, a carbon-containing gas.

Increased Cement Manufacturing for Dams

When humans create cement for dams and other structures, they heat rock containing calcium carbonate, and carbon dioxide is released.

Capture and Store Carbon in Geological Formations

When humans capture carbon from power plants, they sometimes inject it into the ground where it is stored.

Burning Fossil Fuels for Electricity

When humans burn fossil fuels, which take millions of years to form, the carbon in the fossil fuels is released.

Farming Rice

When humans farm rice in paddies, the fields are flooded and bacteria decompose organic matter resulting in methane, a carbon-containing gas.

Carbon Cycle Alterations - Answers

Deforestation in the Amazon

When humans cut down trees and burn them, the carbon that was stored in the trees is released.

Direction: Biosphere to Atmosphere

Planting New Trees

As newly planted trees grow, they take in more carbon dioxide to perform photosynthesis.

Direction: Atmosphere to Biosphere

Burning Fossil Fuels in Automobiles

When humans burn fossil fuels, which take millions of years to form, the carbon in the fossil fuels is released.

Direction: Lithosphere to Atmosphere

Farming Cattle

When cattle release gas from their digestive system, they release methane, a carbon-containing gas.

Direction: Biosphere to Atmosphere

Increased Cement Manufacturing for Dams

When humans create cement for dams and other structures, they heat rock containing calcium carbonate and carbon dioxide is released.

Direction: Lithosphere to Atmosphere

Capture and Store Carbon in Geological Formations

When humans capture carbon from power plants, they sometimes inject it into the ground where it is stored.

Direction: Lithosphere to Lithosphere
Atmosphere to Lithosphere acceptable, since carbon that would otherwise be released to the atmosphere is stored in the lithosphere.

Burning Fossil Fuels for Electricity

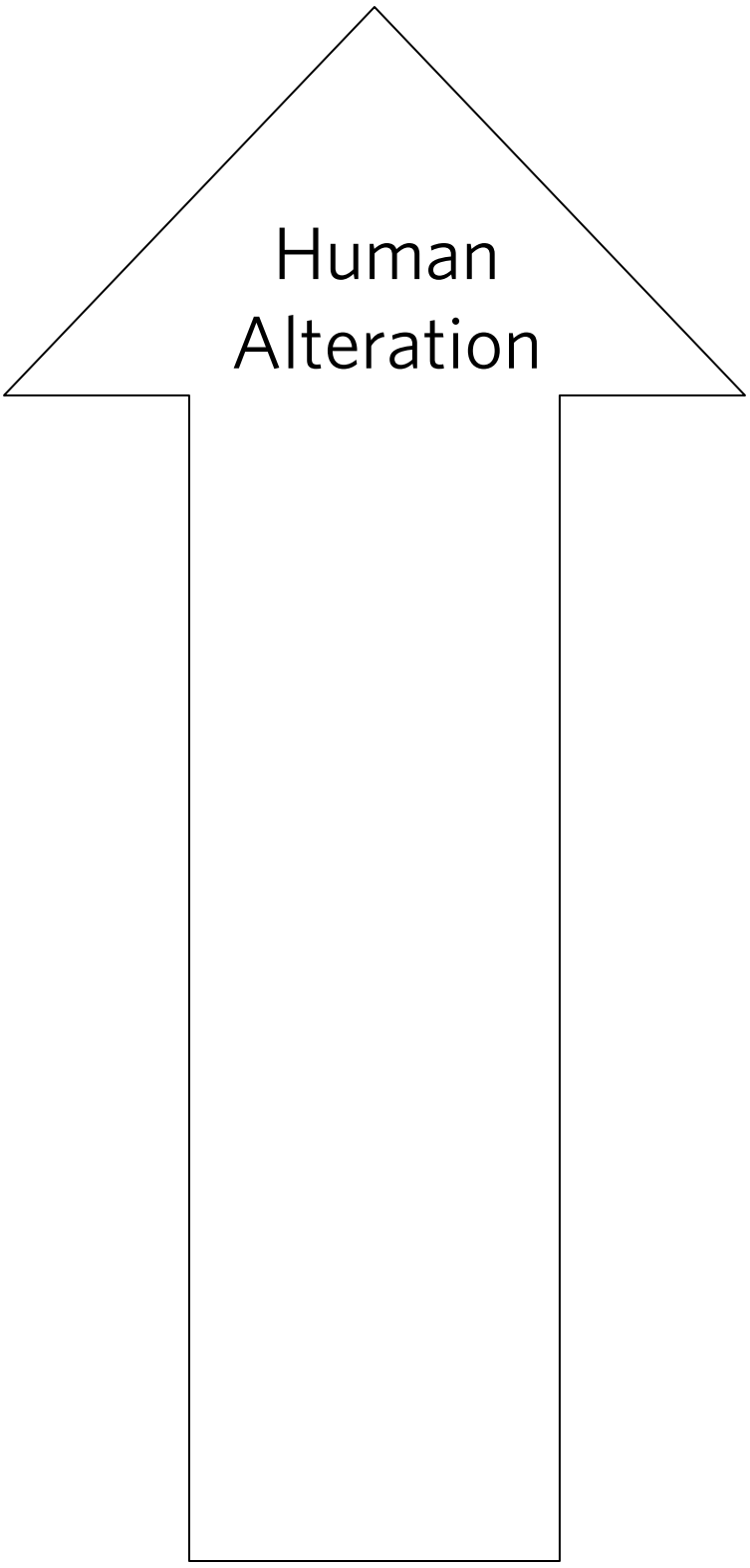
When humans burn fossil fuels, which take millions of years to form, the carbon in the fossil fuels is released.

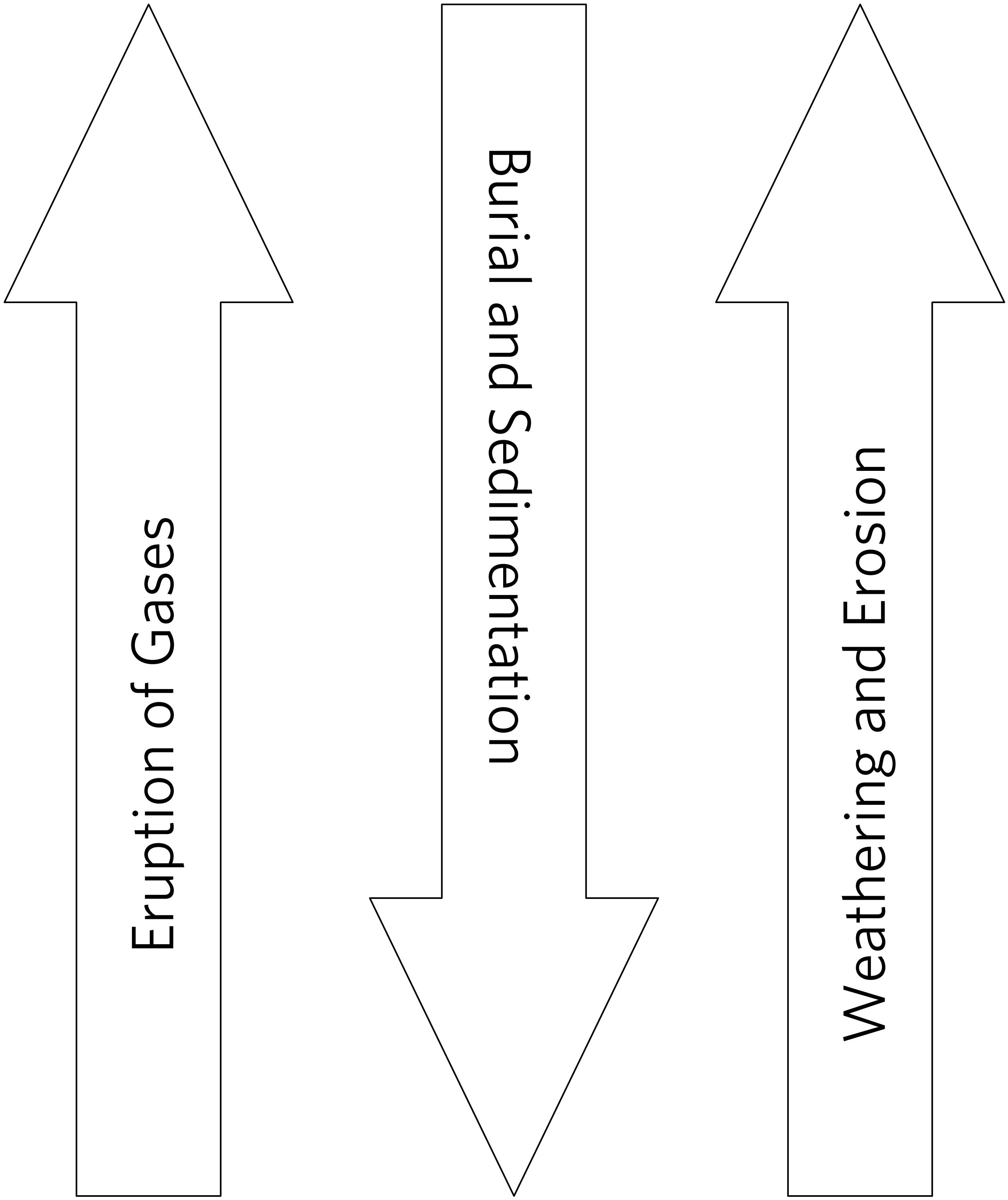
Direction: Lithosphere to Atmosphere

Farming Rice

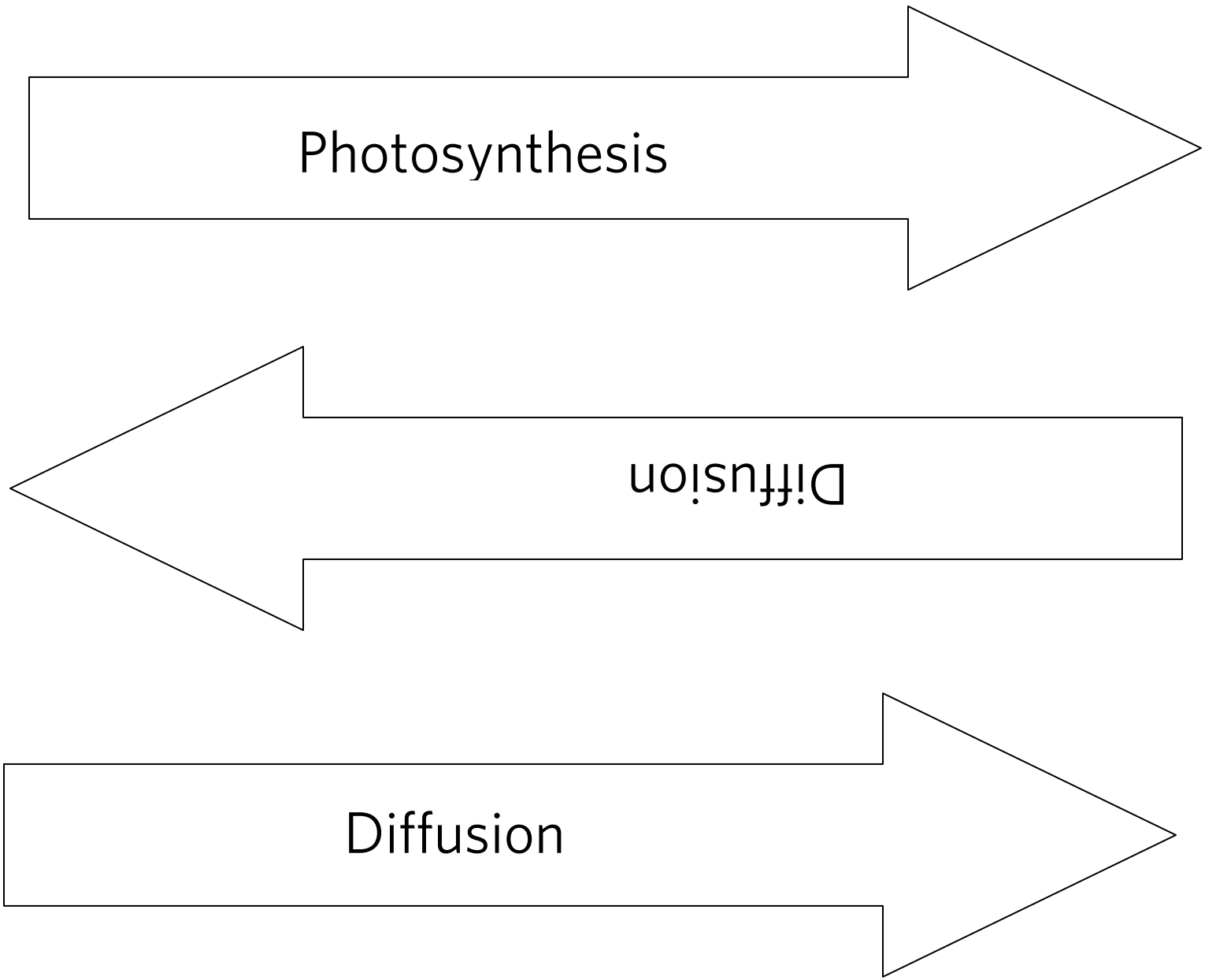
When humans farm rice in paddies, the fields are flooded and bacteria decompose organic matter resulting in methane, a carbon-containing gas.

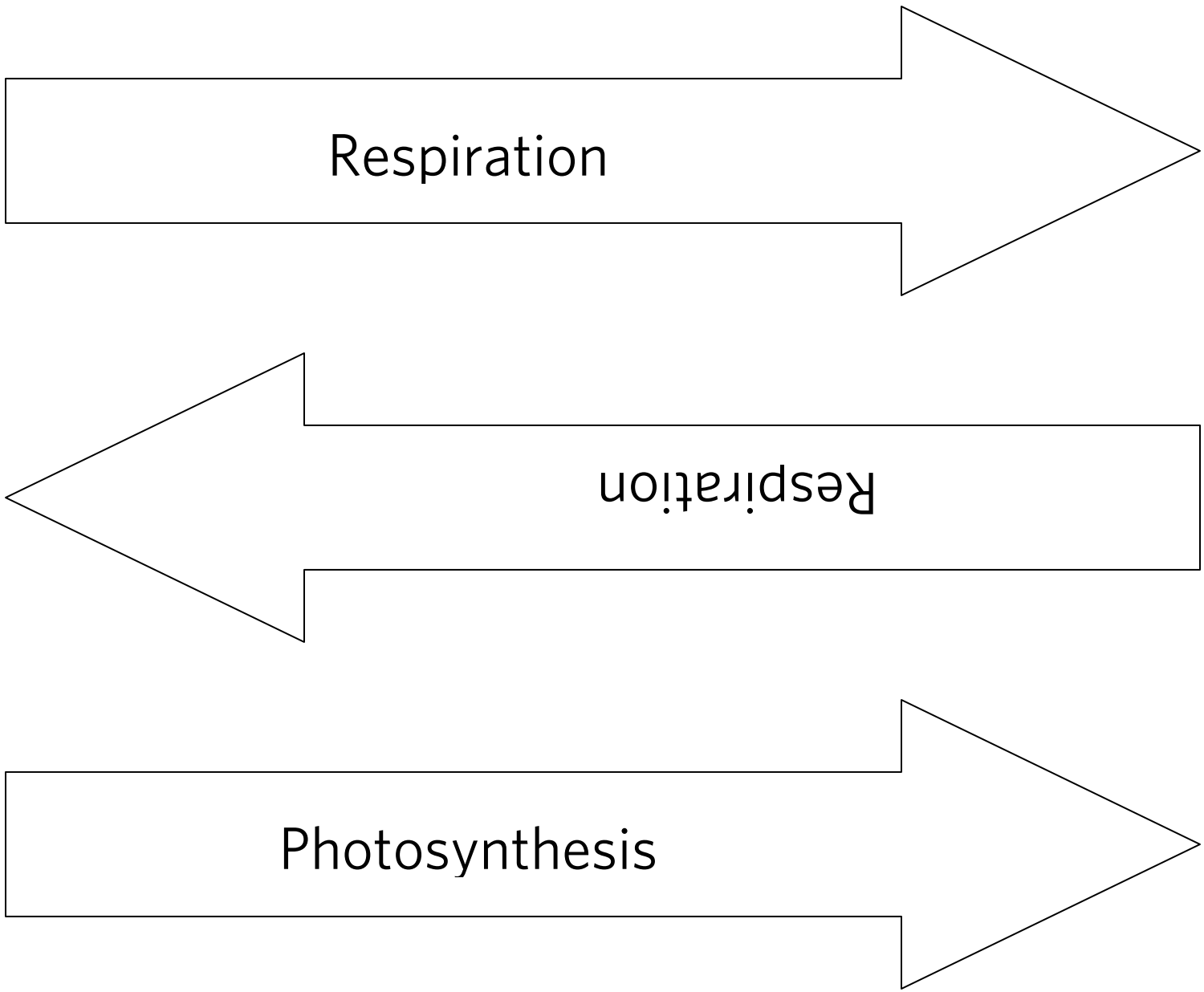
Direction: Biosphere to Atmosphere


Human
Alteration



Eruption of Gases
Burial and Sedimentation
Weathering and Erosion


Photosynthesis
Diffusion
Diffusion


Respiration
Respiration
Photosynthesis