

Carbon Cycle Role-Play

GRADE LEVELS	4 th -8 th grade; Standards for 4 th , 5 th , 6 th , 8 th , 9 th – 12 th
SUBJECTS	Earth Sciences, Developing and Using Models
DURATION	Preparation: 10 minutes Activity: 30-45 minutes
SETTING	Large space: classroom, schoolyard, or cafeteria

Objectives

Students will be able to:

1. recognize that there is a finite amount of carbon on earth.
2. model how carbon moves around in the environment, from one place to another.
3. identify how humans influence the carbon cycle.

Materials

- 14-28 of an object to represent carbon

Teacher tip: The object should be light and small enough to be easily transferred from one student to another. We like to use ping pong balls.

- *Carbon Cycle Role-Play Cards* (7 total, one per group)
- Chalk, if needed for drawing regions

Scientific Terms for Students

carbon: an element that can be found in all living things

carbon dioxide: a chemical compound composed of two oxygen atoms bonded on either side of a carbon atom (CO₂); usually present as a gas

atmosphere: the gases surrounding the Earth

decompose: to be broken down physically and chemically by bacterial or fungal action; to rot

Plants and their processes

algae: plants that mostly grow in water and lacking true roots, stems and leaves.

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: the process by which water, ice, wind, or gravity moves weathered rock or soil

sediment: material, such as stones or sand, deposited by water, wind, or glaciers

weathering: the processes by which rocks exposed to the weather change and break down

Background for Educators

Carbon is an important element for life on earth and can be found in all four major spheres of the planet: biosphere, atmosphere, hydrosphere, and lithosphere (the rigid, rocky outer layer of the earth). Carbon is found in both the living and non-living parts of the planet, as a component in organisms, atmospheric gases, water, and rocks. The carbon moves from one sphere to another in an ongoing process known as the **carbon cycle**. The carbon cycle 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 total carbon on Earth 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 gases surrounding the Earth), the **biosphere** (the parts of the land, sea, and atmosphere in which life exists), the **hydrosphere** (all of Earth's water), and the **lithosphere** (rocky outer layer of the Earth) are the reservoirs and the processes by which carbon moves from one reservoir to another are the flows. Although carbon is relatively common on earth, pure carbon is not. Carbon is usually bound to other elements in compounds. Thus, the carbon cycle, includes many carbon-containing compounds, such as carbon dioxide, sugars, and methane.

Carbon cycles both quickly and slowly

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 from the atmosphere. Some carbon cycle processes happen over much longer time scales. For example, when marine organisms with calcium carbonate skeletons and shells die, some of their remains sink towards the ocean floor. There, 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, respiration, and predator-prey transfer of carbon. 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 from carbon dioxide dissolved in the water around them. Carbon dioxide is also constantly moving between the atmosphere and water via diffusion. The **long-term carbon cycle** involves more of the lithospheric processes. It includes 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.

Humans affect the carbon cycle

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 result in increased carbon dioxide in the atmosphere. The largest source of this change is burning fossil fuels, but other

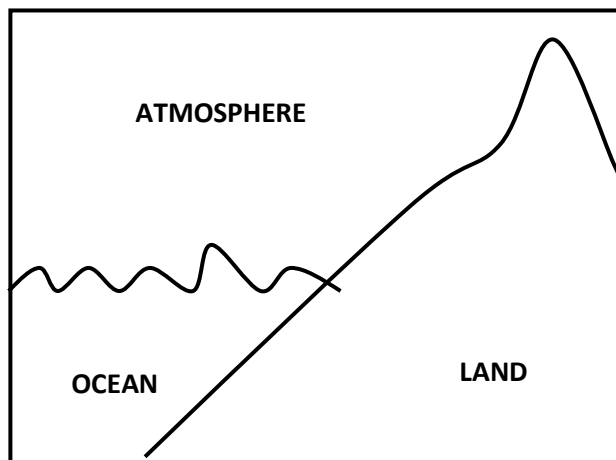
actions such as deforestation and cement manufacturing also contribute to this change in the carbon cycle. Because carbon dioxide and methane are greenhouse gases that help to control the temperature of the planet, the human-induced increase in atmospheric carbon levels is resulting in a host of climatic changes on our planet. As discussed above, the natural carbon cycle is important to learn because it is crucial to many of earth's processes, but 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.

Teacher Prep

1. Read through the **Role Play Summary Table** at the end of the lesson to get a better understanding of the specific flows your students will be learning. Note that the entire carbon cycle is composed of even more specific flows between the atmosphere, biosphere, hydrosphere, and lithosphere than those discussed here. This role-play teaches an age-appropriate version of the carbon cycle.

Teacher Tip: If you think your students would do better with a lesson where they are able to move around the classroom, see the Extension section for an alternate version of this lesson.

2. Collect 14-28 of the objects that will represent carbon.
3. Print double-sided role-play cards.
4. Designate a large open space for this activity.
 - If working outside, use chalk to draw out the regions shown below.
 - If in the classroom, draw a picture on the board of the three regions shown below and then designate different areas of the classroom to represent the ocean, the land, and the atmosphere.



Introduction

We suggest using the **What Contains Carbon?** activity as an introduction to carbon and its different forms. If you do not have time for this activity, review with your students that carbon is a common element on earth. Have students recall some of the things in their daily lives that contain carbon. Make a list of these items on the board.

Explain to your students that the carbon contained in any one thing doesn't stay there forever. The carbon atoms move from one thing to another in what is called the carbon cycle. Parts of the carbon cycle happen very quickly, like when plants take in carbon dioxide from the atmosphere for photosynthesis. But, other parts of the carbon cycle happen very slowly.

Tell students that in this activity, they will learn how carbon moves from one place to another, by performing a carbon cycle role-play.

Role-Play

1. Divide students evenly into 7 groups and distribute the appropriate role-play card to each group. Each group will be a team of actors that will play a certain part of the carbon cycle (**atmosphere, water, algae, marine snail, sediments & rocks, trees, or caterpillars**). The table provided at the end of the lesson plan summarizes all the groups, their options for carbon flow, the explanation for each carbon flow, and their script lines.
2. Distribute **2-4** ping pong balls to each group and explain that these represent carbon atoms.
3. Have students in each group review their role play card to figure out their role in the carbon cycle and decide as a group using their "Options for carbon movement" how they are going to move their carbon.
 - Explain that they can give their carbon to only one other group, or if they have plenty, they can give the carbon to more than one group.
 - Explain that carbon exists in all of these things at the same time and only a portion of the carbon in each thing moves. Therefore, when each group moves their carbon, they can't give away all their carbon: **they must keep at least one carbon atom**.
 - As they move their carbon, they must say their script lines to explain the carbon movement that they have chosen.
4. One at a time, ask each group to give their carbon to another group (or groups).
5. Run the role-play a number of times, telling students to make different choices about carbon movement each time.
6. If you have time, consider running the following variations:
 - **Have all the groups moving their carbon at the same time:** Have one person from each group be the deliverer of carbon and the other group members remain to receive carbon from other groups. Tell students that this is a more chaotic, but more realistic

acting out of the carbon cycle, since in the real world carbon moves between all these areas at the same time.

- **Trace the journeys of only few carbon atoms:** Use only one carbon atom (ping pong ball) and start it with one group. Each group that gets the atom makes a decision about where it goes next. Assign one student to write the journey on the board or a piece of paper. Do this multiple times so that you can compare the journeys of several individual atoms through the different spheres and see how the carbon cycle does not move in one direction, but moves in lots of different directions at the same time.

Discussion: Human Impacts on the Carbon Cycle

1. Explain to students that they just acted out the carbon cycle without human involvement, but humans greatly influence the carbon cycle with some of their activities.
2. Have students guess what movement corresponds to the following human activities:
 - Humans extract and burn fossil fuels for energy (*carbon moves from the sediments and rocks where fossil fuels are buried into the atmosphere*).
 - Humans cut and burn trees to use land for farming, ranching, or building (*carbon moves from the land plants into the atmosphere*).
3. Pull students aside and have them be the humans. Ask them to move the carbon in the appropriate manner for the human activities that you discussed. How did this affect the carbon cycle?
4. Explain that humans have not created more carbon on earth, but that we move carbon from one place to another more quickly than would naturally happen and that this has consequences for the climate of the planet. Some salient examples:
 - Burning fossil fuels takes carbon from sediments and rocks where fossil fuels are buried and puts it into the atmosphere because when fossil fuels are burned they release carbon-containing gases.
 - Cutting and burning trees takes carbon from the land plants and puts it into the atmosphere because when trees are burned, the carbon that was stored in their structures is released as carbon-containing gases.
5. Ask students if they can think of other human activities that might affect the carbon cycle.

Review: Mapping the carbon cycle

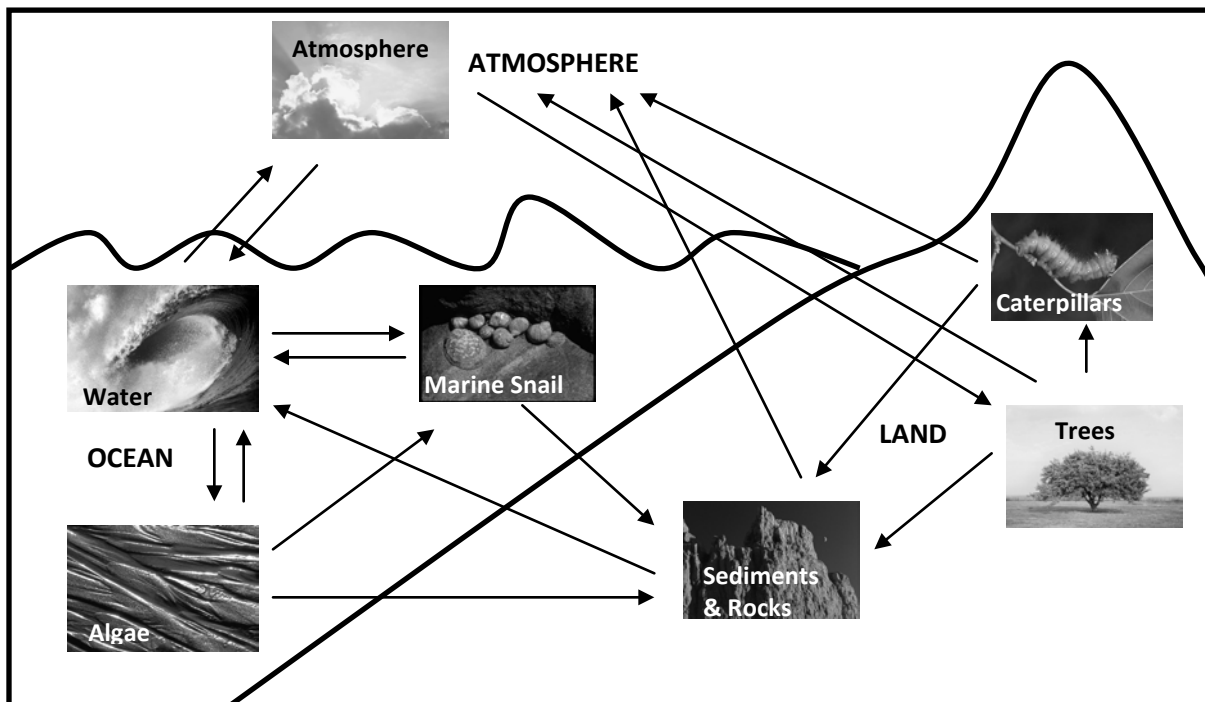
1. Back in the classroom, take back the role-play cards.
2. Review the activity using the picture below as a template. Work with your students to draw all of the carbon flows that they acted out, relying on the groups as “experts” for their representation.

Teacher Tip: For older students, you can introduce the specific terms for the earth’s four spheres.

3. Encourage students to provide explanations for the processes underlying each of the arrows, focusing on the content appropriate for your grade level.

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.



Extensions

- Follow this activity with the **Carbon Cycle Poster** activity, which can serve as a form of assessment.
- You can use **A Carbon Atom's Journey** as an extension or an alternate version for students that do better when they are allowed to move around the classroom. Instead of having seven groups and modeling carbon flow by passing along objects, there are three carbon source regions (atmosphere, ocean, land/plants) and the students move between the different regions.

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 Science 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 (CO₂) 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 (CO₂) 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
<p>Developing and using models</p> <p>3-5: Develop a model using an example to describe a scientific principle.</p> <p>6-8: Develop and use a model to describe phenomena.</p> <p>9-12: Develop a model based on evidence to illustrate the relationships between systems or between components of a system.</p>	<p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>HS-ESS2-D: Weather and Climate Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.</p> <p>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.</p>	<p>Systems and system models</p> <p>5: A system can be described in terms of its components and their interactions.</p> <p>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.</p> <p>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.</p>

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/mess2-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>

Role-Play Summary Table

NAME of GROUP	Options for CARBON FLOWS	Explanation for each CARBON FLOW	SCRIPT LINES
Atmosphere	<ol style="list-style-type: none"> 1. water 2. trees 	<ol style="list-style-type: none"> 1. Carbon dioxide from the atmosphere diffuses and dissolves into water. 2. Carbon dioxide is taken up by land plants to perform photosynthesis. 	<ol style="list-style-type: none"> 1. I am giving carbon dioxide gas to water. It will dissolve in water. 2. I am giving carbon dioxide gas to trees to use for photosynthesis.
Water	<ol style="list-style-type: none"> 1. algae 2. marine snails 3. atmosphere 	<ol style="list-style-type: none"> 1. Aquatic plants use carbon dioxide from the water to perform photosynthesis. 2. Some marine organisms take carbon from the water to build their skeletons and shells. 3. Carbon dioxide can diffuse back into the atmosphere. 	<ol style="list-style-type: none"> 1. I am giving dissolved carbon dioxide to algae for photosynthesis. 2. I am giving carbon to marine snails to help build their shells. 3. I am taking dissolved carbon dioxide and putting it back in the atmosphere as carbon dioxide gas.
Algae (Aquatic Plants)	<ol style="list-style-type: none"> 1. water 2. sediments and rocks 3. marine snails 	<ol style="list-style-type: none"> 1. Cellular respiration and decomposition put carbon back into the water. 2. Carbon from dead plants can be incorporated into sediments. 3. Animals consume aquatic plants and use it as energy or store it in tissues. 	<ol style="list-style-type: none"> 1. I am giving carbon to water when I die and decompose and when I perform respiration. 2. I am giving carbon to sediments and rocks because after I die, some of the carbon in my structures is laid down in sediments, which can turn to rock. 3. I am giving carbon to marine snails because they use their mouths to scrape me off the rocks and eat me.
Marine Snails (Aquatic Animals)	<ol style="list-style-type: none"> 1. water 2. sediments and rocks 	<ol style="list-style-type: none"> 1. Respiration and decomposition put carbon back into the water. 2. Carbon from dead animals can be incorporated into sediments on the ocean floor and can eventually 	<ol style="list-style-type: none"> 1. I am giving carbon to water when I perform respiration and when I die and decompose. 2. I am giving carbon to sediments and rocks because when I die my hard, carbon-containing shell sinks to the ocean floor and becomes

NAME of GROUP	Options for CARBON FLOWS	Explanation for each CARBON FLOW	SCRIPT LINES
		become sedimentary and metamorphic rocks.	part of the sediment, which can then become rock.
Sediments and Rocks	1. water 2. volcano to atmosphere	1. Weathering and erosion of rocks deposits carbon in rivers and oceans. 2. Volcanic eruptions spew carbon-containing gases into the atmosphere.	1. I am giving carbon to water because when I am weathered and eroded, my carbon flows into water. 2. I am giving carbon to the atmosphere in a quick fury because volcanoes erupt and put carbon from rocks back into the atmosphere.
Trees (Land Plants)	1. atmosphere 2. sediments and rocks 3. caterpillars	1. Cellular respiration and decomposition put carbon back into the atmosphere. 2. Carbon from dead trees can be buried and incorporated into sediments. 3. Plants are consumed by animals that use carbon for energy or store it in tissue.	1. I am giving carbon to the atmosphere when I perform respiration and when I die and decompose. 2. I am giving carbon to sediments and rocks because when I die, I can be buried in sediments and slowly become part of the rocks. 3. I am giving carbon to caterpillars because you have eaten me and will use my carbon for energy or to make your body's structures.
Caterpillars (Land Animals)	1. atmosphere 2. sediments and rocks	1. Respiration and the decomposition of dead animals put carbon back into the atmosphere. 2. Carbon from dead animals can be buried and incorporated into sediments.	1. I am giving carbon to the atmosphere because when I breathe I release carbon dioxide to the atmosphere. 2. I am giving carbon to sediments and rocks because when I die I can be buried and some of the carbon in my body can become part of sediments.