



Carbon Cycles!

LESSON

GRADE LEVEL 7-12

CATEGORY Energy,
Atmosphere and Climate

TOPIC Climate Change,
Ecosystems, Carbon Cycle

TIME

- Warm-up: 10–20 minutes
- Activity: 20 minutes
- Wrap up: 10–30 minutes

MATERIALS

- Carbon Cycles Copy Pages (for Station Signs and Activity Cards)
- Coloured paper; red, orange, grey (or white), green, blue and yellow (or brown) for Station Signs and Activity Cards
- Coloured markers that match the colour of Station Signs and Activity Cards; 2–3 markers per colour
- Index cards or popsicle sticks, one per student (use as “travel logs” to record path of carbon)
- 6–10 Skipping ropes
- Optional: Cones to mark stations
- Optional: Masking tape to attach station sign to cone or wall

SETTING

Gymnasium or outdoor playing area

GROUP SIZE 20-30 students

SUBJECT AREAS

Science, Social Studies, Language Arts,
Physical Education

SKILLS

Classifying, organizing, assessing, reading,
evaluating, role playing

Overview

In this active game, students follow the path of carbon through the carbon cycle to learn where carbon is stored and how it circulates. In the first round of the game, students move from one component of the Earth to the next, discovering there are short and long term carbon cycles and that the short carbon cycle is closely linked to energy flow in ecosystems. The second round highlights how human actions, through the use of fossil fuels and clearing of the world's forests, results in an increase in the amount of carbon dioxide in the atmosphere.

Background

Like water in the water cycle, carbon in the carbon cycle moves between various components of Earth by different processes. Carbon dioxide, a form of carbon found in the atmosphere, is a greenhouse gas, and as such plays a critical role in regulating Earth's temperature. Understanding where carbon is stored and how it is captured and released—naturally and by human activity—is essential in understanding human-induced climate change.

Carbon is one of the basic elements on Earth and is found and stored in a variety of Earth's major components. In each component, carbon can be in different forms (chemical compounds); for example in:

- the atmosphere as the gas, carbon dioxide;
- living things (biotic component of ecosystems) mainly as sugars, starches, and cellulose (various forms of carbohydrates) in plants; and as carbon compounds, including proteins, nucleic acids and carbohydrates in the soft tissues of animals, as well as calcium carbonate in hard structures of animals such as bone, coral and shell;
- soil as the remains of once living things (dead organic matter) and in living bacteria, fungi and other microorganisms (i.e., the decomposers);
- the ocean as dissolved carbon dioxide;
- Earth's crust as calcium carbonate (calcite) in sediments and rock originating from parts of living things (e.g., chalk and limestone) and as modified carbohydrates in fossil fuels (crude oil, coal, and natural gas).

Carbon is found all around us: it is in everything living or once living, in the air we breathe, the ground we walk on, and even carbonated drinks! Not only do we burn fossil fuels as a source of energy, we also use them as the raw material for many chemical products, including pharmaceuticals, solvents,

fertilizers, pesticides, and plastics. Plastics are used to make everything from clothes to skateboards to computers. The only place carbon is not found is in things that are composed of pure mineral (e.g., quartz), pure metal (e.g., gold), or simple compounds such as volcanic rocks and salts.

In the “short carbon cycle”, carbon generally moves from the atmosphere to plants, then to animals (the living things or biotic component of ecosystems), to the soil, and back to the atmosphere. The time it takes to complete this short cycle can be a few hours to several weeks or hundreds of years if the carbon becomes incorporated into a structural component of an organism (e.g., the trunk of a cedar tree or the bones of a whale). In the “long carbon cycle”, carbon in living things can become trapped in sediments or fossil fuels in the Earth’s crust. Once in the Earth’s crust, the carbon is stored for extremely long periods of time - for thousands to millions of years - and rarely released, except through erosion of sediments and volcanic activity. Of all the carbon on Earth, most of it is stored in the Earth’s crust as sediments from the ocean and land.

Ocean ecosystems also are part of the short carbon cycle. Similar to the short cycle on land, carbon dioxide generally moves from the ocean waters to marine algae (plant-like organisms) to marine animals, to biologically active ocean sediments, then back to the ocean water. Due to its size, a large amount of carbon is stored in the ocean as dissolved carbon dioxide; there is a slow, balanced exchange of carbon dioxide between the atmosphere and the water in the ocean.

The carbon cycle is directly linked to energy use by all life on Earth – including humans. Some of the energy from the sun (visible light) is captured and transformed by plants during the process of photosynthesis and then stored in the chemical bonds of carbon based compounds called carbohydrates, mainly glucose (sugar). Carbohydrates are “food” made by plants; they are essential for all life on Earth. The stored energy in these carbon molecules is passed through food chains and food webs and is used by organisms at each level. This movement of energy through ecosystems is called energy flow. Eventually all energy leaves the Earth’s systems as heat into space. The energy in fossil fuels is energy from the sun transformed by plants and algae approximately 300 million years ago. Contrary to popular belief, fossil fuels are not made of dinosaurs; oil is derived from mostly tiny marine organisms that become buried in ocean sediments, slowly changing over time into a fossil fuel. More recent coal deposits are comprised of plant material.

Carbon dioxide is released from living things when they use the energy in the carbohydrates to move, grow and reproduce (i.e., the process of respiration). It is also released through the

burning of these same carbohydrates found in things that were once living such as wood, charcoal, and fossil fuels (i.e., the process of combustion), or in volcanic eruptions. The current balance of carbon in each of the Earth’s components supports the vast array of life on Earth. Human activity is tipping this balance by releasing the carbon stored in fossil fuels to the atmosphere, leading to climate change.

Note: See the *Primer* and the lessons *Greenhouse Effect Part One* and *Part Two* for further information and activities relating to the greenhouse effect and greenhouse gases.

Procedure

Set-up

1. Prepare five Station Signs and corresponding Activity Cards (lesson copy pages) onto coloured paper as follows:
 - Living Things – Green
 - Soil – Yellow (or brown)
 - Ocean – Blue
 - Air, Round One and Round Two – grey (or white)
 - Earth’s Crust, Round One and Round Two – orange

Copy the Volcano Wild Cards (Activity Cards) onto red paper; they are part of the Earth’s Crust station.

Cut out the Activity Cards and organize into eight sets of cards, with twelve cards per set. The eight sets are:

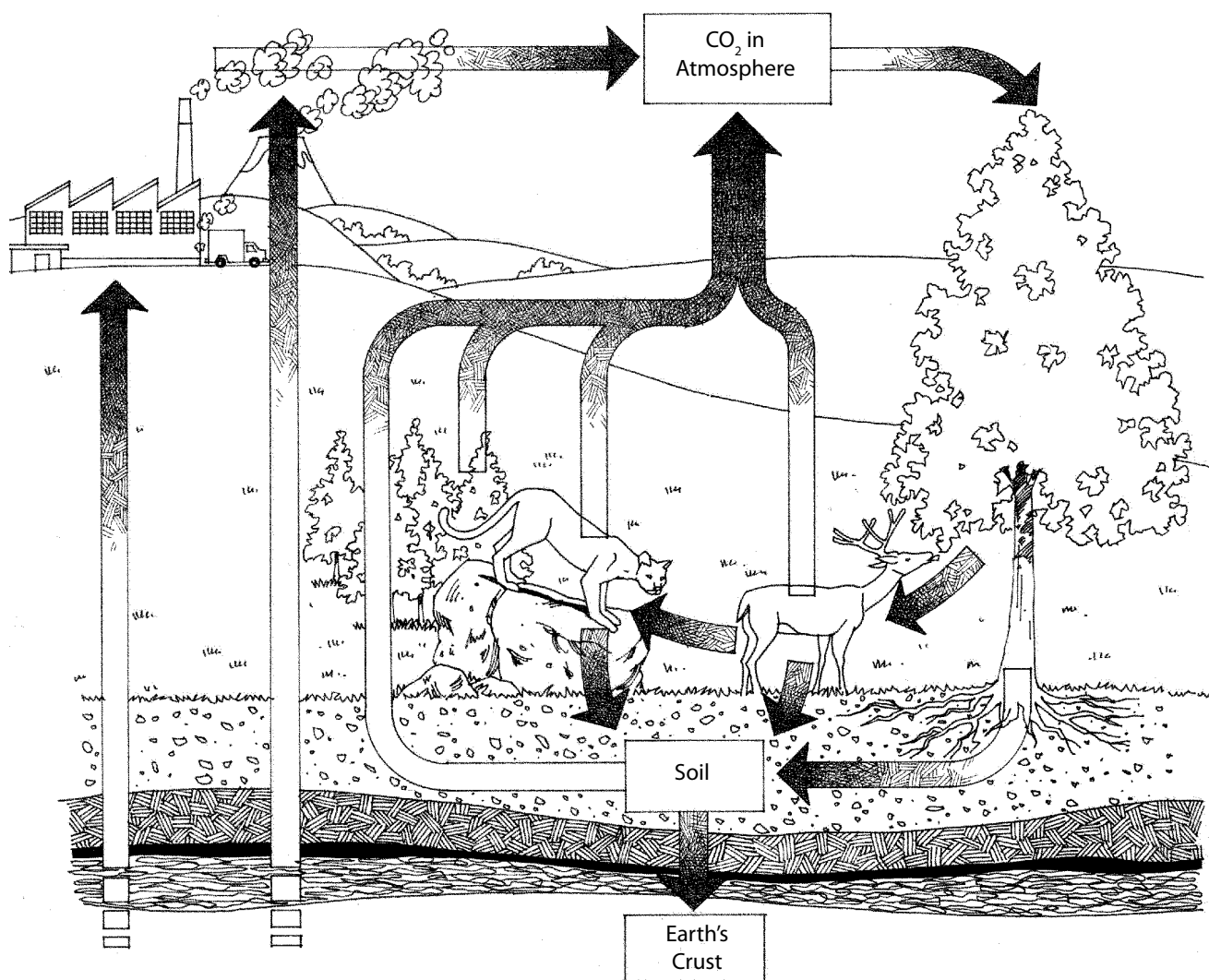
- Living Things
- Soil
- Ocean
- Volcano Wild Cards
- Air, Round One
- Air, Round Two
- Earth’s Crust, Round One
- Earth’s Crust, Round Two

The game is played in two rounds but only Earth’s Crust and Air have different Activity Cards for each round. In Round Two, human activity is introduced by using the second set of Activity Cards for the Earth’s Crust and Air stations. Note these cards are labeled with either a “1” or “2” to each with identification.

Tip: Use labelled envelopes or plastic bags to keep the eight sets of Activity Cards separated.



Carbon Cycle Diagram



2. Prepare the students' "Travel Logs" (the popsicle sticks or index cards) by labelling one side with a number "1" and the other side with "2". Alternatively, have the students label the sticks or cards during the explanation of the activity.
3. Set up the playing area by placing Station Signs at least 10 metres apart in the approximate shape of a circle. Use the cones help to identify the station from a distance. At each station, place the appropriate Activity Cards for Round One in a stack next to the Station Signs, along with the matching coloured markers. Reminder: before beginning Round Two, replace Round One Activity Cards at Earth's Crust and Air stations with the Round Two Activity Cards.
4. Place the Volcano Wild Cards and the skipping ropes at the Earth's Crust station. If skipping ropes are not

available, direct students to do jumping-jacks at this station.

Warm Up

1. Explain to the students that carbon is an element and can be found in different forms (molecules and compounds) all around us. If helpful, remind students that an example of a compound is water; it is made up of the two elements hydrogen and oxygen.
2. To check prior knowledge ask the students, "What things have carbon in them?" Record the students' responses. If students are having difficulties answering the question, provide the hint that all life on Earth is carbon based. Identify some of the basic carbon compounds, including carbon dioxide, calcium carbonate, and carbohydrates.

Ensure students are aware of the varied use of fossil fuels in our world today, including as a base for making plastics. See the introduction/background section for more information.

3. Identify the components of the Earth where carbon is located (e.g., atmosphere, living things, soil, ocean, Earth's crust). Group items from the student generated list into the Earth components. Add things as necessary to help explain what carbon based thing could be found in each component.
4. Help the students to recognize the different processes of the carbon cycle and the different carbon compounds involved. For example, during photosynthesis carbon dioxide is combined with water to make carbohydrates. Cellular respiration is the reverse process, where carbohydrates are broken down, releasing energy and carbon dioxide. In animals, carbohydrates can also be broken down during digestion, and the carbon used to make proteins or calcium carbonate structures such as bone. Carbon can also be trapped in limestone and chalk (sedimentary rocks) during sedimentation. See the Primer for more details.

The Activity

Round One

1. Inform students they are about to become carbon and travel through the carbon cycle in an active game. Point out the location of each of the five stations, each one a component of the Earth. Tell the students that their task is to follow one possible path of a carbon atom as it goes through the carbon cycle, discovering where carbon is found and how it moves from one place to another.
2. Explain they are to keep a Travel Log to record their journey through the carbon cycle. The travel log will be used at the end of the activity to compare journeys. Hand-out index cards or popsicle sticks to each student. If not already prepared, have each student record a number "1" on one side and a number "2" on the other.

Explain each time they arrive at a station they should mark one vertical line on their Travel Log using the coloured markers at each station. Remind them to start on the left and go across to the right. Emphasize that if they draw an Activity Card that instructs them to stay at that station, they should make another mark on their Travel Log – it is important to see how long they stay at a station!

Tip: In place of coloured markers, students can record the first letter of the station (e.g., O for Ocean, S for Soil, etc.) on their Travel Log.

3. Explain to the students they move from station to station by drawing a card and following the instructions on the cards. Students should form lines at each station; upon arriving at a station, they join the end of the line. When they reach the front of the line, they pick up an Activity Card from the top of the stack and read it aloud. After returning their card to the bottom of the stack, they move to the station indicated on the card. If a student draws a card that instructs them to stay at that station, they replace the card and go to the back of the line.
4. Indicate that there will be two rounds of the game played. For Round One, they should use the side of the index card or popsicle stick that is labelled with the number "1".
5. Do not reveal the following aspect of the game before it begins - make this as unexpected and fun as possible! Position either yourself or an assistant at the Earth's Crust station to help students "escape" this station by using the Volcano Wild Cards. Note the number of times a student has drawn a card instructing them to "stay". After a student draws their third "stay" card (there should be three marks on their Travel Log), simulate a volcanic eruption, give the student a Volcano Wild Card to read and/or inform them that they have been exploded out of the Earth's Crust and into the atmosphere. The student moves to the Air station. Alternatively, instruct students to draw a Volcano Wild Card when they have drawn their third "stay" card.
6. Inform the students that each time they draw a stay card while at the Earth's Crust station, they must jump rope ten times (using the skipping ropes) or do ten jumping jacks at the end of the line. This serves to help keep students engaged as well as simulating how carbon is trapped for long periods of time in sediments, rocks and fossil fuels.
7. To start Round One, send approximately equal numbers of students to each station except Earth's Crust (no one starts at this station). Start the game by saying "Carbon, Cycle!" Allow students to play the game for five to ten minutes. Check to ensure students are correctly marking their Travel Logs and reading all the information on the cards in order to complete the assigned task.
8. End Round One by saying "Carbon, stop Cycling!" Gather students and ask what they experienced. It is important that all the students recognize that some of them got "stuck" at the Earth's Crust and Ocean stations, while



others may have cycled amongst the Air, Living Things and Soil stations. Briefly discuss why, emphasizing the only way out of the Earth's Crust and directly into the atmosphere is through volcanic eruptions. (Weathering of carbonate rocks releases carbon into water and soil.) Also, ensure they understand plants are important in taking carbon out of the atmosphere. Both of these factors are important in understanding the impact of human activities on the short carbon cycle in the next round.

9. If time permits, play Round One again so that students have the chance to move to other stations. Start students who were at Ocean or Earth's Crust at another station. Inform students to continue to use side one of the Travel Log.

Round Two

1. Replace Round One Activity Cards with those for Round Two at the Earth's Crust and Air stations.
2. Ask students to predict what will happen if the human activities of using fossil fuels and removing forests are introduced. Explore their explanations.
3. Play game as before, reminding students to use the second side of their Travel Logs.
4. Student will now be held up at the Air Station. As they do, instruct the students to do jumping jacks at the end of the line each time they draw a stay card.

Wrap up

1. Debrief the game by asking students what they experienced as carbon. Where does carbon go and why? Remind them to use their Travel Logs to help them remember their journey and to determine patterns. Help them summarize their combined experiences either verbally or by drawing a flow diagram.
2. Show students the diagram of the Carbon Cycle. Help the students to recognize and match the two parts of the carbon cycles to their experiences in the game. In the short cycle, carbon moves between Air, Living Things, and Soil while in the long cycle, carbon is stored for long periods of time in large amounts in the Ocean and the Earth's Crust. Identify the processes that move carbon from one component to another, specifically indicating the ones that release carbon dioxide to the atmosphere (respiration, combustion) and those that remove carbon dioxide from the atmosphere (photosynthesis).

3. Review the concept of food chains and food webs in ecosystems. Ask the students how the short carbon cycle compares to food chains. Ensure the students understand that during the process of photosynthesis the energy from the sun is captured by plants and transformed into chemical energy, which is stored in the bonds of carbohydrates – hence plants “produce” food energy. Within ecosystems, as animals in the food chain consume plants or other animals, the carbohydrates are broken down by digestion and respiration, releasing energy and carbon dioxide. Organisms in the soil such as worms, bacteria and fungi feed on dead organisms, breaking down the remaining energy-rich carbon bonds through the process of decomposition and releasing carbon dioxide to the atmosphere. Summarize by stating how carbon is an integral part of the energy flow in ecosystems.

4. Explain how over 350 million years ago in the Devonian period, some of this energy from the sun was trapped in large amounts as dead marine organisms (mostly phytoplankton and zooplankton) and were buried by sediments at the bottom of the ocean. This energy is now stored in the Earth's Crust as oil and natural gas. Ensure the students understand that oil and natural gas are not made of dinosaurs as often portrayed in cartoons, but mostly tiny marine organisms that lived well before the dinosaurs. The oldest coal beds are a result of only partially decomposed plants becoming buried by sediments in the Carboniferous period approximately 300 to 350 million years ago.
5. Ask the students to compare the two rounds. Did their predictions match what happened? As a prompt, ask the students to recall the difference between the activity cards at Earth's Crust and Air between Round One and Round Two. If necessary, read aloud the instructions from some of the Activity Cards. Emphasize how in Round Two, it is human activity, not just volcanic activity, that is releasing carbon from the Earth's Crust by using fossil fuels as a source of energy. The result is more carbon being released into the atmosphere; thus more students ended up at the Air Station. Also emphasize less carbon was able to leave the Air Station and move to the Living Things Station because of the human activity of clearing forests, resulting in fewer trees to take up the carbon during photosynthesis.
6. Revisit the carbon cycle diagram, indicating this change in carbon flow by bolding the arrow from the Earth's Crust to Air and reducing the arrow from Air to Living Things.



7. If the lesson “Greenhouse Effect” has not been done, introduce the concept of the Natural Greenhouse Effect. Explain how greenhouse gases, such as carbon dioxide, absorb much of the heat energy (infrared radiation) emitted from the warmed surfaces of the Earth. The greenhouse gas emit the infrared radiation in all directions in the atmosphere, including back toward the Earth. Ensure students understand that the Natural Greenhouse Effect is necessary to support life on Earth. See the Primer for more information.
8. Emphasize that carbon dioxide is a greenhouse gas and as the amount of carbon dioxide (and other greenhouse gases) in the atmosphere increase due to human activity, the warmer the overall Earth’s temperature becomes. More greenhouse gases means more heat energy in the atmosphere. This is the Enhanced Greenhouse Effect. Identify how the increase of the average global temperature directly relates to the current climate change. This information is covered in The Greenhouse Effect lesson; also see Primer for more information.
9. End the discussion by asking the students to identify some of the impacts of climate change. See Primer for information. Explore with the students some of the things they can do to reduce the amount of carbon dioxide released into the atmosphere (e.g., use less fossil fuel energy by walking or biking more often) and what they can do to promote carbon dioxide being captured and removed from the atmosphere (e.g., by planting trees).

Assessment

1. Ask students to draw the movement of carbon through the short carbon cycle and explain how this also represents the flow of energy through food chains and food webs in ecosystems. Look for evidence that the student understands how energy is passed in a food chain from producer to consumers (herbivores, carnivores and decomposers), and how it eventually leaves the system as heat energy lost to space. The sun as the original source of energy should be clearly represented. Students should clearly indicate how organisms use the energy to fuel their bodies, grow and reproduce.
2. Ask students to create a story of a carbon atom moving through both the short and long carbon cycle and how over time ends up as a fossil fuel. Students should be able to describe the main components of the carbon cycle and the basic biological, chemical, and geological

processes by which carbon moves from one component to another. Look for evidence that the student understands the time scale difference between the short and long carbon cycles, as well as where most carbon is found.

3. Have students choose one thing they could do to reduce the amount of carbon dioxide being released into the atmosphere (e.g., walking, riding their bike, or taking a bus to school more often; buying locally made products) or increase the amount of carbon removed from the atmosphere (e.g., growing vegetables or planting shrubs and trees). Ask them to write a Plan of Action, which indicates what they plan to do, the time line, what they will use to indicate their success, and how they will celebrate. Students should also include any challenges they foresee with their plan and how they might overcome these challenges.

Extensions

1. Review how much amount of carbon is held in each of the atmosphere, lithosphere, hydrosphere, and biosphere. Climate change scientists have calculated the total amount of carbon that should exist but are unable to balance the amount going into the atmosphere and the amount going out. Challenge the students to identify what might be the missing carbon sink (taking carbon dioxide out of the atmosphere). (Possible explanations include the unaccounted use of atmospheric carbon dioxide in the process of weathering carbonate rocks such as dolomite and limestone; ocean-atmosphere processes; and tropical versus boreal forests).
2. Start an Action Project with your class that helps students to see what they can do to slow climate change by reducing the amount of carbon dioxide in the atmosphere.

Possibilities include: walk/ride to school days, establishing “no idle zones” near the school, set up recycle/reuse boxes, make and decorate cloth shopping bags, and planting a native garden or trees in schoolgrounds. See the lesson Action Projects Gallery for more ideas.

3. Invite students to write and add new Activity Cards for each station and play the game again. Try adding different human activity scenarios and observing the impact on the carbon cycle.

