Carbon Travels Game

(Adapted from: STEM Earth Central 2006 – modified version of activity produced by New England Aquarium)

Purpose

- To learn that carbon is one of the most important, and abundant elements on Earth and can be found everywhere.
- To experience the concept of residence time by remaining in a pool for several dice rolls.

Overview

This activity provides an introduction to the carbon cycle and, more broadly, to biogeochemical cycling, the greenhouse effect and climate change. During the activity, students research one carbon pool in depth, share their knowledge with peers and then see how carbon pools are connected by fluxes as they roll game dice to move from station to station around the classroom. Students keep track of the carbon pools they visit, and the process that takes them to the next carbon pool.

Content Questions

What are the major pools and fluxes of the global carbon cycle?
What is residence time and how does it play a role in the carbon cycle?
How does today's carbon cycle differ from the carbon cycle prior to 1700?

Student Outcomes

Students will be able to:

- Present their in-depth carbon pool research to their peers
- List all the major pools and fluxes in the global carbon cycle
- Define residence time and provide at least one example from the carbon cycle
- Compare and contrast the carbon cycle pre and post 1700

Science Standards

5-8
Science in Personal and Social Perspectives
- Human activities can induce hazards. Such activities can accelerate natural changes.

9-12
Physical Science
- Chemical reactions can take on both very short and very long time scales.

Life Science
- The atoms and molecules on the earth cycle among living and non-living components of the biosphere.
- Human beings live within the world's ecosystems and modify them in multiple ways.

Science in Personal and Social Perspectives
- Materials from human societies affect both physical and chemical cycles of the earth.

Time

60-120 minutes

Level

Secondary (Middle & High School)

Materials and Tools

- Materials on the carbon cycle (*Carbon Atom Adventure Story*, *Carbon Background, etc.*)
- Poster making materials (enough for 8 posters)
- *Carbon Cycle Station Instructions*
- *Journey Table* (1 set per student)
- 8 dice

Preparation

- Print/copy *Carbon Atom Journey Tables* & *Carbon Cycle Adventure Story Booklets*
- Make a classroom example of the *Carbon Atom Journey Table* (on overhead, white or blackboard)
- Write essential, unit and content questions somewhere visible in the classroom.

Pre-requisites

Basic knowledge of systems concepts and terms – pools and fluxes, box and arrow diagrams. (*Paperclip Factory Analogy* and/or *Carbon Cycle Adventure Story*).

Background

See the *GLOBE Carbon Cycle Teacher Background*.

What To Do and How To Do It

<table>
<tr><td rowspan="2">ENGAGE</td><td>Student Grouping: Whole Class</td><td>Time: 10 minutes</td></tr>
<tr><td colspan="2">*Note: Students may have completed this engagement exercise if they participated in the Carbon Cycle Adventure Story. If so, move on to Explore.
Tell students that you want to begin teaching about carbon today, but you can't seem to find it. Ask students if anyone saw carbon today on their way into class.
This will help start generating ideas about where carbon is found and how prevalent it is in the world around us.
Record the ideas of where carbon is found on the board.
Solicit additional ideas about the carbon cycle. What is carbon? Where is it found? How does carbon move from one place to another (the processes)? What forms does it take (C, CO_2, CH_4, $CaCO_3$, glucose)?
Differentially highlight/circle the pools and fluxes.
Group student's ideas into the major carbon pools. (Atmosphere, Terrestrial Life, Soil, Surface Ocean, Marine Life, Deep Ocean, Fossil Fuels, Ocean Sediment/Earth's Crust).</td></tr>
<tr><td rowspan="2">EXPLORE</td><td>Student Grouping: Small groups</td><td>Time: 30 minutes</td></tr>
<tr><td colspan="2">Assign each group a major global carbon pool (except Ocean Sediment) to research.
Each group should prepare a short (1 page) document/poster about their pool, which includes information about the related fluxes.
While students prepare their posters, hang the Carbon Cycle Station Instructions for the game around the room.</td></tr>
<tr><td rowspan="2">EXPLAIN</td><td>Student Grouping: Whole Class</td><td>Time: 15 minutes</td></tr>
<tr><td colspan="2">Student groups briefly present their research and hang their poster next to the station instructions.
Help answer any additional questions students may have about carbon pools and fluxes.</td></tr>
</table>

ELABORATE/ INVESTIGATE	Student Grouping: Whole Class	Time: 25 minutes
	• Hand out copies of the *Journey Table* and tell students the game will begin pre-1700 (before the industrial revolution), and they may start anywhere in the cycle. • Students follow the instructions, move around the room at their own pace and fill out their tables. After 10 turns they stand to the side to indicate they are done. • Discuss the pre-1700 results • Flip over the instructions to begin the post-1700 simulation. • Students complete another 10 turns under the new conditions.	
EVALUATE/ WRAP-UP	Student Grouping: Whole Class	Time: 15 minutes
	• Discuss – What was different before and after 1700? What do the differences reflect? (Burning of fossil fuels & land use change) • Discuss – Using their *Journey Table*, ask students to observe the amount of time they stayed in each pool. How did this vary between pools? (Use the **Mini-Activity** *Turnover Rate & Residence Time* to dig deeper into the topic – the *Getting to Know Global Carbon* activity will also provide depth to the discussion of residence time.) • Optional: To enhance both of the discussions above you may have students draw a path of their journey on the board, each student adding in their own journey and then comparing the difference between the diagrams from pre and post-1700. • Preview the *Global Carbon Cycle Diagram*	

Assessment

- Students write a story or comic strip to describe their journey through the global carbon cycle. They should include information they learned from other student's presentations, creatively deal with pre vs. post 1700, and address residence time.

Adaptations

- To enhance the concept of residence time, place colored beads or paper slips at each station. Students should collect a new item (keeping them in order) each time they roll the dice. At the end of 10 rounds ask students to examine their own color pattern and the pattern of other students. What do they observe?
- To emphasize states of matter (carbon) add a column to the data table.
- Options for larger classes: 1) include multiple dice at each station, 2) half the class follows the pre-1700 cycle, then the other half the class follows the post-1700 cycle

Resources

STEM Earth Central 2006 – modified version of Carbon Travels activity produced by New England Aquarium

EPA Climate Change Kids Page – Flash Animations:
http://epa.gov/climatechange/kids/animations.html

Windows to the Universe – The Carbon Cycle Game (Flash):
http://www.windows2universe.org/earth/climate/carbon_cycle.html

Dr. Art's Guide to Planet Earth – The Carbon Cycle:
http://www.planetguide.net/cool/carboncycle_activity.html

Environmental Literacy Council – Carbon Cycle:
http://www.enviroliteracy.org/article.php/478.html

Northeast Science Center Collaborative – Climate Change Backpack:
http://sciencecentercollaborative.org/backpack.php

GLOBE Carbon Cycle

Name: _____ *Date:* _____

Carbon Cycle Journey Table

Instructions: Pick a station to start in- Atmosphere, Fossil Fuels, Soil/Detritus, Surface Ocean, Intermediate/Deep Ocean, Terrestrial Life, or Marine Life. Read the instructions, roll the die and see which station you go to next! Keep taking turns by rolling the dice and moving between stations as they instruct you.

Starting from: _____

Pre-1700

Where is carbon now?	How did carbon leave? (The process)	Where did carbon arrive?

Turn your sheet over when instructed that it is after 1700.

Starting from: _____

Post-1700

Where is carbon now?	How did carbon leave? (The process)	Where did carbon arrive?

What's Your Story?

What happened to you on your journey? Where did you go, and how did you get there? Can you see any patterns?

Atmosphere Pre-1700

You are paired with two oxygen – you are in carbon dioxide, or CO_2!

Roll the Dice

If you roll a:

1: Stay in the **Atmosphere** 1 turn, then roll again.

2 or 3: Become part of **Terrestrial Life**. A plant has taken you up as part of photosynthesis and synthesized you into sugar or a longer carbon chain.

4, 5 or 6: Go into the **Surface Ocean**. You have dissolved in the ocean waters.

Atmosphere Post-1700

You are paired with two oxygen – you are in carbon dioxide, or CO_2!

Roll the Dice

If you roll a:

1: Stay in the **Atmosphere** 1 turn, then roll again.

2 or 3: Become part of **Terrestrial Life**. A plant has taken you up as part of photosynthesis and synthesized you into sugar or a longer carbon chain.

4, 5 or 6: Go into the **Surface Ocean**. You have dissolved in the ocean waters.

Terrestrial Life Pre-1700

You are part of a carbon chain – cellulose in a tree trunk, sugar in fruit, or muscle in an animal.

Roll the Dice

If you roll a:

1 or 2: Go to the **Atmosphere**. You've been converted by respiration into CO_2

3, 4, 5, or 6: Go into the **Soil**. The organism you were a part of died, and now the carbon that made it up has fallen to the ground and is decaying. Carbon never dies!

Terrestrial Life Post-1700

You are part of a carbon chain – cellulose in a tree trunk, sugar in fruit, or muscle in an animal.

Roll the Dice

If you roll a:

1 or 2: Go to the **Atmosphere**. You've been converted by respiration into CO_2.

3: You're wood or other material that has been burned (combustion) by humans as part of changing land use. Go to the **Atmosphere**.

4, 5, or 6: Go into the **Soil**. The organism you were a part of died, and now the carbon that made it up has fallen to the ground and is decaying. Carbon never dies!

Soil/Detritus Pre-1700

You are part of a carbon chain, such as cellulose in a fallen leaf.

Roll the Dice

If you roll a:

1*, 2, 3, 4**: Stay in the **Soil** 1 turn, then roll again.

**If you roll 1 twice in a row, you are carried down to the Surface Ocean by a stream.*

***If you roll 4 five times in a row, you become a fossil fuel*

5, 6: Go into the **Atmosphere**. The chain you are a part of decayed and became carbon dioxide.

Soil/Detritus Post-1700

You are part of a carbon chain, such as cellulose in a fallen leaf.

Roll the Dice

If you roll a:

1: Human disturbance of the land, causes you to be carried down to the **Surface Ocean** in runoff.

2, 3, 4**: Stay in the **Soil** 1 turn, then roll again.

If you roll 4 five times in a row, you become a **Fossil Fuel

5, 6: Go into the **Atmosphere**. The chain you are a part of decayed and became carbon dioxide.

Surface Ocean Pre-1700

You are carbon dioxide dissolved in the surface waters of the ocean.

Roll the Dice

If you roll a:

1: Stay where you are in the **Surface Ocean** one turn, then roll again.

2 or 3: Go to the **Atmosphere**. You are coming out of solution to be carbon dioxide gas.

4 or 5: Go into the **Intermediate/Deep Ocean**. You are carried along by water currents.

6: Become part of **Marine Life**. Algae has taken you up out of the water through photosynthesis, and synthesizes you into a carbon chain.

Surface Ocean Post-1700

You are carbon dioxide dissolved in the surface waters of the ocean.

Roll the Dice

If you roll a:

1: Stay where you are in the **Surface Ocean** 1 turn, then roll again.

2 or 3: Go to the **Atmosphere**. You are coming out of solution to be carbon dioxide gas.

4 or 5: Go into the **Intermediate/Deep Ocean**. You are carried along by water currents.

6: Become part of **Marine Life**. Algae has taken you up out of the water through photosynthesis, and synthesizes you into a carbon chain.

Intermediate/Deep Ocean
Pre-1700

You are carbon dioxide dissolved in the deeper waters of the ocean.

Roll the Dice

If you roll a:

1*, 2, 3, or 4: Stay where you are 1 turn, then roll again.

If you roll 1 twice in a row, you become part of **Ocean Sediment. You've settled to the bottom of the ocean!*

5 or 6: Go into the **Surface Ocean**. You are carried along by water currents.

Intermediate/Deep Ocean
Post-1700

You are carbon dioxide dissolved in the deeper waters of the ocean.

Roll the Dice

If you roll a:

1*, 2, 3, or 4: Stay where you are 1 turn, then roll again.

If you roll 1 twice in a row, you become part of **Ocean Sediment. You've settled to the bottom of the ocean!*

5 or 6: Go into the **Surface Ocean**. You are carried along by water currents.

Marine Life Pre-1700

You are part of a carbon chain in an algae, or a marine mammal!

Roll the Dice

If you roll a:

1, 2, 3, 4, or 5: Go to **Surface Ocean**. You've been exhaled by marine life, converted to carbon dioxide gas in respiration.

6: Go to the **Intermediate/Deep Ocean**. The organism you were a part of died, and the carbon that made it up is now drifting downwards in the ocean. Carbon never dies!

Marine Life Post-1700

You are part of a carbon chain in an algae, or a marine mammal!

Roll the Dice

If you roll a:

1, 2, 3, 4, or 5: Go to **Surface Ocean**. You've been exhaled by marine life, converted to carbon dioxide gas in respiration.

6: Go to the **Intermediate/Deep Ocean**. The organism you were a part of died, and the carbon that made it up is now drifting downwards in the ocean. Carbon never dies!

Ocean Sediment Pre-1700

You can roll the die, but you're not going anywhere anytime soon! You are Sediment, and will become sedimentary rock.

Roll the Dice

If you roll a 1 five times in a row, after 10 million years you become **fossil fuel**.

If you roll a 6 five times in a row, after 10 million years you are released into the **atmosphere** by a volcano as carbon dioxide gas.

Ocean Sediment Post-1700

You can roll the die, but you're not going anywhere anytime soon! You are Sediment, and will become sedimentary rock.

Roll the Dice

If you roll a 1 five times in a row, after 10 million years you become **fossil fuel**.

If you roll a 6 five times in a row, after 10 million years you are released into the **atmosphere** by a volcano as carbon dioxide gas.

Fossil Fuel Deposits
Pre-1700

You are part of a carbon chain in oil or natural gas.

Roll the Dice

You can roll the die, but you're not going anywhere! You are ancient plants compressed and transformed into fossil fuel, and you are under many layers of rock – for now…

Stay in the Fossil Fuel for 10 turns.

Fossil Fuel Deposits
Post-1700

You are part of a carbon chain in oil or natural gas.

Roll the Dice

If you roll a:

1, 2, 3, or 4: Stay where you are in **Fossil Fuel Deposits** for 1 turn. You have not been extracted from underneath the rocks. Roll again.

5 or 6: Go to the **Atmosphere**. You've been burned in a car or power plant and converted into carbon dioxide gas