CHICAGO BOTANIC GARDEN

Activity 1.1: The Carbon Cycle

Grades 10 – 12

Description:
(Optional if you have not covered the carbon cycle)

Part 1: Modeling the Carbon Cycle. Students discuss the components of the carbon cycle as a class and then break into groups to create their own models of the carbon cycle. Once they have completed their models, they research other models of the carbon cycle as found in research texts and online. They add missing components to their model and discuss the differences. They then address the role of natural and human-induced carbon sinks, sources, and release agents in modifying the carbon cycle.

Part 2: The Carbon Cycle Game. Students play a game in which they take on the role of a carbon atom moving through the carbon cycle. They will follow their atom based on random flips of the coin through the various levels of the food chain, and through biotic and abiotic processes that make up the carbon cycle. They then answer discussion questions based on their experiences in the game. (This activity was modified from an activity at www.enviroliteracy.org/pdf/labbccar1.pdf.)

Materials:

Part 1
- Student question sheet
- Colored pencils
- Resources and/or computers that have carbon-cycle diagrams

Part 2

Per group
- Two coins (quarters, nickels, etc.)
- Colored pencils

Per student
- Carbon cycle game board
- Instruction sheet
- One dry bean, candy, or other small object that can be used to represent a carbon atom.
- Lab notebook

Time: Two to three class periods (for entire activity)

National Science Education Standards:
- Life Science, The Interdependence of Organisms, Grades 9 to 12, p. 186, Item #1: "The atoms and molecules on the Earth cycle among the living and nonliving components of the biosphere."
- Earth and Space Science, Geochemical Cycles, Grades 9 to 12, p. 189, Item #1: "The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on Earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles."
- Earth and Space Science, Geochemical Cycles, Grades 9 to 12, p. 189, Item #2: "Movement of matter between reservoirs is driven by the Earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life."

AAAS Benchmarks:

- The Physical Setting, Processes That Shape the Earth, Grades 9 to 12, p. 74, Item #1: "Plants alter the Earth's atmosphere by removing carbon dioxide from it, using the carbon to make sugars and releasing oxygen. This process is responsible for the oxygen content of the air."
- The Living Environment, Flow of Matter and Energy, Grades 6 to 8, p. 120, Item #2: "Over a long time, matter is transferred from one organism to another repeatedly and between organisms and their physical environment. As in all material systems, the total amount of matter remains constant, even though its form and location change."
- The Living Environment, Flow of Matter and Energy, Grades 9 to 12, p. 121, Item #1: "At times, environmental conditions are such that plants and marine organisms grow faster than decomposers can recycle them back to the environment. Layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. By burning these fossil fuels, people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide."

Guiding Questions:

- How does carbon cycle though biotic and abiotic components?
- What are carbon sources, sinks, and release agents?

Vocabulary

Carbon source: A place or entity that releases carbon into the atmosphere (e.g.: an organism performing cellular reparation, decaying organic matter, a power plant).

Carbon sink: A place or entity that removes or absorbs carbon from the atmosphere (e.g.: a plant performing photosynthesis).

Carbon release agent: A trigger for the release of carbon (e.g.: A forest fire, a volcano).

Photosynthesis: The process by which organisms (plants, algae, and some bacteria) convert water and carbon dioxide into organic molecules using energy from the sun.

Cellular respiration: The process by which organisms obtain energy by breaking down organic molecules such as glucose in the presence of oxygen.

Part 1: Introducing the Carbon Cycle

Time: One class period

Procedure

1. Begin by asking the class what they know about carbon. They may mention the processes of cellular respiration and photosynthesis among other things.

2. Next, ask the students how carbon atoms move through the environment. Record student answers on the board. The result should be the foundation for a simplified version of the carbon cycle, including eating and respiration in animals and photosynthesis in plants. You may need to guide the discussion to include oceans/water and rocks and minerals and the role both play in the carbon cycle. Do they contain carbon? What role do they play in the carbon cycle?

3. After the discussion, have students work in groups to create their own carbon-cycle diagram.

4. Once students have completed their diagram, have them research and compare their cycle with others illustrated in texts, encyclopedias, or online. Have them identify the differences and modify their own cycle, using a different colored pencil, so they can see the additions they have made.

5. Once students have modified their own cycles, bring groups together to share what they have learned. Add to the new elements the students have discovered to the board and create a class carbon cycle diagram.

6. Introduce the concepts of a carbon sink, carbon source, and carbon release agent (see vocabulary section at the beginning of this lesson). Have students identify and label each part of their carbon cycle as a source, sink, or release agent. Ask students why these might be important factors to identify.

7. Students can work together in groups to answer the questions on the Carbon Cycle Worksheet or complete them at home.

Part 2: The Carbon Cycle Game

Time: One class period

Procedure:

1. Divide students into groups of three. Each student should receive a playing piece representing a carbon atom, an instruction sheet, and a game board. Each group needs two coins and colored pencils.

2. Explain to students that they will be playing a game in which they are taking on the role of a carbon atom. Have them place their game pieces on space #1. At the start of their turn, they will toss the coins and follow the instructions as directed on the instruction sheet. Remind students not to follow the sequence of the numbers, but to follow the moves directed by their toss of the coins. Two or more players can occupy the same place. When your carbon atom is returned to the atmosphere, you have completed one cycle. Continue playing until told to stop.

3. Have students use the colored pencils to keep track of their cycles on their individual game boards, with each color representing a single cycle. Remind students to **use a different color for each cycle**. They should label the cycles 1st, 2nd, etc. and keep track of the following:
    - Who visited the most organisms?
    - Who completed the most cycles?
    - Who completed the longest cycle? The shortest?
    - Who spent the most time in the atmosphere?

4. Have students answer the following discussion questions in their lab books.

Discussion Questions

1. What parts of the carbon cycle game did you find surprising? What did you learn from playing the game that you didn't know before?
2. In the course of the carbon cycle, are carbon atoms themselves ever created or destroyed? Are carbon atoms ever changed into other kinds of atoms? Are they ever changed into other compounds? Explain.
3. What phase changes occur in the state of carbon atoms in the course of the cycle? When are carbon atoms part of a solid, liquid, or gas.
4. When are carbon atoms part of something living (biotic)? When are they part of something non-living (abiotic?)?
5. Much of the food ingested by each organism is metabolized in cell respiration. Why is this so?
6. What happens to carbon atoms as a result of respiration?
7. Why is a natural ecosystem not polluted by built up wastes from the various organisms? Diagram how waste products of organisms are used by other organisms.
8. Do you think all possible pathways of carbon were included in this diagram? What carbon sources or sinks may be missing from the diagram? Why do you think these pathways were not included?
9. What role did chance play in the carbon cycle game? What role do you think chance plays in the actual carbon cycle?
10. Do you think there is a way to "win" in the carbon cycle? Why or why not?

CHICAGO BOTANIC GARDEN

Introducing the Carbon Cycle

Name_____ Date_____ Class_____

1. What gas do humans and animals exhale? Write the formula for this exhaled gas.

2. Can humans be considered carbon sinks? If so, for how long? What living organisms are better long-term sinks than humans?

3. List two important carbon sinks (things that store carbon), two important sources (things that release carbon), and one important release agent (things that trigger sources) for carbon.

4. Research shows that there is a correlation between increased carbon in the atmosphere and global temperature increases. If sources release more carbon into the atmosphere than sinks can remove, what might be the results? What might happen if the reverse were true and sinks took up more than sources?

The Carbon Cycle Game – Student Directions

1. Your teacher will give you: this instruction sheet, colored pencils, a playing piece for each student in your group, a game board for each student, and two coins.

2. Place your playing pieces on space #1. Flip the coins as instructed on the instruction sheet. Flip your coins at the start of the turn following the instructions as you go. Do not follow the sequence of the numbers. Instead, follow the moves that the coins present. Two or more players can occupy the same place. When your carbon atom is returned to the atmosphere, you have completed one cycle. Continue playing until told to stop.

3. On your individual game board, use the colored pencils to keep track of your cycles with each color representing a single cycle. Label the cycles 1st, 2nd, etc. Keep track of the following:
    - Who visited the most organisms?
    - Who completed the most cycles?
    - Who completed the longest cycle? The shortest?
    - Who spent the most time in the atmosphere?

4. Answer the discussion questions in your lab book.

Discussion Questions

1. What parts of the carbon cycle game did you find surprising? What did you learn from playing the game that you didn't know before?

2. In the course of the carbon cycle, are carbon atoms themselves ever created or destroyed? Are carbon atoms ever changed into other kinds of atoms? Are they ever changed into other compounds? Explain.

3. What phase changes occur in the state of carbon atoms in the course of the cycle? When are carbon atoms part of a solid, liquid, or gas.

4. When are carbon atoms part of something living (biotic)? When are they part of something non-living (abiotic?)?

5. Much of the food ingested by each organism is metabolized in cell respiration. Why is this so?

6. What happens to carbon atoms as a result of respiration?

7. Why is a natural ecosystem not polluted by built up wastes from the various organisms? Diagram how waste products of organisms are used by other organisms.

8. Do you think all possible pathways of carbon were included in this diagram? What carbon sources or sinks may be missing from the diagram? Why do you think these pathways were not included?

9. What role did chance play in the carbon cycle game? What role do you think chance plays in the actual carbon cycle?

10. Do you think there is a way to "win" in the carbon cycle? Why or why not?

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Carbon Cycle Game Rules

***Note**: H = Heads T = Tails*

Start at Number 1

1. **Your carbon atom is now a molecule of CO_2 in the atmosphere.**
   Flip two coins
   TT Not absorbed; your carbon atom remains in the atmosphere for another turn.
   TH or HH Your carbon atom is absorbed into a leaf of a plant. Go to number 2.

2. **The molecule of CO_2 with your carbon atom is now in the leaf of a plant.**
   Flip two coins
   TT No sunlight! Therefore, no photosynthesis. The CO_2 molecule with your carbon atom returns to the atmosphere. Go back to number 1.
   TH or HH Sunlight! Photosynthesis. Your carbon atom is incorporated into a sugar molecule by photosynthesis. Go to number 3.

3. **Your carbon atom is now in a molecule of sugar in a plant.**
   Flip two coins
   TT The sugar molecule with your carbon atom is broken down in cell respiration to provide energy for plant growth. Your carbon atom is released into the atmosphere as a molecule of CO_2. Go back to number 1.
   TH or HH The sugar molecule with your carbon atom is incorporated into a molecule making up the tissue of a plant. Go to number 4.

4. **Your carbon atom is now in a molecule of sugar in a plant.**
   Flip two coins
   TT The plant is eaten by an animal. Go to Number 5 and take another turn to determine what kind of animal.
   TH or HH The plant part dies. It becomes dead organic matter or detritus. Go to Number 6.

5. **The plant tissue with your carbon atom is eaten by a primary consumer.**
   Flip one coin twice
   T & T Mammal herbivore–go to 8A
   T & H Bird–go to 8B
   H & T Insect–go to 8C
   H & H Human, perhaps yourself–go to 9

6. **Your carbon atom is now in a molecule of dead organic matter or detritus.**
   Flip two coins
   TT or TH Consumed by a detritus feeder or decomposer. Go to 10 and take another turn to determine which one.
   HH Fire! Go to 7.

7. **The molecule with your carbon atom is now being broken down by fire. Oxygen is combining with your carbon atom and it is being released in a molecule of carbon dioxide. Go immediately back to number 1 without taking a turn.**

8. **8A, 8B, and 8C The plant tissue with your carbon atom is now being ingested by a primary consumer as part of its food.**
   Flip two coins
   - TT The molecule with your carbon atom is metabolized into a molecule making up the tissue of the consumer's body. Go to 11P.
   - TH Cell respiration! Go to 12.
   - HH The molecule with your carbon atom is not digested. It passes through the intestinal tract as fecal waste. Go to 6.

9. **The plant tissue with your carbon atom is now being ingested by a human, perhaps yourself, as a part of food.**
   Flip two coins
   - TT The molecule with your carbon atom is metabolized into a molecule making up a tissue in your body. Go to 11H.
   - TH Cell respiration! Go to 12.
   - HH The molecule with your carbon atom is not digested, It passes through the intestinal tract and out as fecal waste. Go to number 6.

10. **The molecule containing your carbon atom is now being ingested by a primary detritus feeder or decomposer.**
    Flip one coin twice
    - T&T Earthworm – go to 15E.
    - T&H Decomposer – fungus (mushroom); Go to 15F.
    - H&T Decomposer – bacteria; Go to 15B.
    - H&H Insect – go to 15I.

11H. Your carbon atom is now in a molecule making up a tissue of your body or another human's body.
Flip two coins
- T The molecule is broken down and metabolized in cell respiration – go to 12.
- H When the human dies of injury and/or disease and if the body is cremated, the carbon atom will go to number 7.

11P. Your carbon atom is now in a molecule making up a tissue of a primary consumer or herbivore.
Flip two coins
- TT The molecule is broken down and metabolized in cell respiration. Go to 12.
- TH The primary consumer is eaten by a secondary consumer. Go to 13.
- HH The primary consumer dies of injuries and/or disease. Go to 6.

11S. Your carbon atom is now in a molecule making up a tissue of a secondary consumer or a carnivore.

Flip two coins

TT	The molecule is broken down and metabolized in cell respiration. Go to 12.
TH	The secondary consumer is eaten by a third-order consumer. Go to 14.
HH	The secondary consumer dies of injuries and/or disease. Go to 6.

11T. Your carbon atom is now in a molecule making up a tissue of a third-order consumer or a carnivore.

Flip two coins

TT	The molecule is broken down and metabolized in cell respiration. Go to 12.
TH	The third-order consumer is eaten by another third order consumer. Go to 14.
HH	The third-order consumer dies of injuries and/or disease. Go to 6.

12. The molecule containing the carbon atom is now being broken down in cell respiration to provide energy for the consumer's movements and functions. In this process your carbon atom is combined with two oxygen atoms and is released back into the air as carbon dioxide (CO_2). Go immediately back to number 1 without taking another turn.

13. The molecule with your carbon atom is now being ingested by a secondary consumer.

Flip two coins

TT	The molecule is metabolized, making up tissue of the consumer's body. Go to 11S.
TH	Cell respiration! Go to 12.
HH	The molecule with your carbon atom is not digested. It passes through the intestinal tract and out as fecal matter. Go to 6.

14. The molecule with your carbon atom is now being ingested by a cow – a consumer.

Flip two coins

TT	The molecule is metabolized into a molecule making up tissue of the consumer's body. Go to 11T.
TH	Cell respiration! Go to 12.
HH	The molecule with your carbon atom is not digested. It passes through the intestinal tract and out as fecal matter. Go to 6.

15B. The molecule with your carbon atom is now being absorbed by a bacterium.

Flip one coin

T	It gets incorporated into a molecule of the bacteria. Go to 16.
H	It gets broken down and metabolized in cell respiration. Go to 12.

15E The molecule with your carbon atom is now being ingested by an earthworm.

Flip two coins

TT	It gets incorporated into a molecule of the worm's body. Go to 17.
TH	It gets broken down and metabolized in cell respiration. Go to 12.
HH	It is not digested; it passes through the intestinal tract and out as fecal matter. Go to 6.

15F. The molecule with your carbon atom is now being absorbed by a fungus (mushroom).

Flip one coin

T	It gets incorporated into a molecule of the fungus. Go to 18.
H	It gets broken down and metabolized in cell respiration. Go to 12.

15I. The molecule with your carbon atom is now being ingested by an insect grub.

Flip two coins

TT	It gets incorporated into a molecule of the insect's body. Go to 19.
TH	Cell respiration! Go to 12.
HH	It is not digested. It passes through the intestinal tract and out as fecal waste. Go back to 6.

16. Your carbon molecule is now a molecule making up the bacterium's body.

Flip two coins

TT	The molecule is broken down and metabolized in cell respiration. Go back to 12.
TH	The bacterium is eaten by an earthworm. Go to 15E.
HH	The bacterium dies. Go to 6.

17. Your carbon molecule is now a molecule making up the earthworm's body.

Flip two coins

TT	The molecule is broken down and metabolized in cell respiration. Go back to 12.
TH	The worm is eaten by a bird. Go to 15E.
HH	The worm dies of injury or disease. Go to 6.

18 Your carbon molecule is now a molecule making up a mushroom.

Flip two coins

TT	The molecule is broken down and metabolized in cell respiration. Go back to 12.
TH	The mushroom is eaten by an insect. Go to 15I.
HH	The mushroom matures and dies. Go to 6

19 Your carbon molecule is now a molecule making up the body of an insect.

Flip two coins

TT	The molecule is broken down and metabolized in cell respiration. Go back to 12.
TH	The insect is eaten by a small mammal. Go to 8A.
HH	The insect dies of injury or disease. Go to 6.

Carbon Cycle Game

14 Tertiary Consumer

12 11T

1 CO_2 in the Atmosphere

PRODUCERS

12 11P

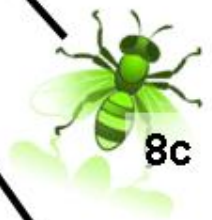
13 Secondary Consumer

12 11S

6 DETRITUS

5 PRIMARY CONSUMER (Herbivore)

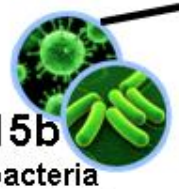
12 11P



12 11P

10. DETRITUS FEEDERS & DECOMPOSERS

7 FIRE

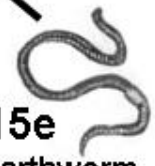


15b bacteria

12 16

15r mushroom

12 18



15e earthworm

12 17

15i Grub

12 19

12 11H

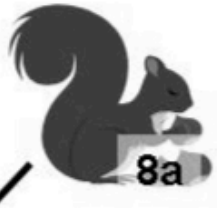
Carbon Cycle Game

14 Tertiary Consumer

12 11T

1 CO_2 in the Atmosphere

PRODUCERS



12 11P

12 11P

13 Secondary Consumer

12 11S

6 DETRITUS

5 PRIMARY CONSUMER (Herbivore)

12 11P

10. DETRITUS FEEDERS & DECOMPOSERS

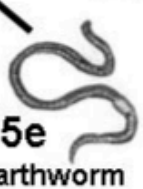
7 FIRE

15b bacteria

12 16

15r mushroom

12 18



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