LESSON 3: IT'S A BIRD…IT'S A PLANE…IT'S…CARBON!
A CARBON CYCLE ADVENTURE STORY

PURPOSE/QUESTION
Students will use elements with a story to understand carbon's abundance in the earth system as well as it role in the earth system.

GRADE LEVEL
9-12

TIME TO COMPLETE
60-90 minutes

STANDARDS
See appendix below-pg. 7

LEARNING OUTCOMES
- Students will explore a system using the carbon cycle model
- Students will learn that carbon is one of the most important and abundant elements on Earth.
- Students will learn that carbon can be found everywhere.

STUDENT OBJECTIVES
- List the major pools and fluxes of the carbon cycle.
- Diagram the carbon cycle using box and arrow models
- Describe what components of the carbon cycle make it a system

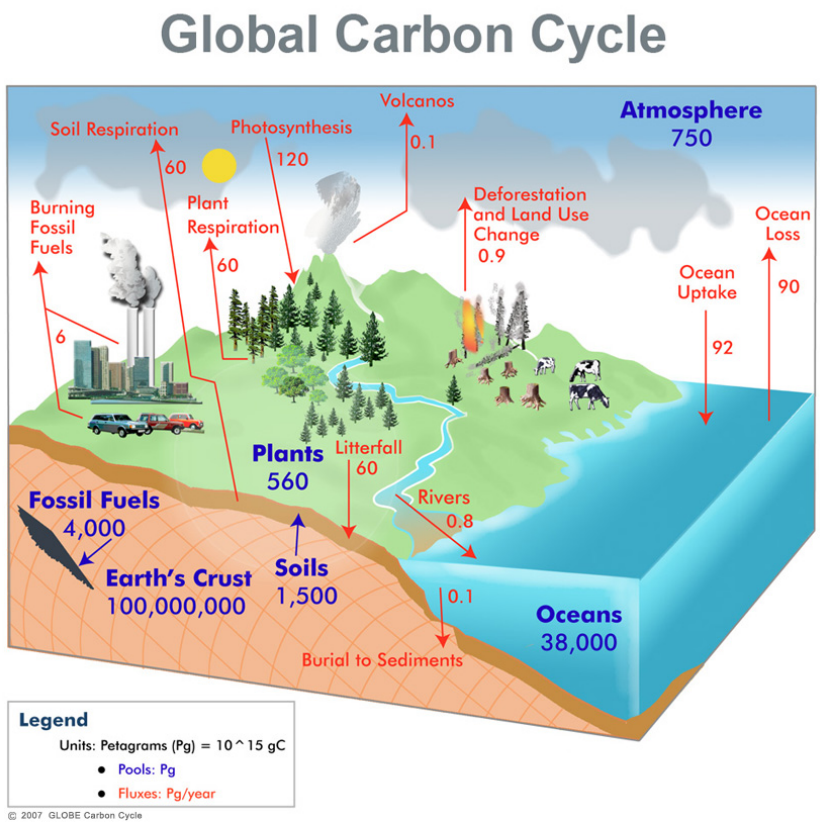
TEACHER BACKGROUND

This activity provides an introduction to the carbon cycle and systems thinking. It could also be used as an introduction to the carbon cycle and, more broadly, to biogeochemical cycling, the greenhouse effect and climate change. During the activity, students read about a carbon atom that begins in the atmosphere as part of carbon dioxide. Students choose where the atom will travel next, i.e. into a leaf via photosynthesis or dissolve into the ocean. Students keep track of the carbon pools they visit, and the process that takes their carbon atom on to the next pool.

A basic understanding of atoms and elements may be helpful, but the introduction pages of the booklet may suffice. An introduction to the concept of pools and fluxes might also be useful (perform *Paperclip Factory Analogy*).

All systems consist of a set of interacting components that, together, form a more unified entity. As an example, an engine, wheels, brakes, transmission and chassis interact together to form a system we identify as a car. In the environment, systems tend to be very intricate because the number of components is often large and the ways in which they interact are complex. To deal with this complexity, scientists often simplify environmental systems by lumping multiple components together and treating them as individual 'pools' and treating the transfer of materials between them as 'fluxes.'

Pools, also known as stocks or reservoirs, represent any place where a given substance can reside. In the carbon cycle, examples of individual pools might include soils, leaves, wood, whole trees and ecosystems or the entire biosphere. Note that these examples overlap and that carbon pools can be grouped together or treated separately. Carbon in trees can be considered a single pool, or it can be divided into leaves, wood and roots. If necessary, these pools can be further subdivided into sugars, starches, and other compounds. Alternatively, trees can be grouped with crops, grasses and shrubs to form a single global plant pool. How scientists make these decisions depends on the questions being asked and the scale of a particular study. The movement of material from one pool to another is known as a flow, or flux. For example, in the global carbon cycle, carbon moves from the atmosphere to the plant pool through the process of photosynthesis. Hence, photosynthesis represents a flux and is, in fact, one of the most important fluxes in the carbon cycle.



The flux of carbon out of this plant pool occurs through the transfer of leaves and other dead plant materials to soils (a process known as litterfall) and through respiration, which releases carbon dioxide back into the atmosphere. These examples are just a few of the pools and fluxes that make up the entire global carbon cycle.

As we proceed, we should keep in mind that no system occurs in complete isolation. Because all things in the universe are in some way interconnected, scientists studying any system must draw artificial boundaries around what they believe are the most important components for a particular study. Although we can view an automobile as a discrete system, its function relies on external inputs in the form of fuel, parts and other materials, as well as outputs in the form of exhaust and heat. Each of these is affected by processes that occur outside the normal boundaries of what we view as a car. If needed, we could capture these processes by treating cars as subsystems that act within larger systems of transportation, energy and environment. How we draw the boundaries depends on what we are trying to achieve. In the investigations we're about to embark on, we can treat the carbon cycle as a single system, a series of interacting subsystems, or as just a part of the overall Earth system (which also includes the nitrogen cycle, the energy cycle, the water cycle and more).

PREREQUISITE KNOWLEDGE & SKILLS

- Atoms
- Elements

VOCABULARY

- Carbon Pool
- Flux
- Refer to "Glossary of Terms" at the end of the Carbon Cycle Adventure Story

MATERIALS & TOOLS

- Carbon Cycle Adventure Story Booklet (per individual or student pair)
- Carbon Atom Journey Table (per individual or student pair)
- Carbon Cycle Adventure Story Map of Flows (separate – for use by teacher)
- White board, chalk board, large paper or overhead projector & markers/chalk
- Pencil or pen for each student

LESSON LINKS

- Carbon Cycle Adventure Story – found on page 3-9
- Carbon Atom Journey Table – found in lesson 3 folder

ESSENTIAL QUESTIONS-PART 1

1. After reading pages 1-3 explain why you feel Carbon is an important atom and element. Give no less than 3 reasons.
2. What do you understand about carbon now after reading the adventure story that you did not understand before? Explain.

PROCEDURE – Part 1
Engage and Explore

1. 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.

2. Record the ideas of where carbon is found on the board.

3. 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)?

4. Tell students, carbon and the carbon cycle will be the subject for the next few class periods and they will begin by reading an adventure story where they follow Mr. Carbon, a carbon atom through the global carbon cycle.

   Grouping: Individual/Pairs/Groups of Three

5. Students follow a carbon atom through the carbon cycle by reading then choosing their own adventure story.

6. Students begin by reading aloud pages 1 through 3 of the *Carbon Cycle Adventure Story*.

7. Show students the Glossary of Terms (on the last page) as a reference for any terms ***(bold and italic)*** they don't understand.

   Instruct students to read the Adventure Story and record their journey in the Journey Table.
   - Students will record: 1) the pools where carbon currently resides, 2) the flow or process chosen within the booklet which will take the carbon atom to another pool, 3) the pool where carbon moves to.
   - Students should also record any questions that come to mind or terms they do not understand (and are not listed in the glossary)

   Note: The adventure can be run as long or as short as time allows, providing that students/student groups have experienced at least 5 pools during their journey.

ESSENTIAL QUESTIONS-PART 2

1. Where is carbon stored (pools)?
2. What are some ways that carbon moves (fluxes) between pools?

PROCEDURE – PART 2
Explain

1. After a Journey is completed ask students for any questions they may have. Record questions on a class list and tell students **you** will not answer these questions now, but they will be answered through classroom activities and individual student investigations.

2. Define any vocabulary terms that students need clarification on.

3. Introduce or review the concept of basic systems.
   - **Review:** If students performed the *Paperclip Simulation* or another systems activity. Review box and arrow diagrams and systems terminology (stock/pool and flow/flux).
     - o Show students one example of how to create a multi-box and arrow diagram from their story data.

   - **Introduce:** If this is students' first experience with systems.
     - o Ask students to look at their Journey Table and give a few examples of where carbon is found - where they traveled to during their journey. Record these on the board and explain to students that places where carbon is stored are called **pools, stocks or reservoirs**.
     - o Now ask students to share the processes by which carbon left these pools and entered other pools. Tell students that the movement of material from one pool to another is called a **flux, flow or transfer**.
     - o Tell students that an easy way to represent the interaction of pools and fluxes is through the use of box and arrow diagrams. Where boxes represent pools and arrows represent fluxes (Figure1).
       - Show an example of a one-box diagram using some of the pools and fluxes written on the board (Figure 2).
       - Expand the one box diagram into a two-box diagram.

FIGURE 1

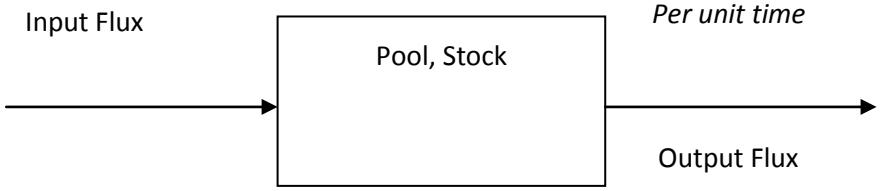
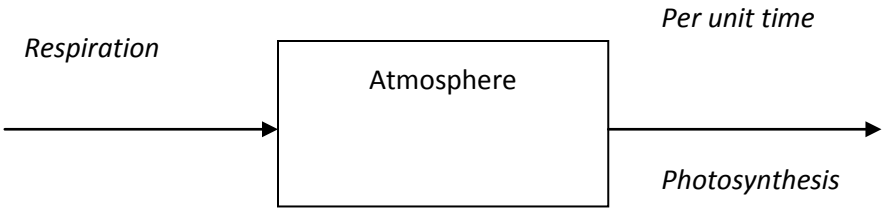


FIGURE 2



ESSENTIAL QUESTIONS-PART 3

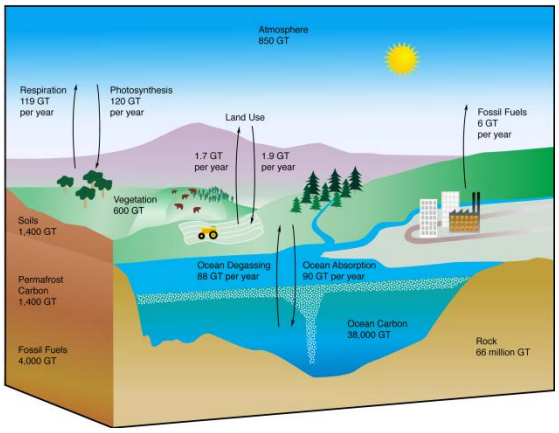
1. Can systems contain sub-systems?
2. How can we represent systems?

PROCEDURE -3

ELABORATE and EVALUATE

1. Develop the classroom carbon cycle diagram based on each student's journey.

2. Tell students to form partners/small groups and create a multi-box and arrow diagram by combining their journeys through the carbon cycle.



Carbon moves through the Earth's atmosphere, oceans, and land in a process called the carbon cycle.
—Credit: NSIDC, modified from NASA Earth Science Enterprise

3. When all students have added their own pools and flows to the group carbon cycle diagram have a representative from each group come to the board and add a few pools and fluxes to the class diagram (start by writing the Atmosphere at the top of the board).

4. Use the *Carbon Cycle Adventure Story Map of Flows* to assist students if necessary.

5. Discuss the complexities of the carbon cycle.
   - Ask students to share one thing they leaned about the carbon cycle from this activity.
   - Did students find themselves returning to one pool or another more often than others?

6. What does that indicate about systems in general? (systems within systems)

7. Are there ways that one could simplify the carbon cycle flow created during your adventure to better understand the carbon cycle at a global scale? (Lead in to *Getting to know the Global Carbon Cycle.*

TOOLS FOR ASSESSMENT

- Completion of *Journey Table*
- Group diagram of journey using the box and arrow method
- Concept Quiz – found on pg. 10
- Essay – found on pg.14
- Foldables®
- Student Reading and Science Notebook Assessments – found in ***Rubrics*** folder

WEBSITES FOR FURTHER LEARNING

- EPA Climate Change Kids
- Windows to the Universe – The Carbon Cycle Game
- Dr. Art's Guide to Planet Earth – The Carbon Cycle
- Environmental Literacy Council – Carbon Cycle

STUDENT READING RESOURCES

- The Carbon Cycle
- Effects of Changing the Carbon Cycle
- The Case for Climate Change

LESSON 3-APPENDIX

HYPER LINKS WEB ADDRESSES

PREREQUISITE KNOWLEDGE AND SKILLS

- **Atoms and Elements**
  http://www.nyu.edu/pages/mathmol/textbook/atoms.html

VOCABULARY

- **Carbon Pool**
  http://www.expertglossary.com/climate-change/definitions/C
- **Flux**
  http://mynasadata.larc.nasa.gov/science-glossary/?page_id=672?&letter=F

WEBSITES FOR FURTHER LEARNING

- **EPA Climate Change Kids –** An interactive student friendly site where students can understand not only the carbon cycle but learn about the different elements that tell us about how Earth's climate is changing.
  http://www.kidsnewsroom.org/climatechange/
- **Windows to the Universe – The Carbon Cycle Game –** An interactive diagram that allows students to travel through the carbon cycle and better understand its pools and fluxes.
  http://www.windows2universe.org/earth/climate/carbon_cycle.html
- **Dr. Arts Guide to Planet Earth – The Carbon Cycle –** An accompaniment to Dr. Art's Guide to Planet Earth this site gives students the opportunity to learn more about the Earth System including the carbon cycle.
  http://www.guidetoscience.net/cs/drart/print/docs/drart/chapter7.htm
- **Environmental Literacy Council – Carbon Cycle –** An instrument for teachers and students to better understand the Earth system.
  http://www.enviroliteracy.org/article.php/478.html

STUDENT READING RESOURCES

- **The Carbon Cycle**
  http://earthobservatory.nasa.gov/Features/CarbonCycle/
- **Effects of Changing the Carbon Cycle**
  http://earthobservatory.nasa.gov/Features/CarbonCycle/page5.php
- **The Case for Climate Change**
  http://climate.nasa.gov/news/index.cfm?FuseAction=ShowNews&NewsID=506

LESSON 3-STANDARDS

National Science Education Standards

Unifying Concepts and Processes

- Systems, order, and organization
- Evidence, models, and explanation

Standard B – Physical Science

- Structure and properties of matter

Standard D – Earth and Space Science

- Energy in the earth system
- Geochemical cycles

National Education Technology Standards

Standard 1: Creativity and Innovation

- Use models and simulations to explore complex systems and issues

Standard 3: Research and Information Fluency

- Process data and report results

Standard 4: Critical Thinking, Problem Solving, and Decision Making

- Collect and analyze data to identify solutions and/or make informed decisions.

National Council of Teachers of Mathematics Standards

N/A

Climate Literacy Principles

Principle 2: Climate is regulated by complex interactions among components of the Earth system.
Principle 4: Climate varies over space and time through both natural and man-made processes.
Principle 5: Our understanding of the climate system is improved through observations, theoretical studies, and modeling

Energy Literacy Principles

Principle 2: Physical Earth processes are the result of energy flow through the earth system.
Principle 3: Biological Earth processes depend on energy flow through the earth system.

LESSON 3-ESSENTIAL QUESTIONS ANSWER KEY

Essential Questions-1

1. After reading pages 1-3 explain why you feel carbon is an important atom and element. Give no less than 3 reasons.
   [answers will vary: the building block of life, 4th most abundant element in the universe, can be found in the atmosphere, soil, oceans and other bodies of water, earth's surface (rocks), molecules of carbon can be used to make CO_2, glucose, caffeine, when combining with other molecules carbon can be a solid, liquid, or gas]

2. What do you understand about carbon now after reading the adventure story that you did not understand before? Explain.
   [Answers will vary.]

Essential Questions-2

1. Where is carbon stored (pools)?
   [Forest biomass, wood products, soil, atmosphere, fossil fuels, plants, oceans]

2. What are some ways that carbon moves (fluxes) between pools?
   [burning fossil fuels, soil and plant respiration, photosynthesis, litterfall, volcanoes, deforestation, land use change, ocean loss and uptake]

Essential Questions-3

1. Can systems contain sub-systems?
   [Yes, sub-systems are the parts that make up the larger system. When sub-systems break-down or function inefficiently it causes problems in the larger systems.]

2. How can we represent systems?
   [Systems can be represented using 2D and 3D models, representing the real system.]

Name: _____ Date: _____

Carbon Cycle Journey Table

Instructions: As you read the Adventure Story, record your journey in the table. If you encounter anything you do not understand including new vocabulary record your questions below.

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

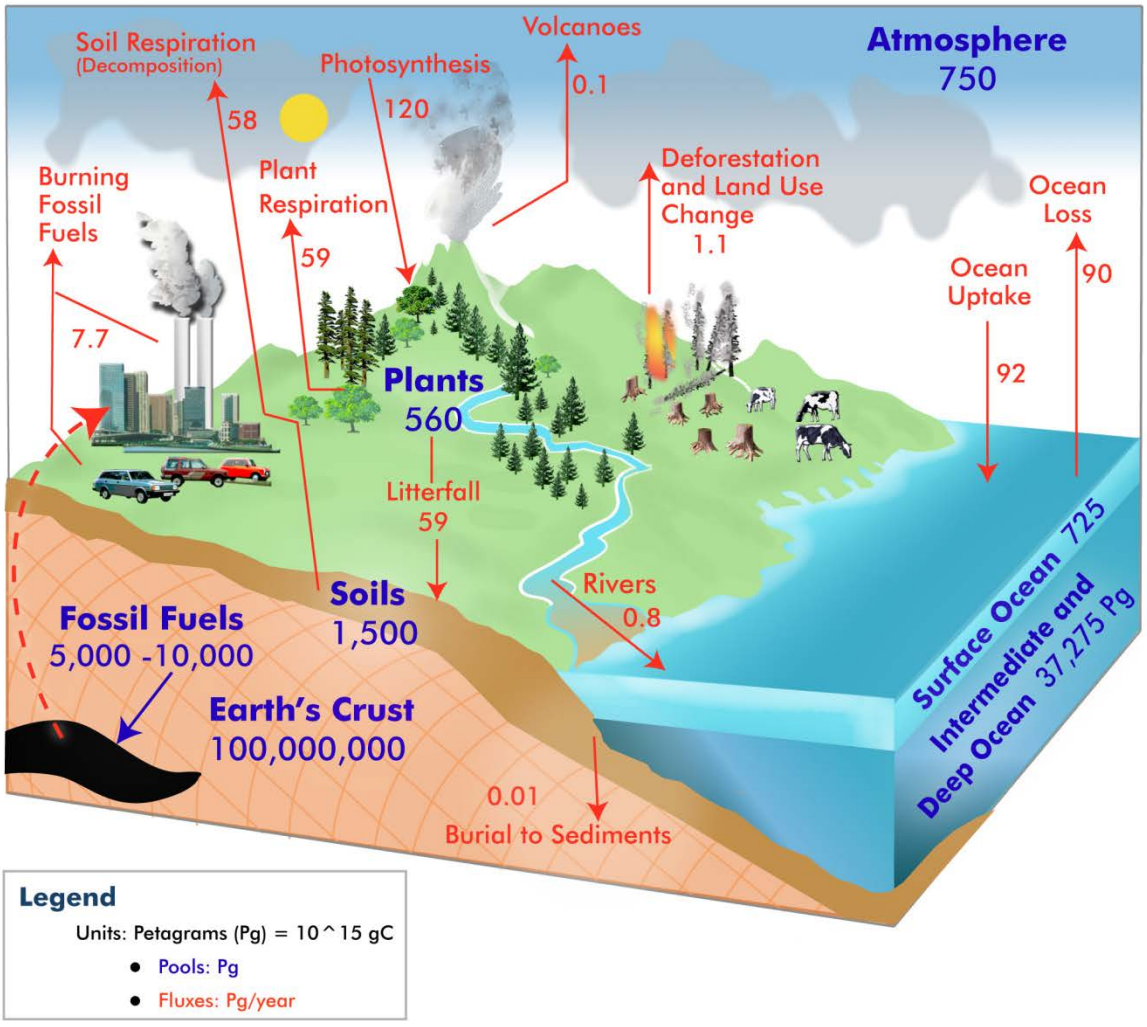
Vocabulary and Questions:

Name: _____ Date: _____

Science Concept Quiz

Lesson 3: Carbon Cycle Adventure Story

Global Carbon Cycle



Data Sources: Adapted from Houghton, R.A. Balancing the Global Carbon Budget. Annu. Rev. Earth Planet. Sci. 007.35:313-347, updated emissions values are from the Global Carbon Project: Carbon Budget 2009.

Using the diagram on page one to answer the following question. In order to understand how carbon is cycled and how atmospheric CO_2 will change in the future, scientists must carefully study the places in which carbon is stored (pools), how long it resides there, and processes that transfer it from one pool to another (fluxes). Identify two pools and two fluxes from the choices below.

A. Burning fossil fuels, plant respiration, photosynthesis, and volcanoes
B. Burial of sediment, oceans, earth's crust, and fossil fuels
C. The Global Carbon Cycle is too complex a system to identify pools and fluxes.
D. Litterfall, burning fossil fuels, plants, and soils

_____ points out of 20

I. Answer

A.◯ B.◯ C.◯ D.◯ E.◯

_____ points out of 15

II. What is the main concept behind the question?

1. Changes over time
2. Making Predictions
3. Carbon storage and transfer
4. Understanding the definition of a cycle

_____ points out of 25

III. Provide the reasoning for choosing your answer in part II.

_____points out of 40

IV. Why are the other responses in part I not the best answer choice?

1.

2.

3.

4.

Use the rest of this page if more room is needed to fully communicate your thoughts.

Teacher Answer Key

1. D

2. 3

3. Answers may vary.
   3-The legend states that red identifies carbon fluxes and blue identifies carbon pools.

4. Answers may vary.
   A. This list identifies carbon fluxes only.
   B. This list identifies carbon pools only.
   C. Yes the Global Carbon Cycle is a complex system, but scientists have identified many pools and fluxes to help us understand how carbon travels through the earth system.
   D. Litterfall and burning fossil fuels are both fluxes and plants and soils are both pools for carbon storage.

Student Name
Teacher/Class
Date

Lesson 3: The Carbon Cycle Adventure Story

Explain what you understand about the carbon cycle now that you did not know before this activity.

What Is the Expectation?

Evidence of before and after understanding.

Visual representations if applicable

Key vocabulary

Evidence of on grade level spelling and grammar usage