Carbon Cycle Adventure Story

Purpose

- To explore a system – the carbon cycle.
- To learn that carbon is one of the most important and abundant elements on Earth and can be found everywhere.

Overview

This activity provides an introduction to the carbon cycle and systems thinking. It also could be used, more broadly, to introduce 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.

Student Outcomes

Students will be able to:

- 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.

Questions

Content

- Where is carbon stored (pools)?
- What are some ways that carbon moves (fluxes) between pools?
- Can systems contain sub-systems?
- How can we represent systems?

Science Concepts

Grades 9-12

Life Science

- The atoms and molecules on the earth cycle among living and non-living components of the biosphere.
- As matter and energy flows through the system chemical elements are recombined in different ways.

Earth and Space Science

- The earth is a system containing essentially a fixed amount of each stable chemical atom or element.
- Movement of matter between reservoirs is driven by the earth's internal and external sources of energy.

Science in Personal and Social Perspectives

- Natural ecosystems provide an array of basic processes that affect humans.
- Materials from human societies affect physical and chemical cycles of the earth

NGSS (Black- covered directly, gray-addressed, but not directly covered)

- *Disciplinary Core Ideas*
  - Gr.6-8: PS1.B, PS3.D, LS1.C, LS2.A, LS2.B, PS1.A, LS2.C, ESS2.C, ESS3.A, ESS3.C
  - Gr.9-12: PS3.D, LS1.C, LS2.B, ESS2.E, PS1.A, PS1.B, PS3.B, LS2.C, ESS2.C

Science and Engineering Practices

- Asking Questions
- Developing and using models
- Analyzing and interpreting data

- *Crosscutting Concepts:*
  - Cause and Effect
  - Systems and system models
  - Energy and matter

Time/Frequency

60-90 minutes

Level

Secondary (Middle & High School)

Materials and Tools

- Carbon Cycle Adventure Story Booklet (per individual or student pair)
- *Carbon Story Journey Table* (per individual or student pair)
- White board, chalk board, large paper or overhead projector & markers/chalk

Prerequisites

- None required.
- Helpful: A basic understanding of atoms and elements.
- Helpful: The concept of pools and fluxes (*Paperclip Simulation*).

Prerequisites

- Print/copy *Carbon Story Journey Table* & *Carbon Cycle Adventure Story Booklet*
- Make a classroom example of the Carbon Atom Journey Table
- Write essential, unit, and content questions somewhere visible in the classroom

Background

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, it's 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).

To learn more about systems, the Earth system and teaching about systems see the Resources section below. To learn more about the carbon cycle see the Carbon Cycle eTrainings and *Introduction to the Global Carbon Cycle* on the GLOBE Carbon Cycle webpage under Resources —Teacher Preparation.

What To Do and How To Do It

ENGAGE	**Grouping:** Class	**Time:** 10 Minutes

*Note: Students may have completed this engagement exercise if they participated in the *Carbon Travels Game*. If so, move on to Explore.

- Tell students that you want to begin teaching about carbon today, but you cannot seem to find it. Ask students if anyone saw carbon today on their way into class.
  - 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)? What states of matter does it take on (liquid, solid, gas)?
- Tell students carbon and the carbon cycle will be the subject for the next few class periods (or more) and they will begin by reading an adventure story where they follow Mr. Carbon, a carbon atom through the global carbon cycle.

EXPLORE	**Grouping:** Small Groups	**Time:** 20-30 Minutes

- Tell students they will soon have the opportunity to follow a carbon atom through the carbon cycle by reading a "choose your own adventure story".
- Students begin by reading aloud pages 1 through 3 of the *Carbon Cycle Adventure Story.*
  - You may choose to pause here for some additional lessons/notes on the forms and states of matter that carbon is found in before moving on. {e.g. A review of 10th grade biochemistry}(10-90 minutes)
- Show students the Glossary of Terms (on the last page).
- Instruct students to read the Adventure Story and record their travels 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 also record questions that come to mind or terms they do not understand
  - Students could also record the form/state of carbon as it moves through the cycle
- 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.

EXPLAIN	**Grouping:** Class	**Time:** 15 Minutes

- 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.
- Define any vocabulary terms that students need clarification on.
- 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).
    - ➢ Demonstrate how to create a multi-box and arrow diagram from story data.
  - **Introduce:** If this is students' first experience with systems.
    - ➢ 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.

- 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**.
- 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 (Figure 1).
- Show an example of a one-box diagram using some of the pools and fluxes on the board (Figure 2). Expand the one box diagram into a two-box diagram.

FIGURE 1

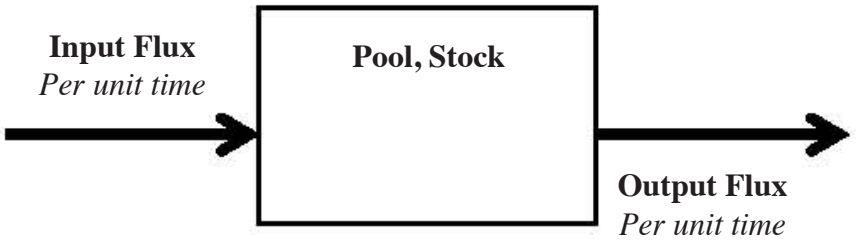
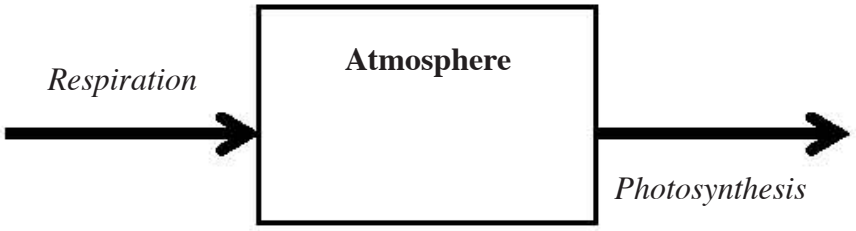


FIGURE 2



ELABORATE	**Grouping:** Small Groups/Class	**Time:** Varies

- Develop a classroom carbon cycle diagram based on each student's journey
- Tell students to form partners/small groups and create a multi-box and arrow diagram by combining their journeys through the carbon cycle.
- 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).
- Use the *Carbon Cycle Adventure Story Map of Flows* on page 7 to assist students if necessary.

EVALUATE	**Grouping:** Individual	**Time:** 15 Minutes

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

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? (Connection to *Getting to know the Global Carbon Cycle*.)

Assessment

- Completion of a *Journey Table*
- Group diagram of journey using the box and arrow method

Adaptations

- For younger or special education students, create a blank diagram on the board, which includes all the boxes and arrows. Have students suggest how to fill it in.
- For advanced students, begin to discuss pool size and flux (process) speed. Alter the class diagram to include larger boxes for larger pools and larger arrows for faster fluxes.
- To help build academic vocabulary for language learners consider creating a word wall for key terms.

Extensions

- Students develop their own carbon cycle game based on their reading from the *Carbon Cycle Adventure Story* (see *Carbon Travels Game* for ideas).

Resources

Systems:

- GLOBE Carbon Cycle – Paperclip Simulation (An introductory activity to systems)
- GLOBE Earth System Activities – https://www.globe.gov/do-globe/for-teachers/earth-system-science-posters
- The Creative Learning Exchange: http://www.clexchange.org/
- A Waters Foundation Project – Systems Thinking in Schools: http://www.watersfoundation.org/
- iSee Systems – Systems Thinking Software: http://iseesystems.com

Carbon Cycle:

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

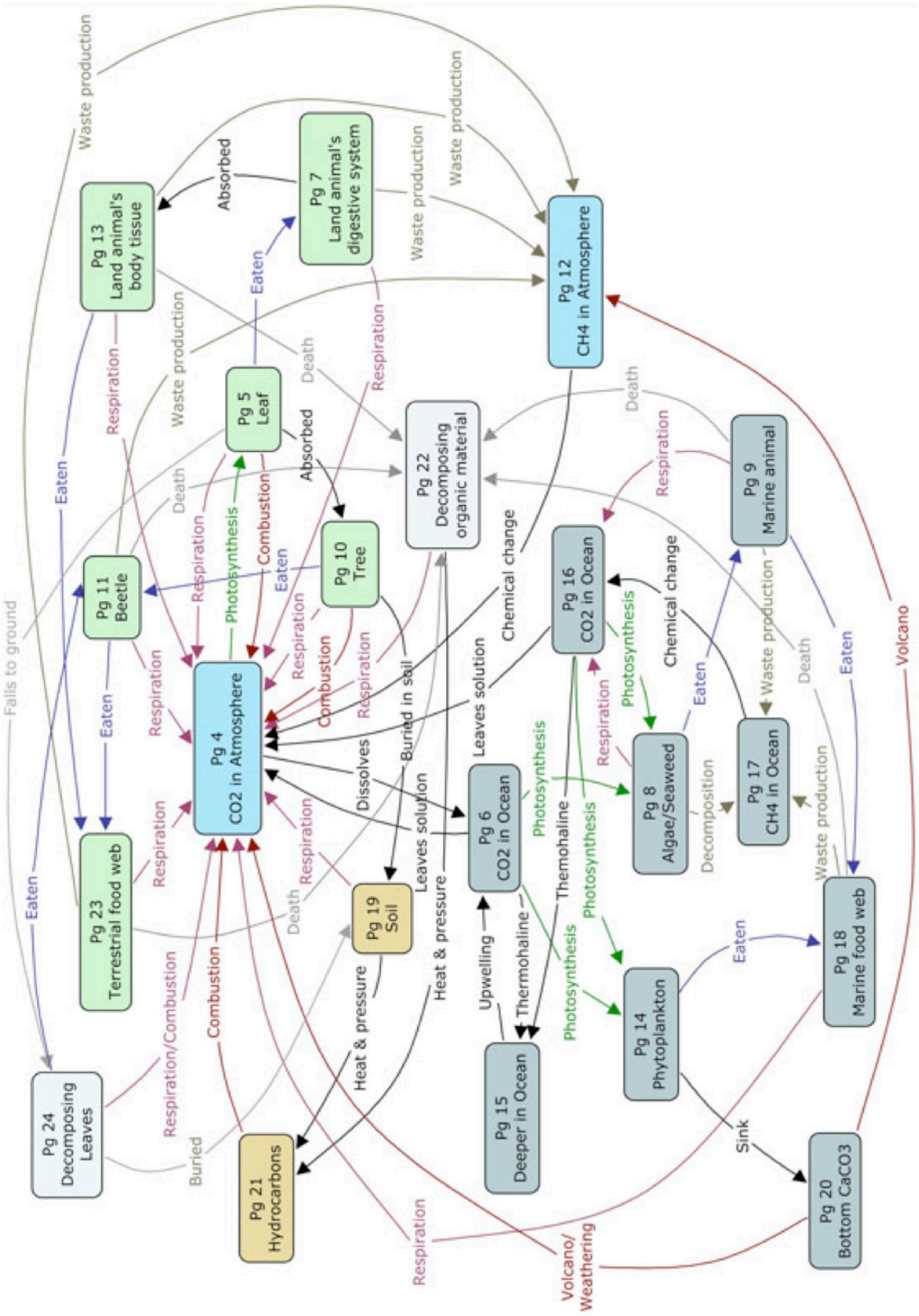
Name: Date:

Carbon Cycle Adventure Story - 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?
Example: Atmosphere	Photosynthesis	Plant Leaf
Plant Leaf		

Vocabulary and Questions:


Pg 4 CO2 in Atmosphere
Pg 5 Leaf
Pg 6 CO2 in Ocean
Pg 7 Land animal's digestive system
Pg 8 Algae/Seaweed
Pg 9 Marine animal
Pg 10 Tree
Pg 11 Beetle
Pg 12 CH4 in Atmosphere
Pg 13 Land animal's body tissue
Pg 14 Phytoplankton
Pg 15 Deeper in Ocean
Pg 16 CO2 in Ocean
Pg 17 CH4 in Ocean
Pg 18 Marine food web
Pg 19 Soil
Pg 20 Bottom CaCO3
Pg 21 Hydrocarbons
Pg 22 Decomposing organic material
Pg 23 Terrestrial food web
Pg 24 Decomposing Leaves
Waste production
Absorbed
Eaten
Respiration
Death
Photosynthesis
Combustion
Chemical change
Leaves solution
Buried in soil
Dissolves
Falls to ground
Respiration/Combustion
Heat & pressure
Upwelling
Thermohaline
Decomposition
Sink
Volcano
Volcano/ Weathering
Buried