Follow the Carbon Atom:
A self-guided adventure through the carbon cycle

Purpose
To provide students with an opportunity to explore a simple system by self-selecting steps through the carbon cycle.
To understand that carbon is one of the most important, and abundant, elements on Earth and can be found everywhere.
To understand that carbon is an important greenhouse gas; however, while carbon is important in trapping heat within the Earth's atmosphere, too much carbon in the atmosphere can be detrimental to the climate we depend on.

Overview
Students will work individually or in pairs in reading about carbon in various locations within the carbon cycle, and then select the next step in a carbon atom's journey. Students will keep track of their locations, the length of time at that location (if noted) and then the process that will take their carbon atom on to the next step. As a result of the activity, students will begin to understand the complexity of a system, the carbon cycle, and the importance of this element to life on Earth.

Essential Question
Where is carbon on Earth and how does it move between components of the Earth system?

Student Outcomes
Students will collect information on the carbon atom such as location within the cycle, length of time that the carbon atom will remain (when provided) and the processes that will take the carbon atom on to the next location within the carbon cycle
Students will compare their carbon atom's journey with those of their peers and then with the complete carbon cycle
Students will begin to understand the complexities of systems, such as the carbon cycle

Science Concepts
Modeling
Systems thinking
Connections between components of a system

Time
45 – 60 minutes (approximately one class period)

Level
Secondary (middle and high school in the U.S.)

Materials and Tools
Copies of the Carbon Atom adventure booklet, CD or access to the online version (in development)

Carbon atom journey table (Appendix A)
Overhead projector (if using transparency) & wet erase pen
Copy of complete carbon cycle map (Appendix B)
Copy of global carbon cycle diagram (appendix C)
Markers for white board or large paper (or chalk for black board)
Pencils or pens for each student or student pair
Computers if using CD version
Computers with Internet connection if using online version

Preparation

Gather all materials. Write essential question somewhere visible in the classroom. Draw the table from Appendix A on white or black board or large paper or print Appendix A onto transparency film. Print/copy Carbon Adventure booklets for each student or student pair; load CDs onto computers if using CD version (when available); point browsers on computers to online version (when available). Print/copy student table (Appendix A) for each student or student pair. Print/copy complete carbon cycle map (Appendix B) and global carbon cycle diagram (Appendix C) onto transparency film or draw onto white or black board or large sheet of paper or print enough copies for students to view in small groups.

Pre-requisites

None, however some basic understanding of atoms and elements would be helpful. The introduction pages of the booklet may suffice.

Background

Carbon, often called the building block of life, is the most abundant element in living things and makes up approximately 50% of the total dry weight of plants and animals. Carbon is exists in Earth's atmosphere, soils, oceans and crust and cycles between these components on differing scales of time and space. Scientists have studied carbon and other elements for hundreds of years, attempting to track location and processes of movement. Scientists use models in many fields of study. Models can be simple or very complex. In general, the purpose of models is to help improve the scientists' understanding of a system and the associated components of that system or multiple systems. Scientists can also use models to understand the interactions of the components of a system and to consider theoretical outcomes of particular real-world scenarios.

The basic part of any system includes reservoirs or pools and the processes that move components from pool to pool. Pools, also known as stocks, are places where an entity is stored. The process or movement of that entity from one stock to another is known as a flow, or flux. For example, in the global carbon cycle the plant pool or stock stores carbon in the form of glucose and other organic molecules within the plant. This carbon enters the plant pool through the process, or flow, of photosynthesis. The carbon flow or flux out of this plant pool is through plant respiration, which releases carbon dioxide back into the atmosphere pool. While in this example we have described the carbon cycle in two pools the complete carbon cycle includes many more pools and fluxes.

What To Do and How To Do It

Have students share the reading aloud of pages 1 through 3 of the Carbon Atom adventure booklet. Have students refer to the Glossary of Terms (on the last page) for any terms ***(bold and italic)*** they don't understand. Additional terms may need to be discussed and defined in class. Review tasks of the students or student pairs of recording the following information on the "*My journey with a carbon atom*" table (Appendix A): 1) the pools where carbon currently resides, 2) the length of time that the carbon atom will remain in this pool (if it's noted – some pools may not list the time due to the short term), and 3) the flow or process chosen within the booklet which will take the carbon atom to another pool. The adventure can be run as long or as short as time allows, providing that students/student groups have experienced at least 5 pools of their journey. The adventure could also be experienced over the course of several days; students could note where they have travelled and could begin where they finished.

After students have finished their journey or when the allotted time has expired, have students compare their journey with their neighbors in the classroom. Have students (as a class) construct their collective, or class, journey on the white or black board or large paper. They should have all begun on page 4, where the carbon atom is in the atmosphere as carbon dioxide. From that point there might be a diversion into the two possible flows (into a plant leaf or into the ocean), and so on. Have students draw boxes around the pools (atmosphere, plant leaf, ocean, etc) and arrows in between the pools denoting the flows they experienced. They should also note along the arrows the processes or flows (e.g. photosynthesis, dissolves, etc) that moved their carbon atom to the next pool. After all students have added their various pools and flows to the class carbon atom journey discuss the complexities of thie cycle or system. What was the most interesting pool or flow they experienced and why? Did students find themselves returning to one pool or another more often than others? Ask students to tell one thing they leaned about the carbon cycle from this activity. Show students the complete carbon cycle map (Appendix B), either on the board or on the overhead projector. Ask students to comment on any differences they notice between the cycle experienced collectively by their class and the complete cycle. Are there pools on the complete cycle that none of the students visited? Show students the global carbon cycle diagram (Appendix C), from the overhead projector, computer screen or other recreation. The progression from their journey to the carbon cycle map to the global carbon cycle diagram should help them to see that carbon can be found everywhere in various forms. Ask students what they learned about the importance of carbon to life on Earth. How important is carbon to maintaining our climate? What happens if too much carbon ends up in the atmosphere? Why?

This activity can provide a basic understanding of the carbon cycle and systems thinking as well as a good introductory activity to studying the Greenhouse Effect and climate change. Complementary activities may be the Paperclip Factory simulation and Plant-a-Plant classroom experiments.

A modification to this activity could include constructing a system in the classroom or in the schoolyard using yarn of different colors. Each student is given a different color of yarn. They all begin at station 1 (carbon dioxide in the atmosphere – page 4 of the booklet), with one end of their yarn tied to a stationary object (chair leg, post, etc). Students (perhaps in pairs) would read the description for station 1 (page 4); then each student or student pair would roll a die to determine their selection (rather than the students making their own selection). For pages with only 2 selections, even and odd numbers could be used to determine the flow to another pool; for pages with more than 2 selections, the actual number displayed on the die would determine the flow to another pool. Using this scenario, the journey would be much more random. As students move to their next pool they would let out their yarn on the ground walking to their next pool and looping it around a chair leg or other stationary object. The students or student pairs would then read the station for the pool determined by the previous roll of the die. They would then roll the die again to determine their next flow, laying the yarn on the ground as they move. At the end of the activity a physical representation would have been created on the ground. The different colored yarns would allow each student or student pair to follow their journey within the larger cycle. This modification would require a much larger area that a standard classroom (perhaps outside), 24 chairs or other stationary objects to loop yarn around as well as signs to identify the chairs as the various pools within the carbon cycle activity, balls of yarn of different colors equal to the number of students or pairs of students. A comparison between the journeys of each student or student pair as well as the complete carbon cycle diagram would be helpful for understanding of systems and the carbon cycle. While collection of pools, time in pools and flows between pools could be done after the activity, it may be easier to have students working in pairs collect this information as they roll the die.

Further Investigations

The following Web sites (arranged by grade level) offer additional carbon-related activities to continue building an understanding of the carbon cycle:

Teacher's Domain (All Grades)
www.teachersdomain.org
Includes: Multimedia from NOVA and other public television series; includes Background information, discussion questions, related standards global warming/climate change specific lesson plans included

National Public Radio's "It's All About Carbon" (All Grades)
www.npr.org/news/specials/climate/video/
Includes: A cartoon series developed as part of Climate Connections (produced by NPR and Public Broadcasting System), Episodes 1 through 5 currently available

USDA Forest Service's Natural Inquirer (Grades 6-8)
www.naturalinquirer.usda.gov
Specifically:

- Volume 5, Number 1 Facts to the Future Edition
  - includes: Where in the World is Carbon Dioxide?: The potential impact of rising levels of CO_2 on US forests

Volume 6, Number 1 Urban Forest Edition
includes: I've got you covered: The amount of pavement covered by street trees, Balancing act: Urban trees and the carbon cycle, Good to the last drip: How urban trees help to reduce pollution Don't be so fuel-ish!: How much fuel is saved when cars are parked in the shade?

"Carbo" the Carbon Atom (Grades 7-10)
www.letus.northwestern.edu/projects/gw/cycles/carbo/index.html
Includes: Follow a carbon atom through the environment

National Public Radio's Climate Connections (Grades 7-12)
www.npr.org/templates/story/story.php?storyId=9657621
Includes: A joint series between NPR and National Geographic: focused on climate change around the world, Background information

National Geographic Article (Grades 7-12)
Exerpt: http://magma.nationalgeographic.com/ngm/0402/feature5/index.html
Full: http://magma.nationalgeographic.com/ngm/0402/feature5/online_extra.html
Includes: CO_2 in the atmosphere-anthropogenic causes, Photosynthesis and respiration Eddy flux towers, Field measurements to validate tower measurements, Missing carbon-tree growth in the Eastern US, fire suppression in Western US, additional growth in Europe, Siberia, warming contributes to increased growth in the arctic, How long can forest CO_2 uptake last? Permafrost CO_2 release, FACE studies mentioned, Carbon dissolves in ocean waters, Geologic sequestration in the North Sea

NASA Earth Observatory (Grades 9-12)
http://earthobservatory.nasa.gov/Library/CarbonCycle
Includes: Carbon Cycle Intro, Photosynthesis and respiration, Carbon in land and sea-Chlorophyll movie, The Human Role, NASA missions to study CO_2 and climate

NOAA Earth System Research Laboratory (Grades 9-12)
www.cmdl.noaa.gov/ccgg/iadv
Includes: Atmospheric CO_2, CH_4 and other atmospheric gas concentration displayed in time series, seasonal patterns and at locations around the world

US Carbon Cycle Science Program (Grades 9-12)
www.carboncyclescience.gov
Includes: Background, Scientific research

Trees-carbon (Grades 10-12)
http://esa21.kennesaw.edu/activities/trees-carbon/trees-carbon.pdf
Includes: Specific, well laid out instructions for calculating CO2 storage by trees; Requires some knowledge of chemistry (element mass, unit conversion), and math (log10, means)

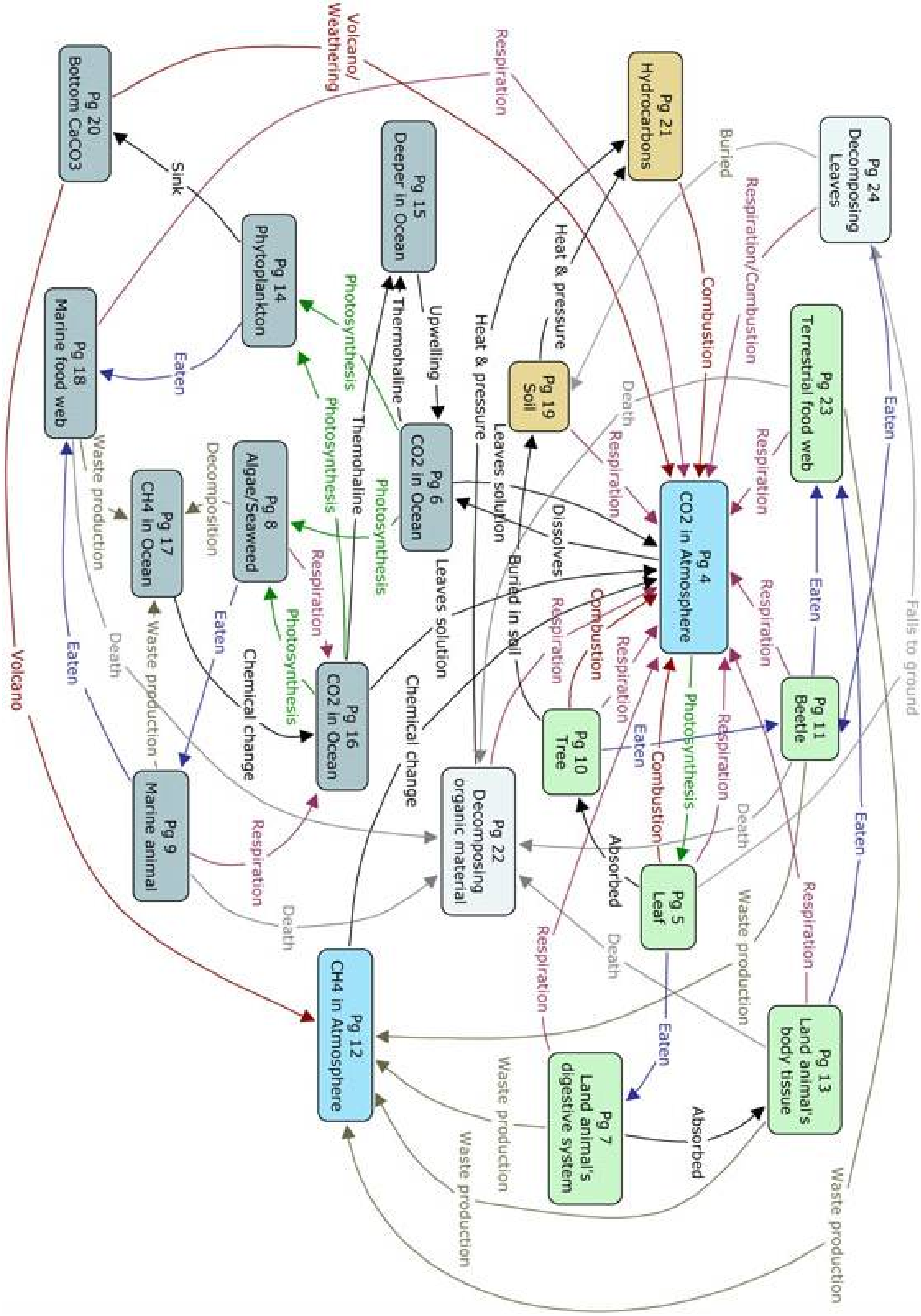
APPENDIX A – Carbon atom journey table

My journey with a carbon atom

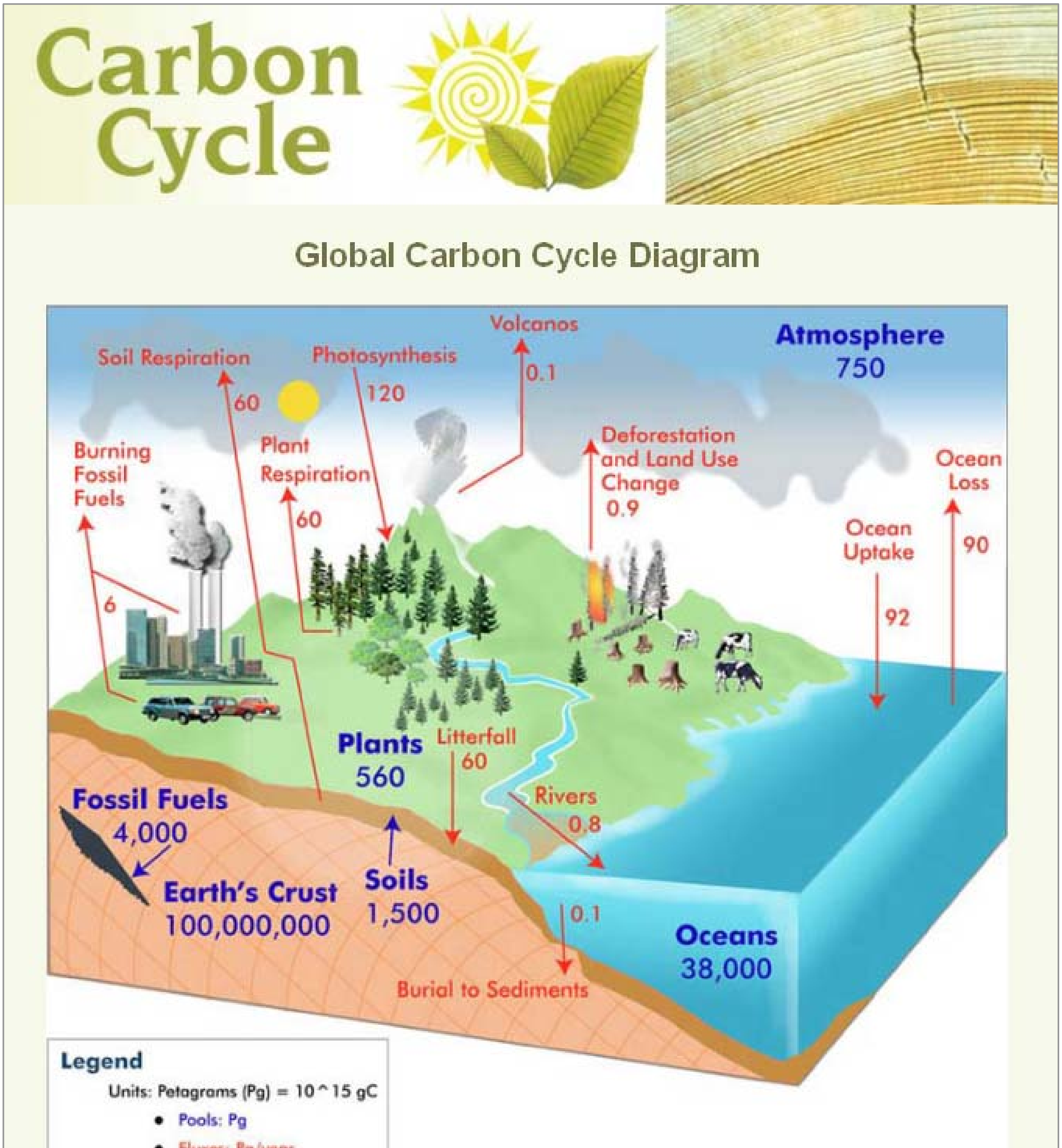
As you travel through your journey, following the carbon atom, record the reservoir, or pool, carbon is in, how long it might remain in the pool (use hints in the text if available or guess), and how did carbon leave the pool to move to the next one. Part of the first line (from page 4) has been filled out as an example.

Reservoir/Pool	Time within Pool (Estimate)	How did I leave the Pool?
Atmosphere	*Approx. 100 years*	

APPENDIX B – Carbon cycle map of possible flows



APPENDIX C – Global carbon cycle diagram



Source: www.globe.gov/projects/carbon