Carbon Journey

Focus Questions:

Where is carbon stored, and how is it moved and re-distributed around the Earth system via the Carbon Cycle?

Preview

All living things are made of simple chemical elements including oxygen, carbon, hydrogen, nitrogen, calcium and phosphorus. These elements combine to form the complex molecules that make up the structures of living things. Because carbon is good at bonding with many elements, it is the primary building block of many life forms. Carbon makes up about 19% of the mass of a typical animal, and about 12% of the mass of a typical plant. Carbon is not only found in living things; it is also present in non-living things including rocks, soils, oceans, and the atmosphere.

These locations where carbon is stored are called "reservoirs." Because the Earth system is dynamic, the carbon atoms are constantly being exchanged from one reservoir to another in what is known as the carbon cycle. The rate of exchange of a substance from one reservoir to another is known as a flux. (E.g., the process of photosynthesis is responsible for the fast flux of CO_2 from the atmosphere to plants.) The exchange, or flux, of carbon atoms takes place on a variety of time scales from seconds to millennia. The most rapidly occurring exchanges take place between living plants and the atmosphere; the slowest are between carbon stored in rocks and the other reservoirs. There are many types of processes that move carbon from one reservoir to another. These processes include photosynthesis, plant and soil organisms' respiration, combustion, decomposition, and deforestation. Geological processes, include weathering, erosion, and sedimentation.

Theoretically, when the carbon cycle is in equilibrium, the exchanges in and out of each reservoir are in balance so that the carbon in any one reservoir stays the same over time. However, over the past 150 years the rate at which carbon is being released into the atmosphere has exceeded the rate at which it is being transferred to other locations in the carbon cycle's reservoirs for storage. This escalating release of CO_2 (carbon dioxide) to the atmosphere is due to increasing rates of deforestation as well as the burning of fossil fuels from the growing demand for energy. The amount of carbon in the atmosphere plays an important role in maintaining an ideal temperature balance on Earth. Too much carbon, in the form of CO_2 (carbon dioxide) or CH_4 (methane) in the atmosphere absorbs excess heat which, in turn, warms the planet; too little CO_2 or CH_4 and the Earth cools.

Time

1 class period to prepare activity; 1 class period to play game and discuss results.

Materials

- Beads to collect at each of the reservoirs in the journey (having a separate color for each bucket is recommended)
- Bracelet string to hold beads in order
- Buckets to represent reservoirs: Oceans, Plants, Soils, Atmosphere, Animals, Fossil Fuels, Rock, etc., labeled with photographs or pictures of carbon storage types
- Graphic of the carbon cycle
- Cardboard cubes with processes
- Labels and pictures for carbon reservoirs
- Scissors to cut out labels and string
- Glue sticks or tape to affix labels to buckets and cubes
- Carbon journey station labels

Vocabulary (Terms)

Absorption
Assimilation
Combustion
Consumption
Decomposition
Dissolve
Erosion
Flux
Outgas
Photosynthesis
Reservoir/ Pool
Respiration
Sink
Sources
Weathering

Activity 1C-Carbon Journey

Prepare

Activity Steps:

Make Game Pieces

1. Begin with discussion of reservoirs of CO_2 and how carbon (C) moves from one reservoir to another via various processes which occur at a variety of rates from very slow (geologic) to very fast (seconds).

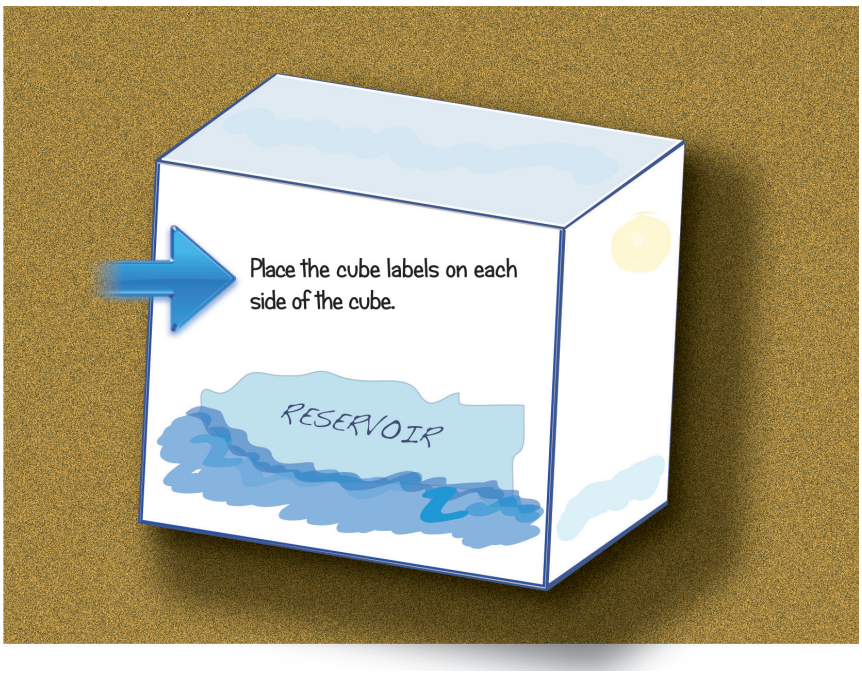
2. Label your reservoir containers (bowls, boxes, small buckets, or bags) with the names of the reservoirs they represent. Place a colored flag in each reservoir (or place a sign on the wall) to make the reservoirs easier to see.

3. Put colored beads into each reservoir's container to represent that reservoir. (using a different color of bead for each reservoir.)

4. Make CO_2 cups or bracelets to travel around the room with the participants as they are journeying through the carbon cycle.

5. Make process cubes or dice–1 for each station with "stay" or "process name" on the sides.
The "Reservoir Cube Labels" will fit 3" to 4" boxes, or use the template provided to create your own boxes.
Draw your own illustrations to represent each reservoir. Place the cubes next to their matching reservoir bucket.
(See drawing of sample cube below.)

6. Give each student a copy of the "Carbon Journey Passport." They will record where they traveled by writing the name of the reservoir visited and the process that sent them there.



Reservoir Cube Labels

Reservoir: Marine Mammals

Process Name	Number of Sides	Go to: Reservoir
Respiration	1	Ocean Water
Consumption	2	Ocean Animals or Marine Mammals
Sedimentation	2	Carbon Containing Rock (Limestone)
Excretion / Death Decomposition	1	Marine Sediments

Reservoir: Fossil Fuels

Process Name	Number of Sides	Go to: Reservoir
Combustion	3	Atmosphere
Burial and Rock Formation	1	Carbon Containing Rock
Stay in Reservoir	2	Remain in Fossil Fuels

Reservoir: Ocean Water

Process Name	Number of Sides	Go to: Reservoir
Dissolving	1	Ocean Animals (Carbonate Shells)
Outgassing / Exchange	1	Atmosphere
Absorption	2	Ocean Animals or Marine Mammals
Photosynthesis	1	Ocean Plants
Stay in Reservoir	1	Remain in Ocean Water (Move to Deeper Water)

Reservoir Cube Labels

Reservoir: Marine Sediments

Process Name	Number of Sides	Go to: Reservoir
Erosion / Weathering	1	Ocean Water
Dissolving	2	Ocean Water
Burial Sedimentation	2	Carbon Containing Rock
Underwater Volcanoes	1	Ocean Water

Reservoir: Land Animals

Process Name	Number of Sides	Go to: Reservoir
Burial and Decomposition /Sedimentation	1	Fossil Fuels
Consumption	2	Stay in Land Animals
Respiration	2	Atmosphere
Excretion / Death / Decomposition	1	Soil

Reservoir: Fresh Water

Process Name	Number of Sides	Go to: Reservoir
Dissolving	1	Fresh Water
Outgassing / Exchange	2	Atmosphere
Respiration	1	Fresh Water Animals
Photosynthesis	2	Fresh Water Plants

Reservoir Cube Labels

Reservoir: Soil

Process Name	Number of Sides	Go to: Reservoir
Respiration (Microbes)	2	Atmosphere
Weathering / Erosion	2	Ocean Water or Fresh Water
Assimilation	2	Land Plants

Reservoir: Carbon Containing Rock

Process Name	Number of Sides	Go to: Reservoir
Weathering / Erosion	3	Fresh Water or Ocean Water or Soil
Sedimentation	1	Other Rock (Stay in Carbon Containing Rock)
Stay	2	Remain in Carbon Containing Rock

Reservoir: Ocean Plants

Process Name	Number of Sides	Go to: Reservoir
Consumption	2	Marine Mammals or Ocean Animals
Death and Decomposition	2	Ocean Animals (Small Animal Tissues)
Burial Decomposition	1	Marine Sediments
Stay	1	Remain in Ocean Plants

Reservoir Cube Labels

Reservoir: Land Plants

Process Name	Number of Sides	Go to: Reservoir
Consumption	2	Land Animals (Tissue and Bones)
Death Decomposition	1	Soil (or Small Land Animals)
Burial	1	Fossil Fuels
Deforestation / Combustion	1	Atmosphere
Stay	1	Remain in Land Plants

Reservoir: Atmosphere

Process Name	Number of Sides	Go to: Reservoir
Photosynthesis	2	Land Plants
Respiration	2	Land Animals or Fresh Water Animals or Marine Mammals or Ocean Animals
Dissolving	1	Ocean Water
Stay	1	Remain in Atmosphere

Reservoir: Ocean Animals

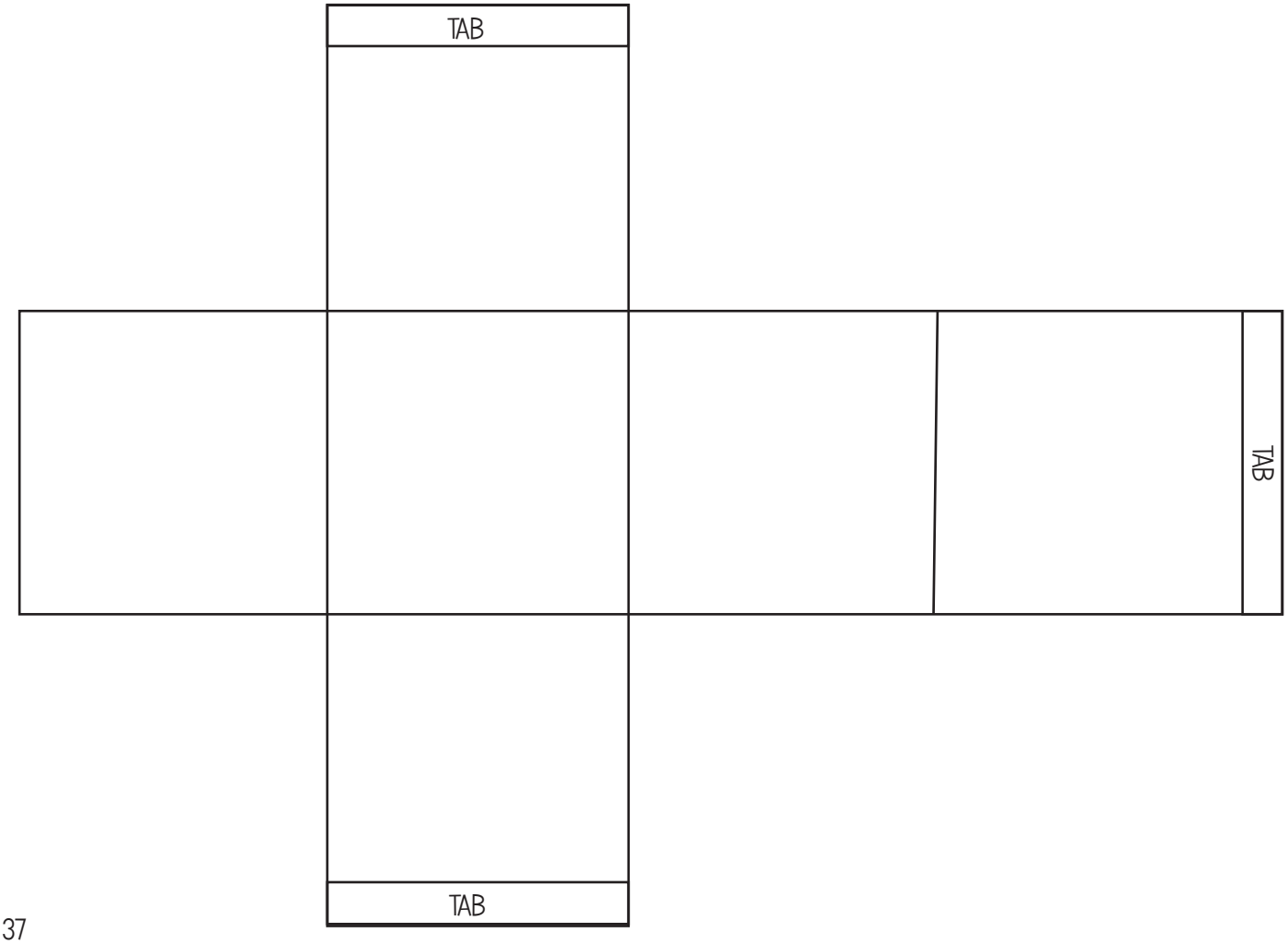
Process Name	Number of Sides	Go to: Reservoir
Death and Decomposition	2	Carbon Containing Rocks (Carbonate Limestone)
Dissolving	1	Ocean Water
Consumption	1	Marine Mammals or Ocean Animals
Absorption	1	Skeletons of Ocean Animals
Death and Decomposition	1	Marine Sediments

Reservoir Cube Labels

Reservoir: Freshwater Animals

Process Name	Number of Sides	Go to: Reservoir
Death and Decomposition	2	Carbon Containing Rocks (Carbonate Limestone)
Dissolving	1	Fresh Water
Consumption	2	Land and Water Animals
Respiration	1	Atmosphere

Directions: Either enlarge the template below to a full page, or re-draw it to fit on a full page. Copy 13 of the templates on cardstock. Cut them out and fold on the lines. Tuck the tabs under the sides to form a cube. Hint: If you plan to re-use these each year, glue the tabs and cover them in clear contact paper and store in a box. OR—don't glue the tabs so that you can flatten the boxes for easy storage after playing the Carbon Journey game.



Name: _____

Carbon Journey Passport

Journey Number	Reservoir Choose where your journey will begin as a carbon atom. Write that station here next to #1:	Process Roll the cube. Write the process here. Then move to the reservoir indicated on the cube.
1		
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Set up and Play Game

1. Secure a large space to play, such as a cafeteria, gymnasium, or outdoor space.

2. Place reservoir containers with flags or wall signs and process cubes at each station.

(Optional: Put colored beads in each reservoir container to represent each stop in a reservoir. Each participant will need a cord on which to string each bead or a cup to hold them in.)

(Alternative: A sticker or ticket with a hole punch could be used in place of the beads, or a paper chain can be built as participants travel between reservoirs.)

3. Gather participants and explain rules of the game (see items 6-8 below for rules).

4. Distribute participants to stations to begin their journey.

5. When they arrive at each reservoir, the participants will pick up a bead and string it on their bracelet to record their stop in the journey. They also record the reservoir name on the "Carbon Journey Passport."

6. Roll the process cube and read the label on top to determine the process by which they are released from the reservoir. Record the process on their "Carbon Journey Passport." Move to the reservoir named by the roll of the cube.

7. Some labels say "stay" to demonstrate a long residence time at a reservoir. When "stay" is rolled, participants repeat their turn at that station by going to the back of the line and waiting for another turn. They should record a second, third, etc. turn on their journal and add another bead to their bracelet.

8. Play the game for a given length of time, such as 5 -10 minutes, or for a certain number of journey turns.

Clean Up and Discuss

Collect and put away game pieces and other materials.

Diagram your journey on large piece of paper or shared class diagram, such as a white board. (See sample at the end of this lesson.) You can simplify the drawing by using squares to represent the reservoirs. Draw black arrows mapping your travels. Label the processes by which you traveled with the words from the cubes. Circle those words with dashed ovals.

Discuss the "stays" or extra turns at a reservoir. Does it make sense that a carbon atom would spend more time in some reservoirs than others?

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Marine Mammals **Respiration** **Go to:** **Ocean Water**	**Marine Mammals** **Consumption** **Go to:** **Marine Mammals or Ocean Animal**
Marine Mammals **Consumption** **Go to:** **Marine Mammals or Ocean Animal**	**Marine Mammals** **Sedimentation** **Go to:** **Carbon Containing Rock (Limestone)**
Marine Mammals **Excretion/Death Decomposition** **Go to:** **Marine Sediments**	**Marine Mammals** **Sedimentation** **Go to:** **Carbon Containing Rock (Limestone)**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Fossil Fuels **Combustion** **<u>Go to</u>:** **Atmosphere**	**Fossil Fuels** **Combustion** **<u>Go to</u>:** **Atmosphere**
Fossil Fuels **Combustion** **<u>Go to</u>:** **Atmosphere**	**Fossil Fuels** **Burial and Rock Formation** **<u>Go to</u>:** **Carbon Containing Rocks**
Fossil Fuels **Stay in Reservoir** **<u>Go to</u>:** **Remain in Fossil Fuels**	**Fossil Fuels** **Stay in Reservoir** **<u>Go to</u>:** **Remain in Fossil Fuels**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Marine Sediments **Erosion/Weathering** **Go to:** **Ocean Water**	**Marine Sediments** **Dissolving** **Go to:** **Ocean Water**
Marine Sediments **Dissolving** **Go to:** **Ocean Water**	**Marine Sediments** **Burial Sedimentation** **Go to:** **Carbon Containing Rock**
Marine Sediments **Burial Sedimentation** **Go to:** **Carbon Containing Rock**	**Marine Sediments** **Underwater Volcanoes** **Go to:** **Ocean Water**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Ocean Water **Dissolving** **Go to:** **Ocean Animals (Carbonate Shells)**	**Ocean Water** **Outgassing/ Exchange** **Go to:** **Atmosphere**
Ocean Water **Absorption** **Go to:** **Ocean Animals or Marine Mammals**	**Ocean Water** **Absorption** **Go to:** **Ocean Animals or Marine Mammals**
Ocean Water **Photosynthesis** **Go to:** **Ocean Plants**	**Ocean Water** **Stay in Reservoir** **Go to:** **Remain in Ocean Water (move to deeper water)**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Land Animals **Burial** **Decomposition/ Sedimentation** **<u>Go to:</u>** **Fossil Fuels**	**Land Animals** **Excretion/ Death/ Decomposition** **<u>Go to:</u>** **Soil**
Land Animals **Consumption** **<u>Go to</u>:** **Remain in Land Animals**	**Land Animals** **Consumption** **<u>Go to</u>:** **Remain in Land Animals**
Land Animals **Respiration** **<u>Go to</u>:** **Atmosphere**	**Land Animals** **Respiration** **<u>Go to</u>:** **Atmosphere**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Fresh Water **Dissolving** **Go to:** **Fresh Water**	**Fresh Water** **Outgassing/ Exchange** **Go to:** **Atmosphere**
Fresh Water **Outgassing/ Exchange** **Go to:** **Atmosphere**	**Fresh Water** **Respiration** **Go to:** **Fresh Water Animals**
Fresh Water **Respiration** **Go to:** **Fresh Water Animals**	**Fresh Water** **Respiration** **Go to:** **Fresh Water Animals**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Soil Respiration (Microbes) **Go to:** **Atmosphere**	**Soil Respiration (Microbes)** **Go to:** **Atmosphere**
Soil Weathering/Erosion **Go to:** **Ocean or Fresh Water**	**Soil Weathering/Erosion** **Go to:** **Ocean or Fresh Water**
Soil Assimilation **Go to:** **Land Plants**	**Soil Assimilation** **Go to:** **Land Plants**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Carbon Containing Rock **Weathering/Erosion** **Go to:** **Fresh Water or Soil or Ocean Water**	**Carbon Containing Rock** **Weathering/Erosion** **Go to:** **Fresh Water or Soil or Ocean Water**
Carbon Containing Rock **Sedimentation** **Go to:** **Other Rock (Stay in Carbon Containing Rock)**	**Carbon Containing Rock** **Weathering/Erosion** **Go to:** **Fresh Water or Soil or Ocean Water**
Carbon Containing Rock **Stay** **Go to:** **Remain in Carbon Containing Rock**	**Carbon Containing Rock** **Stay** **Go to:** **Remain in Carbon Containing Rock**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Ocean Plants **Consumption** **Go to:** **Marine Mammals or Ocean Animals**	**Ocean Plants** **Consumption** **Go to:** **Marine Mammals or Ocean Animals**
Ocean Plants **Stay** **Go to:** **Remain in Ocean Plants**	**Ocean Plants** **Death and Decomposition** **Go to:** **Ocean Animals (Small Animal Tissues)**
Ocean Plants **Death and Decomposition** **Go to:** **Ocean Animals (Small Animal Tissues)**	**Ocean Plants** **Burial Decomposition** **Go to:** **Marine Sediments**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Land Plants **Consumption** **<u>Go to</u>:** **Land Animals (Tissues and Bones)**	**Land Plants** **Consumption** **<u>Go to</u>:** **Land Animals (Tissues and Bones)**
Land Plants **Death and Decomposition** **<u>Go to</u>:** **Soil or Land Animals**	**Land Plants** **Burial** **<u>Go to</u>:** **Fossil Fuels**
Land Plants **Stay** **<u>Go to</u>:** **Remain in Land Plants**	**Land Plants** **Deforestation/ Combustion** **<u>Go to</u>:** **Atmosphere**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of cubes.

Atmosphere **Photosynthesis** **Go to:** **Land Plants**	**Atmosphere** **Photosynthesis** **Go to:** **Land Plants**
Atmosphere **Respiration** **Go to:** **Land Animals or Freshwater Animals**	**Atmosphere** **Respiration** **Go to:** **Ocean Animals or Marine Mammals**
Atmosphere **Dissolving** **Go to:** **Ocean Water**	**Atmosphere** **Stay** **Go to:** **Remain in Atmosphere**

Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Ocean Animals **Death and Decomposition** **Go to:** **Carbon Containing Rocks (Carbonate Limestone)**	Ocean Animals **Death and Decomposition** **Go to:** **Carbon Containing Rocks (Carbonate Limestone)**
Ocean Animals **Dissolving** **Go to:** **Ocean Water**	Ocean Animals **Consumption** **Go to:** **Marine Mammals or Ocean Animals**
Ocean Animals **Consumption** **Go to:** **Marine Mammals or Ocean Animals**	Ocean Animals **Absorption** **Go to:** **Ocean Animals (Skeletons)**

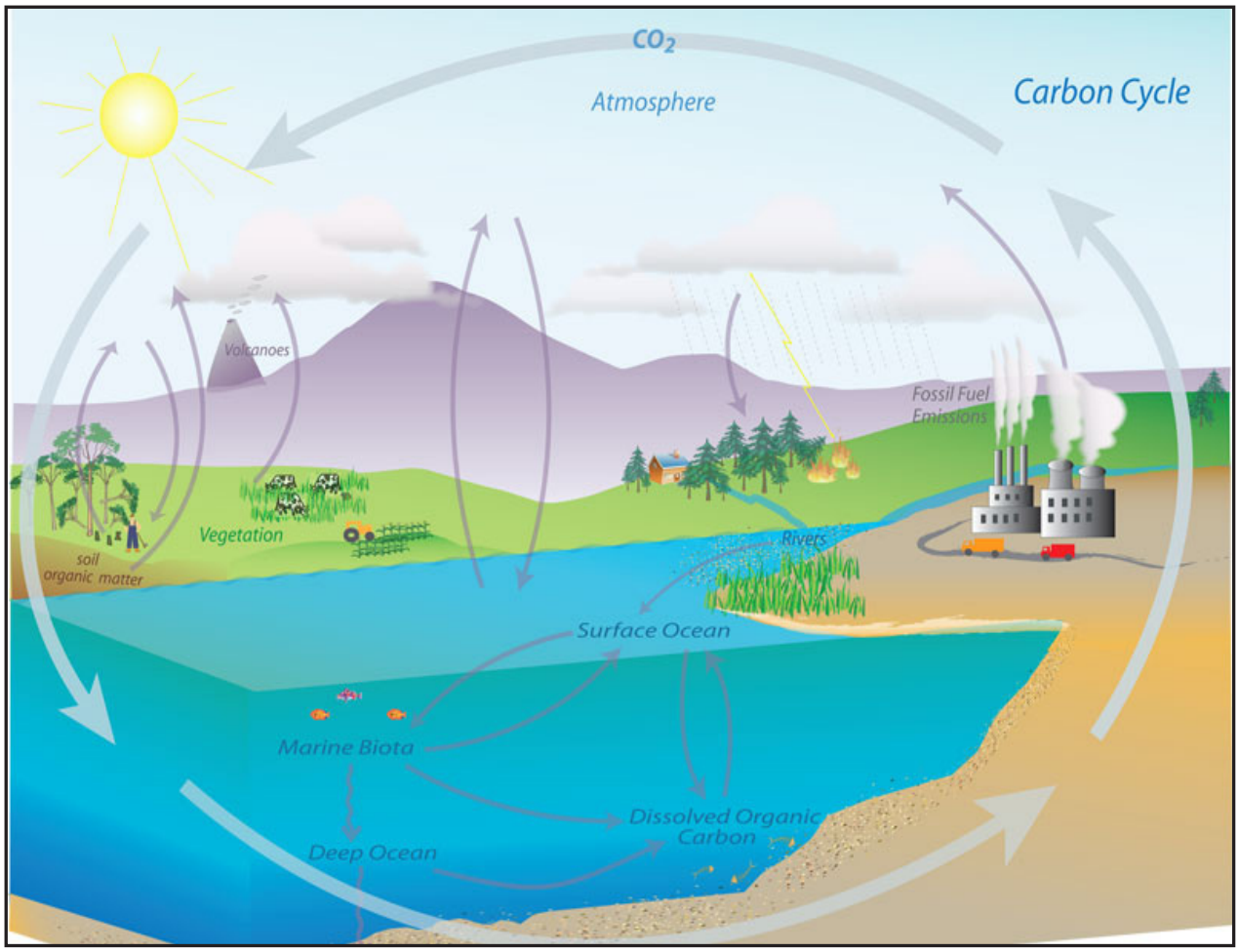
Cube Labels  Cut labels on the solid lines and then attach them to the sides of your cubes.

Freshwater Animals **Death and Decomposition** **Go to:** **Carbon Containing Rocks (Carbonate Limestone)**		**Freshwater Animals** **Death and Decomposition** **Go to:** **Carbon Containing Rocks (Carbonate Limestone)**
Freshwater Animals **Dissolving** **Go to:** **Freshwater**		**Freshwater Animals** **Consumption** **Go to:** **Land Animals or Freshwater Animals**
Freshwater Animals **Consumption** **Go to:** **Land Animals or Freshwater Animals**		**Freshwater Animals** **Respiration** **Go to:** **Atmosphere**

Practice

Got the Big Idea?

Carbon in its many forms is essential to all life on Earth. Carbon atoms are stored in both living and non-living materials. There are four basic reservoirs of carbon-the Earth's solid crust, the oceans, the atmosphere and the biosphere. Carbon atoms cycle from reservoir to reservoir by various processes measured as a flux. These processes include, photosynthesis, respiration, ocean-atmosphere exchange, fossil fuel combustion, and deforestation. Geological processes such as weathering, erosion and sedimentation also transfer carbon atoms on their "journey" through the carbon cycle.



The diagram above shows some of the carbon cycle's land and ocean reservoirs and routes of exchange. See if you can identify the processes that move carbon between the pictured reservoirs.
Source: NOAA (Featured in ESRL's Carbon Cycle Toolkit)

Ponder

The Carbon Cycle Diagram on the previous page shows an artist's interpretation of the carbon cycle. Diagram your own journey from reservoir to reservoir on a large piece of paper. Use arrows to show how you moved through the cycle.

How long did you "reside" in certain reservoirs?

Which locations did you visit multiple times?

Which did you not visit?

Compare your journey to the others in your class and to the diagram on the previous page

How were they similar?

How were they different?

Present

1. Review your game set up. Diagram where to put the reservoirs in your event space. Place all materials in their correct locations according to your diagram.

2. Explain to your players the meaning of the following terms: reservoir, process and flux.

3. Before starting the game, remind players to move about safely by walking from one station to the next.

4. Make sure your players understand that sometimes they may spend more than one turn at a reservoir.

5. When the game is over, have your players explain their journey using the vocabulary terms listed on the first page of this activity.

Background Information for the Teacher

Activity	NSES 5-8	CLEP	CLEP
Carbon Journey In this active lesson, learners take the role of a carbon atom as it moves through the reservoirs and sinks, fluxes and sources that drive the global carbon cycle. Learners create a bead chain based on their trip through the cycle.	**Physical Sci Standard B:** Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. **Earth Sci Standard D:** The earth processes we see today, including erosion, movement of lithospheric plates, and changes in atmospheric composition, are similar to those that occurred in the past. earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet.	**2D:** The abundance of greenhouse gases in the atmosphere is controlled by biogeochemical cycles that continually move these components between their ocean, land, life, and atmosphere reservoirs. The abundance of carbon in the atmosphere is reduced through seafloor accumulation of marine sediments and accumulation of plant biomass and is increased through deforestation and the burning of fossil fuels as well as through other processes. **3B:** The presence of small amounts of heat-trapping greenhouse gases in the atmosphere warms Earth's surface, resulting in a planet that sustains liquid water and life.	**3E:** Life—including microbes, plants, and animals and humans—is a major driver of the global carbon cycle and can influence global climate by modifying the chemical makeup of the atmosphere. The geologic record shows that life has significantly altered the atmosphere during Earth's history. **4G:** Natural processes that remove carbon dioxide from the atmosphere operate slowly when compared to the processes that are now adding it to the atmosphere. Thus, carbon dioxide introduced into the atmosphere today may remain there for a century or more. Other greenhouse gases, including some created by humans, may remain in the atmosphere for thousands of years.

Background Information for the Teacher

CLEP	CLEP	ELF	ELF
6B: Emissions from the widespread burning of fossil fuels since the start of the Industrial Revolution have increased the concentration of greenhouse gases in the atmosphere. Because these gases can remain in the atmosphere for hundreds of years before being removed by natural processes, their warming influence is projected to persist into the next century.	**6C**: Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns. Burning fossil fuels, releasing chemicals into the atmosphere, reducing the amount of forest cover, and rapid expansion of farming, development, and industrial activities are releasing carbon dioxide into the atmosphere and changing the balance of the climate system.	**Energy 3**: The flow of energy drives biogeochemical cycles, which play a key role within and between Earth's systems. **Energy 3a**: The carbon cycle describes the movement of carbon between reservoirs in the atmosphere, ocean, lithosphere, and biosphere. When more carbon is stored in the atmosphere as carbon dioxide or methane, the greenhouse effect is amplified.	**Atmosphere**: Atmospheric circulations transport matter and energy. **Atmosphere 2b**: Unequal heating of the Earth's surface produces movement in the atmosphere.

Background Information

Carbon (C) is the 12th element on the Periodic Table and is most familiar to us as graphite in pencils. Another form of pure carbon, in a different structure, is diamond. Both are made up of atoms of carbon. All of the carbon on Earth today was present when Earth was formed, some 4.5 billion years ago.

Carbon is the 4th most abundant element in the universe after hydrogen (H), helium (He), and oxygen (O). Because of its unique bonding ability, it is considered to be the building block of life and is found in all organic compounds, including fossil fuels, plastics, nylon, plant and animal bodies, and even in DNA.

All of Earth's materials cycle through the spheres in the Earth system. The cycle most familiar to students is the water cycle. Carbon follows a similar cycle, although it is generally a much slower process.

The rate of the processes that transfer carbon from one reservoir to another are called fluxes. The reservoirs where carbon is stored are called sinks when they hold more carbon than they release. The reservoirs are called sources when they release carbon.

Two major carbon cycles can be identified. The geologic carbon cycle, or slow carbon cycle, moves carbon-containing compounds through the rocks, ocean, and atmosphere over millions of years. Through geologic time, the amount of carbon in the atmosphere has changed dramatically based on how much was stored or released from rocks and oceans. The natural processes involved in moving the carbon between the lithosphere and atmosphere are weathering, subduction, and volcanism.

A second carbon cycle, much faster than the first, is the biological/physical carbon cycle. It moves carbon compounds through the atmosphere, oceans, plants, and animals over periods of days to thousands of years. Some of the processes involved in this cycle are photosynthesis, respiration, combustion, and calcification (formation of shells).

The ocean is a huge reservoir (or sink) for carbon dioxide (CO_2) and other carbon containing compounds. The temperature of the ocean, the currents, and the amount of photosynthetic organisms living there largely control the rate of exchange between the atmosphere and the ocean. For example, cold ocean temperatures increase the amount of uptake of CO_2 from the atmosphere by the ocean, while warmer ocean temperatures cause the ocean to release carbon dioxide. Additionally, the presence of nutrients in the ocean allows for larger populations of photosynthesizing microorganisms which, in turn, consume huge amounts of CO_2 from the ocean water. Eventually, some of these living organisms die and settle to the ocean bottom. Over long geologic time scales, this process represents a significant amount of carbon storage.

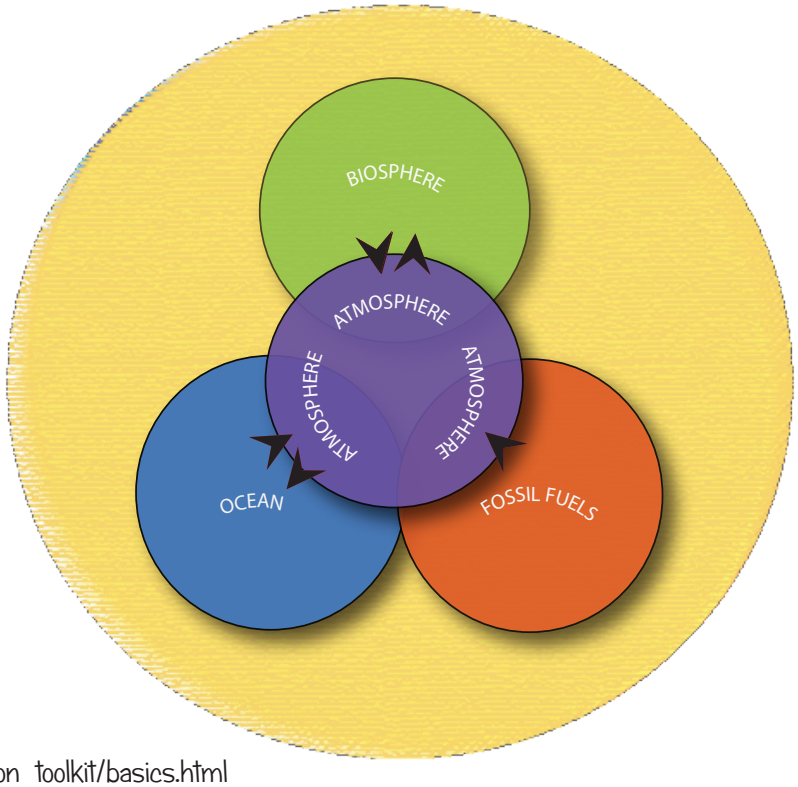
In the past, the natural processes of carbon exchange through the Earth's system have been in balance. Now, anthropogenic (human) activities are releasing more CO_2 into the atmosphere than has been previously recorded over the last half million years. Most of the increase in CO_2 is due to the combustion of fossil fuels. Forest fires and the reduction in forest cover due to land use changes are also causing an increase in the amount of atmospheric carbon dioxide.

Scientists use NOAA and NASA instruments, located in satellites and on Earth's surface, to measure the movement of carbon between the sources and sinks. Carbon dioxide released from volcanoes, combustion, and warming oceans, as well as carbon absorbed through phytoplankton blooms and land vegetation growth, are tracked in an effort to understand and map the complex carbon cycles.

Additional Resources:

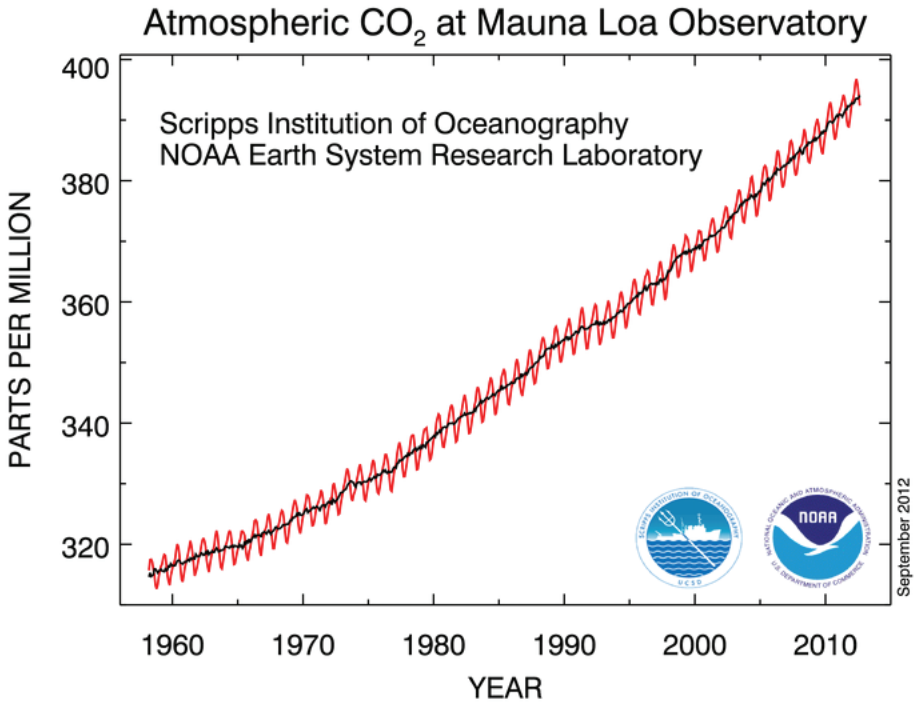
Carbon Reservoirs and Exchange

At time scales of most interest to humans (years to decades to centuries) the atmosphere exchanges carbon with three main reservoirs: the terrestrial biosphere, the oceans, and fossil fuels



http://www.esrl.noaa.gov/gmd/outreach/carbon_toolkit/basics.html

Currently, atmospheric CO_2 levels continue to rise as humans burn fossil fuels at increasing rates.



Instrument Record for Atmospheric Carbon Dioxide (CO_2) at the Mauna Loa Observatory

Glossary

Unit	Activity	Vocabulary Word	Definition
Energy	Carbon Journey	Absorption	Ability of a substance to absorb (take in) materials and energy
Energy	Carbon Journey	Assimilation	The conversion of nutrients into the body of an organism by the processes of digestion and absorption
Energy	Carbon Journey	Combustion	Chemical process that releases energy (E.g., burning wood.)
Energy	Carbon Journey	Consumption	Act of using something up; act of eating or drinking (E.g., a whale consumes, or eats, a fish.)
Energy	Carbon Journey	Decomposition	Decay; rot; breaking down (E.g., a dead tree trunk decays, breaks apart, and returns carbon and nutrients to the soil.)
Energy	Carbon Journey	Dissolve	To become absorbed into a liquid and to break up into component parts (E.g., salt dissolving in water.)
Energy	Carbon Journey	Erosion	The gradual process of wearing away and breaking down by abrasion (E.g., erosion is the process that can occur through the movement of water, wind or glaciers.)
Energy	Carbon Journey	Flux	Rate of movement of carbon atoms between reservoirs (E.g., burning moves carbon atoms from their solid storage in wood to a gas [carbon dioxide] in the atmosphere.)
Energy	Carbon Journey	Outgas	To remove absorbed gas from a solid or liquid (E.g., when a volcano erupts, there is usually a great deal of gas released from the lava. This is called outgassing.)
Energy	Carbon Journey	Photosynthesis	A process occurring in plants that takes the energy of the sun, carbon dioxide and water, and produces sugars and carbohydrates.
Energy	Carbon Journey	Reservoir/ Pool	Carbon-storing natural feature such as the ocean, plants, cells, rocks etc. Carbon can be exchanged from one carbon reservoir to another.

Glossary

Energy	Carbon Journey	Respiration	The process where organisms exchange gases with the environment (E.g., an animal's respiration includes inhaling oxygen and exhaling CO_2.)
Energy	Carbon Journey	Sink	A natural reservoir where carbon is stored
Energy	Carbon Journey	Sources	Reservoirs that release more carbon than they store
Energy	Carbon Journey	Weathering	Chemical and mechanical processes by which things are broken down when exposed to weather elements (E.g., over time and exposure to wind, rain, snow, and temperature changes, sharp mountain peaks are worn down and become rounded.)