Introduction to Climate Science

Carbon Cycle Game

RUTGERS
New Jersey Agricultural Experiment Station

Objective

Youth will model the movement of carbon through the different reservoirs. Youth will understand that the path taken by an atom through a biogeochemical cycle is complex – not a circle – and provides an example of conservation of matter. This lesson encourages youth to think about carbon atoms and how carbon, in all its forms, is impacted by human actions. As a greenhouse gas of most concern, youth connect carbon dioxide to rising global temperatures.

Overview

Youth will take on the role of a carbon atom and record which reservoirs in the carbon cycle they visit. They will compare and contrast their trip with those of the group to discover information about sources and sinks and residence times of the different reservoirs.

Biogeochemical cycle – the turnover or cycling of substances through the compartments of Earth: biosphere, lithosphere, atmosphere, hydrosphere.

Biological pump – the ocean's system for taking carbon dioxide from the atmosphere, making it available for algae & other organisms, and eventually falling to the bottom (sediment).

Reservoirs are locations or pools where carbon tends to move to during the carbon cycle. Reservoirs or pools include vegetation, animal, bacteria and fungi, litter and waste, fossil fuels, industry and vehicles, and atmosphere and ocean.

Residence time is the amount of time a specific particle, in this case, carbon, spends in a particular system.

Rationale

Youth will be introduced to the importance of carbon and its cycling between the living and nonliving parts of the ecosystem. Youth will build off knowledge base and expand/relate climate change to the carbon cycle. This exercise will help the youth convey previous conceptions about climate differences and apply that knowledge to the practical examination of the carbon cycle.

Source

http://coseenow.net (*Kate Florio, Katie Gardner)*

CORE CURRICULUM CONTENT STANDARDS

ESS2: Earth's Systems
- ESS2-A. Earth's Materials & Systems (ESS2-1)

ESS3: Earth and Human Activity
- ESS3-D. Global Climate Change (ESS3-5)

LS1: Structures and Processes
- LS1-C. Matter & Energy Flow in Organisms (LS1-6, LS1-7)

NATIONAL SCIENCE STANDARDS
- Science As Inquiry
- Life Science
- Earth and Space Science
- Personal and Social Perspectives
- History and Nature

Carbon Cycle

Basic Materials

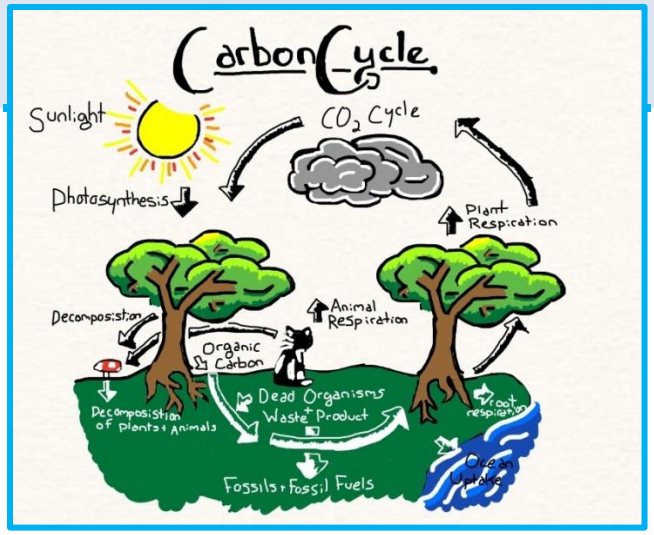
INSTRUCTOR

- 7 dice
- 7 station signs (color or black and white)
- Carbon Cycle Diagram
- Pony beads – enough for each youth (white, light blue, dark blue, light green, pink, dark green, orange, purple, grey, and brown; or 10 distinctly different colors)
- Cups (at least one for each station to put beads in)
- Unopened undisturbed bottle of seltzer or clear soda (optional)

***Bead color at each station should match the station sign color**

YOUTH

- String, lanyard, or pipe cleaner (at least an 8" length per student)
- Carbon Cycle Game Worksheet (1 per youth/group)
- Carbon Cycle Model (1 per youth/group)
- Global Temperature/CO_2 Rise graph (1 per youth/group)
- Carbon Cycle Diagram (1 per youth/group)
- Pencils or pens
- Scrap paper (optional but recommended)



ADVANCED PREP	1 DAY
DO/ENGAGE	20-30 minutes
SHARE/EXPLORE	10-15 minutes
PROCESS/GENERALIZE/APPLY	10-15 minutes

ADVANCED PREP

1. Print out the Carbon Cycle Game Dice (color or black and white, your choice).
   a. Print out enough for at least one die for each station – it is helpful but not necessary to have more than one die for each station.
   b. Cut out the dice and crease along the lines between the faces.
   c. Tape the open edges together to make a cube.
   d. It is helpful to weight the dice with a ball of scrap paper about the same size as the inside of the finished cube. Filled dice roll more easily than empty ones.
2. Print out the Station Markers (color or black & white)
3. Set up each station in a different location around the room. Each station should have:
   a. At least one die – duplicates are especially helpful for the Atmosphere and Surface Ocean stations (youth will visit these often and not having to wait in line to roll dice will make game play faster).
   b. A station marker posted where the youth can easily see it once moving around the room.
   c. A cup filled with the corresponding color of beads.
4. Cut lengths of string or lanyard for each youth.

Advanced Prep for Demonstration

1. Pour vinegar into the bottle – about halfway.
2. Using the funnel, add baking soda to the balloon – at least ¼ full.
3. Fit the balloon snugly on the bottle opening; be careful not to let any baking soda drop into the vinegar.
4. Let the balloon filled with baking soda hang off the bottle until ready to do the demonstration

DO/ENGAGE

1. Draw the group's attention to where you have the bottle and balloon set up. Ask everyone to watch the balloon and bottle.
2. Carefully lift the balloon up to let the baking soda fall from the balloon into the bottle and mixes with the vinegar.
3. Observe the effect on the balloon.
   - Ask, what happened? what was in balloon mixed with what was in bottle and it made a gas/made the balloon expand; Chemical reaction – baking soda (liquid, base) mixed with vinegar (solid, acid) and formed carbon dioxide (gas)
4. Carbon dioxide is talked about a great deal lately. Why? Answers will vary; connection with climate change should be brought up if not by any of the youth
5. What are sources of carbon dioxide?
   - Naturally – decomposition and respiration of plants, animals & soil, ocean – atmosphere exchange, volcano eruptions
   - Anthropogenic (Human) activity – burning of fossil fuels for energy & transportation; land use changes - deforestation, equipment emissions; industrial processes – production of cement, steel, plastics, solvents & lubricants
6. What do you know about carbon? chemical element, symbol is C, forms more compounds than all other elements combined, commonly comes from coal, key ingredient for life, important in dating objects – carbon dating, 6th most abundant element in universe
7. What forms can we see carbon on Earth? solids, liquids, and gases – coal, diamonds, graphite, plants, gasoline, lubricants, charcoal, plastics, carbon dioxide
8. How is carbon found naturally? amorphous – black soot left after carbon containing material is burned; graphite – pencils & lubricants; diamonds – one of hardest substances
9. Review with youth why carbon is so important – fundamental building block of life; all living organisms are built of carbon compounds; important role in many chemical processes; present in other significant greenhouse gases, such as methane, chlorofluorocarbons, and hydrofluorocarbons
   - Explain that carbon is exchanged between the oceans, atmosphere, ecosystem, and lithosphere in the Carbon Cycle.

Instruct the youth they are going to pretend to be a carbon atom moving through the carbon cycle. Review the water cycle as a familiar concept and introduce terms such as reservoir, source, and sink using the water cycle as an example. Go over what reservoirs will be included in the carbon cycle game. (Note: We are not including many other reservoirs, such as fossil fuels).

GAME INSTRUCTIONS

1. Each youth or group of youth will start at a different station.
   - Point out the stations around the room where the directions are for moving to the next station.
2. Give each youth string, lanyard, or pipe cleaner.
   - Have them make a knot or small loop so the beads will not fall off. Youth will keep track of their journey by adding a bead to their string to represent each reservoir they visit.
   - Have them place one bead from the station on their string, lanyard, or pipe cleaner.
3. Each youth or group rolls the dice at the station. This will tell them where to go next.
   - The youth or group will move to the next station or may be told to stay where they are.
   - If a die tells them to stay in place for a turn, they should add another bead of that color before re-rolling.
4. Each time they move to a new station, they do the same thing – take a bead so they do not forget, roll the dice, and follow the directions to move to another station or stay.
5. Youth should read the dice carefully for information about the process that is moving them from one reservoir to another, and then go to their next station as instructed by the dice.
6. As youth represent carbon, an element, they do not "want" to go to any particular place. There is no "goal" they are trying to get to and they should go where the dice take them. Each turn they should roll the appropriate die ONCE, and whatever it says is what they do.

   (Monitor youth during game play to make sure they are not cheating, i.e. "I wanted a _____ bead!")

7. Youth should continue moving through the cycle until they have fifteen beads on their string.
8. Pass out the Carbon Cycle Model, Carbon Cycle Game worksheet, and Carbon Cycle Game diagram to youth when completely finished the Carbon Cycle. The youth will use their beads to decode which reservoirs they represent. Also, pass out the Temperature/CO_2 Rise graph for each youth to explore as they answer their worksheets.

INSTRUCTOR NOTES

It's best to assign youth their starting location. The carbon cycle is a large and complex topic, so youth are able to start from multiple locations and continue through the entire process of the Carbon Cycle.

1. Use the Carbon Cycle Model to represent the journey through the cycle as a series of arrows.
2. Monitor youth as they move through the cycle and remind them of the rules if needed.
3. When youth have finished their cycle, pass out worksheets and have them decode their string of beads back to which reservoirs they represent.
4. Once youth get the hang of it, the game goes quickly, so if you have enough materials you can certainly run the game more than once, with a slightly different focus each time.
5. This is where it is helpful to have duplicate dice for some stations –
   a. If you would like eight youth to start in the atmosphere, you may want to make at least eight atmosphere dice.

SHARE / EXPLORE

1. Ask youth how they think human actions influence the carbon cycle.
2. How can humans influence the increase of carbon dioxide in the atmosphere?
3. Ask a few youth/groups to tell how their carbon atom moved through the cycle.
4. Ask a few youth to share their diagrams.
   - Is a cycle a circle?
5. Overall, which reservoirs did youth visit the most?
6. Have youth describe how many turns they were stuck in specific reservoir. Residence time is important to the connection to climate change – Human actions resulting in the removal of carbon from carbon sinks such as fossil fuels, but emits it as carbon dioxide and directly adding it to the atmosphere, upsets natural balance of cycle
7. What are the processes that move carbon from one reservoir to another? (Choose a few to highlight.)
8. Which reservoirs were most common? How do you know? Why?
9. Were some reservoirs visited multiple times?

PROCESS / GENERALIZE / APPLY

1. What processes move carbon from the atmosphere to the ocean sediments? Gas and air dissolve in water the same way that salt or sugar (solutes) do. Initially, many youth will use the terms "evaporation" and "condensation" when you ask them how carbon moves from one to the other; remind them that those are terms for the water cycle and for changes in state of matter.

Reservoirs (sinks): pools of carbon that can be uniquely defined

Fluxes: the rate of movement of carbon from one reservoir to another

Residence time: the average time that carbon spends in a given reservoir

- Use the seltzer or soda to discuss carbon dioxide moving between air and water, if necessary. The soda is helpful both to show that air and gas dissolves in water in the same way that solutes such as salt do, and to help them connect to the short residence time of gas in liquid (If I open this and leave it here overnight, will it still be fizzy tomorrow?).
- Define the biological pump for youth. The biological pump is the set of processes in the ocean that sequester carbon (make it unavailable to be recycled back into the atmosphere for a long period of time).

2. Identify if any youth were sequestered (Atmosphere – Surface Ocean – Ocean Plants – Deep Particles – Ocean Sediments. (Can also stop at Ocean Consumers between plants and particles).
   - Why is it important to understand about carbon being sequestered? It puts the reservoirs and fluxes out of balance; interferes with the normal carbon cycle. Scientists are interested in areas of the ocean with a very efficient biological pump, as well as areas of the ocean where the biological pump is either less efficient than expected, or decreasing in efficiency.
3. Have youth brainstorm what reservoirs and processes have not been included in the game soils, fossil fuels, sedimentary rocks; burning of fossil fuels, subduction of sediment, and volcanic eruptions for a few examples
4. What conclusions can they draw? Youth will likely have more beads from the atmosphere than other reservoirs. This represents a build-up of carbon dioxide in the atmosphere that is a direct result of burning fossil fuels
5. Why and what is the relation to climate change? This is a good opportunity to re-visit the IPCC global temperature/CO_2 rise graph. There is a natural relationship with the sinks of atmospheric carbon dioxide and the fate of the carbon after it is removed from the atmosphere. When the carbon cycle is in equilibrium, the exchanges in and out of each reservoir are in balance. The rate that carbon is being released into the atmosphere over the past 150 years is more than the rate that it can be transferred to other reservoirs.
   - The amount of carbon in the atmosphere plays an important role in maintaining Earth's temperature balance. Too much carbon/CO_2 in the atmosphere absorbs more heat that warms the Earth.
   - CO_2 is a heat trapping gas and needed to make sure the Earth does not freeze. Too much CO_2 in the atmosphere causes Earth to get warmer. Earth's historical data shows that for each time period when CO_2 increased, so did the temperature.
   - When the temperature in the ocean rises, it releases more CO_2 into the atmosphere.

RESOURCES

COSEE NOW
http://www.coseenow.net/blog/2010/12/ocean-acidification

Science Daily
https://www.sciencedaily.com/releases/2011/01/110107094904

Carbon Cycle Game Diagram

Where did our carbon atom go? Draw arrows to represent all the steps of your journey though the carbon cycle.

For example, if you start in the atmosphere and you roll land plants, draw an arrow from atmosphere to land plants.

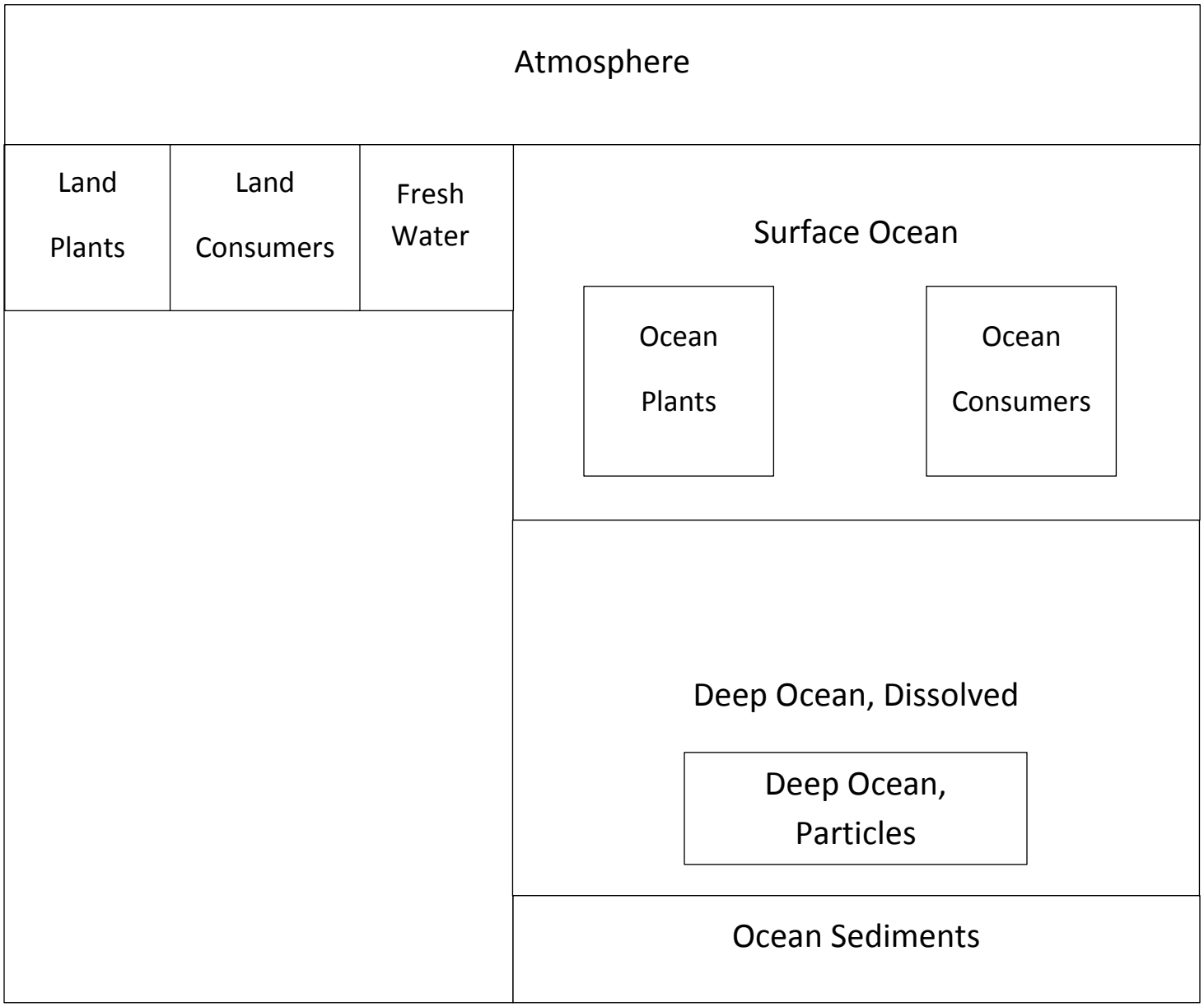
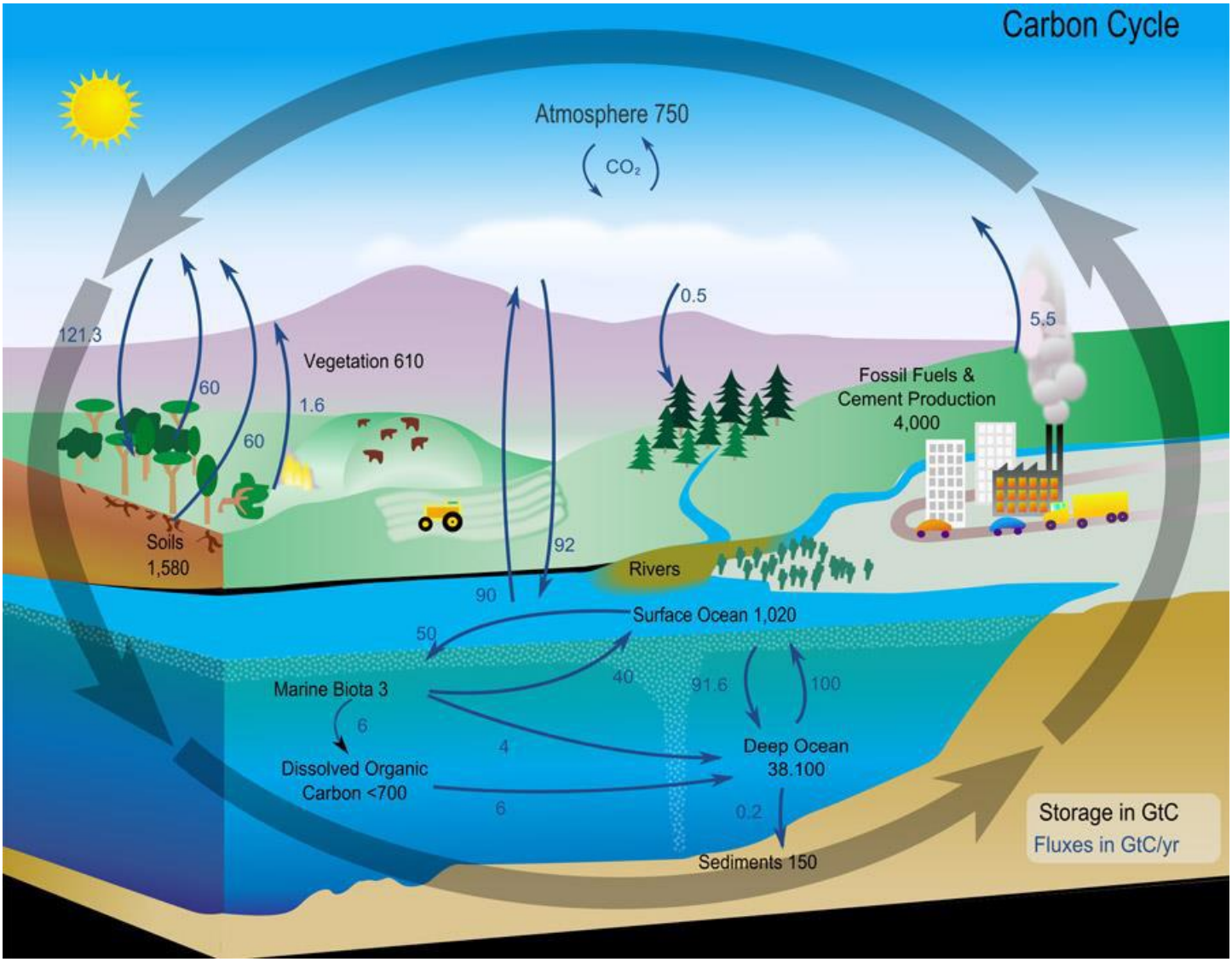


Illustration courtesy of NASA Earth Observatory



Bracelet Worksheet

Name:_____

Where did your carbon atom go? (Use your Key to decode your bracelet)

Bead color	Carbon pool
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	
13.	
14.	
15.	

KEY:

White =	ATMOSPHERE
Light blue =	SURFACE OCEAN
Light green =	OCEAN PLANTS
Pink =	OCEAN CONSUMERS
Dark blue =	FRESH WATER
Dark green =	LAND PLANTS
Orange =	LAND CONSUMERS
Gray =	DEEP OCEAN, PARTICLES
Purple =	DEEP OCEAN, DISSOLVED
Brown =	OCEAN SEDIMENTS

Questions:

Where did you spend the most time? (Which carbon pool?)

Compare your carbon atom's path with your neighbor's. Did you take the same path? Did you go the same places?

Tracking Worksheet

Name:_____

Record your journey as you move through the stations. Where did your carbon atom go?

CARBON POOL

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____

Questions:
Where did you spend the most time? (Which carbon pool?)

Compare your carbon atom's path with your neighbor's. Did you take the same path? Did you go the same places?