INVESTIGATION

Creating a Map of Carbon Flows

(that includes soil ecology)

Time: 45 minutes

Grades: 4th through adult

Summary: Participants write and/or draw places where they know carbon exists (atmosphere, plants, soil, fossil fuels, microbes, etc.) on pieces of paper, use arrows between them to indicate flows, and then move those pieces of paper around on a large floor surface (adding zones and arrows as needed) until they feel that it reflects the carbon cycle with some accuracy. The idea is not to get it all right, but to show that the carbon cycle is incredibly complex, that it involves all of life, and it is probably not actually something that can ever be fully mapped.

I learned this exercise from a group of environmental teachers, and I love it for a number of reasons: 1—participants have to work together as a team, and often end up teaching each other; 2—they create their own flexible map in which they can insert examples that are meaningful to them (rather than looking at the ususal static simplistic ones); 3—in doing so, they get a systems view (and review) of biological, chemical, geological and physical processes, and end up curious about what else could be added. This exercise can be used more than once, and built upon, over time, to track learning. It goes well with the game "Please Pass the Carbon..."

Setting: A wide open space (at least 14 x 14 feet) where people can stand in a circle and look at an expanding map on the floor, OR a large tabletop.

Materials:

- ✓ At least 30 pieces of paper, some cut in half (for places), some into quarters (for arrows) Paper out of the recycling bin will work just fine if one side is blank.
  OR if you are working on a tabletop, use sticky notes, as they will stay in place while people move other ones around.
- ✓ Pens: Sharpies or Magic Markers so that the words can be read at a distance.

✓ (Optional) Video: The Soil Story video provides a 4-minute visual example of flows of carbon moving from one place to another: https://www.youtube.com/watch?v=nvAoZ14cP7Q

Objectives

Participants will:

- See that all of life starts with photosynthesis
- Understand that flows in a complex system can be multidirection
- See that in a complex system, feedback loops are also complex, and that change is not easily predictable
- Understand that human behavior can profoundly influence all of life, positively or negatively
- Develop a sense of awe for the carbon cycle as the circle of life

Goals

Participants will be able to:

- Arrange major flows of the carbon cycle in logical relationships to each other (atmosphere to plants and oceans by photosynthesis and diffusion; organisms to atmosphere by cellular respiration or burning; fuels to atmosphere by burning; plants to soil organisms via root exudates, animal's digestive tracts, and decomposition, etc.)
- Extrapolate that carbon can move from the atmosphere to *any* type of plant, and likewise from plants into *any* animal that eats that specific plant, after hearing several examples.
- Give an example of how carbon can move in more than one direction between two places (for example back and forth between oceans and atmosphere, and back and forth between plants and atmosphere.)
- Visualize flows of carbon between different pools

Assessment: Participants recreate a map on their own or in pairs.

EDUCATIONAL STANDARDS

Next Generation Science Standards

Performance Expectations:

HS-LS2-5 Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere

Science and Engineering Practices:

Obtaining, Evaluating and Communicating Information; Asking Questions and Defining Problems, Constructing Explanations and Designing Solutions

Disciplinary Core Ideas:

LS1.C Organization for Matter and Energy Flow in Organisms; **LS2B** Cycles of Matter and Energy Transfer in Ecosystems; **LS2.C** Ecosystem Dynamics, Functioning and Resilience. **LS4.C** Adaptation. **LS4.D** Biodiversity and Humans.

ESS2.A Earth's Materials and Systems; **ESS2.E** Biogeology; **ESS2.D** Weather and Climate; **ESS3.D** Global Climate Change.

PS1.B Chemical Reactions

Crosscutting Concepts:

Cause and Effect; Scale, Proportion, and Quantity; Systems and Systems Models; Energy and Matter: Flows, Cycles, and Conservation; Stability and Change

Common Core State Standards

SL.9-10.1 and 10-11.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade appropriate topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

Activity

(Optional) Watch "The Soil Story"
This 4-minute video is a nice opening to the activity, as it shows carbon moving from one place to another, with soils as a central narrative.

Hand Out Materials in a Circle
Have participants stand in a circle and give out markers, blank paper, and smaller pieces of paper with arrows already drawn on them. Let them know that they will be working together to build a moveable map showing how carbon flows through the circle of life.

➧ Note: If you have more than 10 to 15 participants, you probably will want to have more than one circle. It can be fun to compare the different maps at the end.

Start the Map
Write down "Atmosphere" "Plants" "Soil organisms" "Oceans" "Humans" each on its own piece of paper, and put them on the floor (or table, if you are working in a smaller space). Give participants a few papers with arrows drawn on them.

Tell participants to rearrange these papers in whatever way they think makes sense, and ask them to put the arrows in between to indicate flows of carbon. (If they need an example, you can put an arrow between "atmosphere" and "plants.")

➧ Note: Depending on the group's familiarity with the carbon cycle, you could start with just the word "atmosphere" and ask them to start brainstorming other places where carbon might be right away.

Add to the Map
Ask participants

› *Where else would carbon be?*

As the first few people say things, ask them to write their answers on the pieces of paper, and add them to the map, with arrows.

Explain that it's okay to move papers and add arrows as things get added.

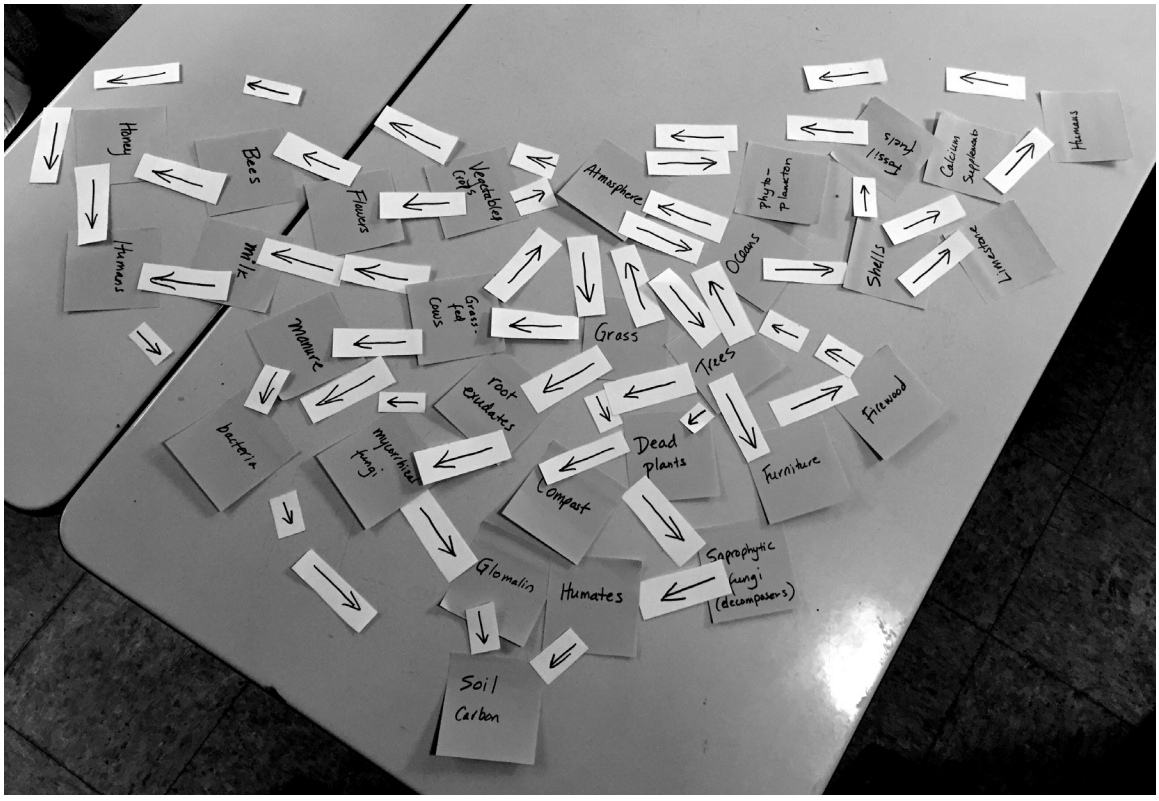
Ask for More Detail

If some participants have the knowledge base to do this, ask them to say whatever they can about *how* carbon moves from one place to another (i.e. photosynthesis, oxidation, diffusion, etc.), as well as what form it is in, and if they know, what the *chemical formula* is (i.e. it's going from being CO_2 in the atmosphere, moving into plants, through the process of photosynthesis, and turning into glucose, which is $C_6H_{12}O_{6.}$)

- Note: You might need to remind participants that carbon can flow in more than one direction between things: for example it can travel from the atmosphere into plants via photosynthesis, but it can also travel from plants back to the atmosphere via cell respiration, oxidation, and decomposition.

Keep Track of Questions

You will likely come up with some questions that no one has an answer for, as your map gets more detailed. Celebrate the questions, reminding participants that



One example of the (almost infinite) possible maps you can make of the carbon cycle. Note that this map has loose ends and missing arrows, and yours will too.

good questions are an essential part of science, and appoint a scribe to keep track of the questions. Cpnsider assigning the most interesting ones for homework.

Expand the Map

Keep asking *where else would carbon be?* and encourage people to add more detail. (For example, they might add "cars" between fossil fuels and the atmosphere.)

If some people are hanging back, ask them what might be added, or if they see something they think should be moved.

If things slow down, throw in a few questions, such as:

- *Where would shells be in this map?*
- *What are all the ways carbon can get into the ocean, and what forms would it take?*
- *What are all the forms of carbon that come out of sheep, and where do they go?* (Wool sweaters, sheep's milk, sheep's milk cheese, sheep dung, sheep urine, sheep drool, lanolin, sheep's breath, sheep burps...)

The Circle of Life

When the map has at least 20 things on it, ask:

- *What do you notice about this map?*

Point out (if someone hasn't already) that what they are creating is not just a map of carbon flows, it is also the circle of life. Ask:

- *Which parts of this map do you care about?*

Thinking about Complexity

Ask some or all of the following questions:

- *Do you think our map is a complete map of all the carbon on the planet?*
- *How easy do you think it would be to create a complete map?*
- *Are we looking at chemistry, biology, physics, geology, social studies, or environmental studies?* (The answer is all of the above.) Explain that what they are seeing is an example of a complex system, with relationships between living and non-living parts.
- *How many parts of this map would impact our lives if they changed? In what ways?*
- *What changes could impact other species? In what ways?*

- *Would you be able to accurately predict what would happen to all the other relationships if you were to change the amount of carbon flowing from one thing to another in this picture?*
- *Which feedback loops or flows do humans have influence over?* (People may answer this in various ways, but the facilator should point out that, in fact, because of the way relationships in complex systems work, we actually have influence over most or maybe even all of it--and we already have influenced most of it. By learning more about how people make choices, and what the consequences of those choices are, we can help to create positive outcomes.)
- *Do you see any leverage points or opportunities where we can make postive change?* (Typically people will point out reductions in fossil fuel burning. Another key leverage point they may not notice is in increasing the area and length of time in which photosynthesis is happening, and learning how to allow the formation of soil carbon.)
- *Do you think it makes sense for us to learn more about how these relationships work?*
- *What is one thing you would be interested to learn more about?*

Take a Snapshot

Taking a photograph of your map is a good way to document a learning baseline for your group and to track change over time. (You can also post it on social media and ask people what they think it is—most people don't know much about the carbon cycle!)

Wrap Up

Ask everyone to take turns answering these questions:

- *What did you learn today, and how do you feel about it?*
- *What is one new question you have?*

Follow Up Later

Look at your snapshot later in the week, semester, or year, after the group has learned more, and ask: "what else would you add to this map?"

A few places you can find carbon

(just to give you an idea of how silly this can get):

Big Pools of Carbon
The Atmosphere/air
Oceans and other bodies of water
All living, dead, or very dead life forms, including:
--All plants, animals, fungi, and bacteria
--Soil carbon and peat bogs
--Shells and fossils, and rocks made from them
--Fossil fuels

More Specifics
Grass
Kangaroos
Sheep
Microbes inside sheep's digestive tracts
Sheep's milk
Inside the stomach of humans drinking sheep's milk
Wool sweaters
Drool from sheep
Urine from sheep
Sheep's manure
Sheep's breath
Dung beetles
Microbes decomposing the manure and respiring CO2
Viruses
Insects
Moss
Ferns
Mushrooms
Blueberry bushes
Apple trees
Grass
Respired from plants
Plant root exudates
Mycorrhizal fungi
Chitin
Glomalin
Inside soil aggregates
Oxidized from dead plants
Humates
Soil bacteria
Nematodes
Earthworms
Worm castings
Worm slimes
Birds
Seeds
Corn
Corn Syrup
Candy bars
Human stomachs
Human bodies
Human bloodstreams
Respired in human's breath
Compost piles
Sewage
In rain clouds formed by hygroscopic bacteria
In raindrops formed by hygroscopic bacteria
Cars
Exhaust
Gas pumps
Fuel tanks
Lawnmowers
Phytoplankton
Rivers
Frogs
Frog slime
Wooden furniture
Paper
Coal
Smoke from fires
Charcoal
Diamonds