Caught Up in the Carbon Cycle

A simulation game that encourages 11- to 15-year-olds to learn about systems that influence climate change

Photos: Pamela Miller

by **Pamela Miller**

IN ORDER TO TEACH students about a global issue such as climate change, we need to pay attention to the many dynamic systems that make up our interconnected world. Often when we visualize a cycle of matter like the water cycle, we imagine a circular path. Closer inspection, however, reveals that most systems are a messy, tangled web of relationships that are hard to conceptualize and understand. By getting students to role-play a carbon molecule during an interactive simulation, they can better grasp the carbon cycle and then begin to unravel and understand the many interwoven matter cycles (e.g., water cycle, nitrogen cycle), processes, relationships, and systems that both influence and are impacted by global climate change.

The following describes an activity that I have had success with in classes of various sizes. It can be conducted on a small scale indoors or on a larger scale outdoors.

Summary: Students simulate the movement of carbon molecules.

Subject Areas: Earth Science.

Duration: Preparation: 50 minutes to print, make and sort the cards; Activity: 45 minutes.

Setting: Ideally a large open area indoors or outdoors.

Objectives: Students will track, understand, and describe the movement of carbon within the carbon cycle.

Materials:

- 7 station markers: pylon with station label and symbol
- 7 station containers to hold option cards
- 44 cards, each with explanations of carbon pathway options
- 1 carbon passport per student
- 1 pencil per student
- 1 large map or 7 individual maps of station locations (if stations cannot be seen from a central spot)
- Whistle or signal to indicate end of activity

Vocabulary: organic, photosynthesis, carbonification, oxidation, weathering, diffusion, decomposition, combustion, respiration, decay, metabolism, biomass, compost, humus, anaerobic, aerobic, aquatic.

Background

Gases like carbon dioxide (CO_2) that absorb and radiate heat back to the Earth are referred to as greenhouse gases. Without any naturally occurring greenhouse gases warming the Earth, the average surface temperature would be well below freezing; however, ever since the Industrial Revolution, humans have increased atmospheric CO_2 concentration by more than 30% by burning fossil fuels such as coal and oil, and clearing land for agriculture, forestry, and industry. As a result, this excess amount of carbon dioxide released into the atmosphere is warming up our planet — so much so that the six hottest years on record have occurred during the last 10 years.

This warmer climate is causing problems because heat is what drives the climate system. Among the many impacts of climate change are rising sea levels and changes in currents, changes in precipitation patterns, reduction of glaciers and permafrost levels, shifts of temperature zones, an increase in the frequency and intensity of storms, more heat waves and droughts, and a higher incidence of forest fires.

To slow the pace of climate change, we have to reduce carbon emissions associated with fossil fuels consumption and the degradation of natural ecosystems. On individual and community levels, restoring green spaces (e.g., by planting trees), favoring public transit and bicycles over cars, making our homes more energy efficient, reducing, reusing and recycling materials and eating locally grown foods are actions that everyone can take to help reduce greenhouse gas emissions.

The Carbon Cycle Game

Teacher Preparation

1. Locate one or more diagrams of the carbon cycle that will provide students with a visual appreciation of its many components. Here are three that were available at the time of writing:
- https://www.fix.com/blog/three-year-garden-crop-rotation-plan/ (March 28, 2018).
- http://www.istockphoto.com/ca/vector/carbon-cycle-gm586726364-100721927 (March 28, 2018).
- https://airs.jpl.nasa.gov/resources/images/126 (March 28, 2018).
2. Create carbon process cards for each station using durable paper.
3. Find 7 containers (e.g., buckets or bags) into which students can easily reach to retrieve cards.
4. Create 7 station signs: Animals, Atmosphere, Combustion, Plants, Rock Cycle, Soils and Water. Include a picture on each sign illustrating its station label.
5. Attach the station labels to each container and place the matching cards in each container.
6. Choose 7 locations outside on the schoolyard that closely match each station description and activity of carbon molecules (e.g., Rock Cycle Station: beside bricks, sand area or concrete).
7. Set up the stations around the playing area. Stations could be set up in advance or the students starting at a station could bring materials to that station location.
8. Prepare a map or chart of station locations, or let students hunt for each station.
9. Determine the amount of time for the simulation as well as a starting and an ending signal for the students.

Activity

1. Brainstorm the different places carbon can go as it moves through and around the Earth. Have the students create a carbon cycle diagram and/or concept map, including both the locations (e.g., Atmosphere, Water, Soils, etc.) and the processes (below).
2. Review vocabulary and carbon cycle processes. Where possible, demonstrate the processes associated with the carbon cycle:

Body building (marine animals)	Metamorphosis (rock cycle)
Carbonification	Oxidation
Combustion	Parasitism
Death	Photosynthesis
Decomposition	Production (material goods and fuels)
Deforestation	Respiration
Diffusion	Sedimentation
Digestion	Weathering chemical and physical (rock cycle)
Extraction	
Harvesting	

3. Provide each student with a passport or recording sheet to track their journey. Clipboards are helpful.
4. Distribute the students evenly at each station. (Students may work singly or in pairs.)
5. Review the following procedure for travelling through the carbon cycle:

   a. At the first station, students record on their passport the location of the station. One at a time, each student (or a student team) randomly chooses an option card, reads it, and replaces the card in the container for the next team. Each option card will describe the reason that carbon travels (process) and the new location of the carbon molecule. Students record the process and the new location (e.g., *1st Station: Atmosphere, Process: Photosynthesis, 2nd Station: Plants, etc.*).

   b. Once the information is recorded, students travel to the new station. At each sequential station, students choose an option card, record their movements, and move to the next station. They continue this until time is called. ***Note:*** *Some station cards require students to stay at the same location. In these cases, students record "same location" and then move to back of the line at that station.*

Follow-up Discussion

1. How did you move through the carbon cycle? What surprised you? How does your journey compare to a carbon cycle diagram? (Sample teacher prompt: Did you move through all the stations in a sequential order, or was your path more convoluted?)
2. At which station did you stay the longest / return to the most? How many different stations did you visit? (Sample teacher prompt: Did you find yourself at the Atmosphere station over and over again?)
3. Are any sources of carbon missing from the simulation? How would you change the simulation to reflect local and global issues? (Sample teacher prompt: The methane production from anaerobic decomposition of organic materials in landfills is not mentioned in any of the cards. How might you create a process card to reflect how your area manages waste as well as any carbon produced from waste systems?)

Making Connections

1. Compare your understanding and diagram of the carbon cycle to your experience in the simulation activity. Create a new diagram/concept map to reflect your new understanding of the carbon cycle.
2. What role does energy play in the carbon cycle? How might carbon's journey change in different seasons? (Sample teacher prompt: For example, levels of carbon dioxide in the atmosphere fall during the summer in the Northern Hemisphere.)
3. How is life interconnected through the carbon cycle? (Sample teacher prompt: How do you personally depend on the carbon cycle?)
4. In the course of the carbon cycle, are carbon atoms themselves ever created or destroyed? Are they ever changed into other kinds of compounds? Explain. (Sample teacher prompt: Consider starting with the process of photosynthesis to illustrate what happens to carbon atoms in the cycle.)
5. What role do we have in reducing the amount of carbon released into the atmosphere? (Sample teacher prompt: What changes can you make in your own life to reduce your carbon footprint?)

Assessment

Key concepts

- Carbon continually cycles through and around the atmosphere (gas), biosphere (life), lithosphere (solid), and hydrosphere (water).
- Earth is a recycling planet. The carbon that is on Earth has been here — although in different states — since the planet was formed.
- Carbon is the building block of life.
- In the carbon cycle, carbon atoms change their chemical partners, physical locations, and physical states.

1. Compare how many carbon locations and processes students understand before and after the simulation activity.
2. Have students role play, write a story, draw a comic strip, compose a rap, song describing the journey of a carbon molecule in first person.

Student Extensions

- Play the carbon cycle simulation game again. What changes or patterns emerge?
- Research one of the issues related to increased CO_2: fracking, tar sands, use of fossil fuels, deforestation. What roles and responsibilities do we have in these issues?
- Research other matter cycles: oxygen, nitrogen, and water. How are these systems interconnected? What impact do we have on these cycles, both positive and negative? What actions can we take to reduce our negative impact?
- Design a self-guided interpretive carbon trail and brochure for your school grounds. Tell the story of the carbon cycle by choosing 5-6 sequential spots where participants can learn about and see evidence of the carbon cycle in action.

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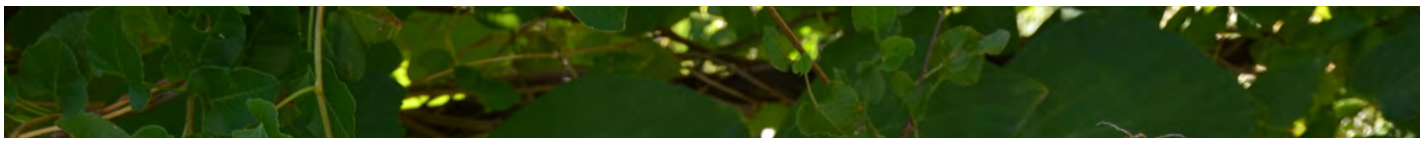
Carbon Cycle Concepts

The following activities demonstrate some of the processes with which carbon molecules are involved during the carbon cycle. Each activity can be set up as a student-run station, or used as teacher demonstration prior to or proceeding the activity "Caught Up in the Carbon Cycle."

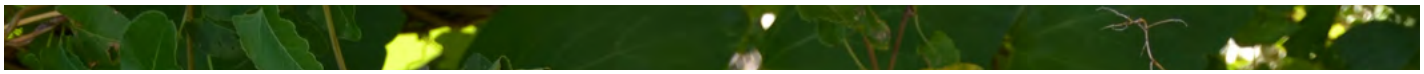
CALCIUM CARBONATE and CHEMICAL WEATHERING	
What is calcium carbonate?	Calcium carbonate is a mineral. Shells of marine organisms, snails, pearls, and egg shells are made from calcium carbonate.
What is chemical weathering?	Chemical weathering is the process by which materials break down into smaller parts because of a reaction between molecules, not by force.
Activity	
Materials: • vinegar or strong acid (e.g., CLR) • eye dropper • rubber gloves • limestone rock • egg shells • baking soda	**Instructions:** 1. Drop a small amount (3-5 drops) of vinegar or stronger acid solution (e.g., Calcium Lime Rust, more commonly known as CLR — rubber gloves required) onto a small amount of baking soda, then egg shells, then the limestone rock sample. 2. Look for a fizzing reaction. Fizzing is evidence that calcium carbonate is present. 3. Now test the rocks in your school ground for calcium carbonate. Calcium carbonate is found in rocks formed from animal shells and structures.
Debrief:	Using this experience as an example, explain how the rock cycle is also part of the carbon cycle. How might acid lakes negatively affect smaller aquatic animals that live in the lake?

DECOMPOSITION and HUMUS	
What is decomposition?	Decomposition is the process by which fungi, bacteria, and invertebrates get energy by consuming carbon compounds found in plants and animals. During this process, which comprises digestion and respiration, carbon compounds are broken down into simple sugars. These sugars are then turned into carbon dioxide and water when oxygen is present. If no oxygen is present, the sugar molecules are turned into methane.
What is humus?	Humus is formed in the last stage of decomposition. Humus is made of carbon compounds like cellulose that are not easily digested by decomposers.
Activity	
Materials: • soil color chart • peat moss • top soil • sand • clay • containers with labels • trowel	**Instructions:** 1. Explain that soils with high levels of carbon compounds are dark black and brown. 2. Using a comparison chart of colours, gather a variety of soils samples from the school yard. Label their respective locations. 3. Compare the color of each sample with the soil comparison chart. 4. Compare the schoolyard samples with fresh compost, triple mix garden soil, and other soil types (e.g., sand and clay). 5. Rank and order the soils from the darkest to the lightest. **Note:** Soil colour charts can be made from brown and black paint chip swatches.
Debrief:	How much organic matter is present in the soils around the school? How might this impact the plants in the schoolyard?

DIFFUSION	
What is diffusion?	Diffusion is the process of particles moving randomly from a high concentration to a lower concentration.
Activity	
Materials: • scented oil or smelly substance (e.g., vinegar) • cotton ball in closed container • 2 people	**Instructions:** 1. Partner 1: Remain at the station. 2. Partner 2: Walk 20 steps away from the station. 3. Partner 1: a. Choose one of the scented oils/smelly substances and drop a small amount (3-5 drops) on the cotton ball in the container. b. Close the lid and shake the container. c. Open the container and wave it in the air. 4. Partner 2: Determine how much time elapses before you can smell and identify the scent, if at all. Try different distances (5 steps, 10 steps, 50 steps) and different scents.
Debrief:	Using this experience as an example, explain diffusion in your own words. Why is the diffusion of carbon through the air, soil, and water a global problem? (e.g., methane release in the arctic.)

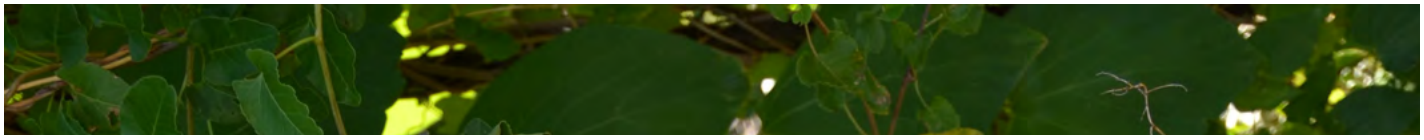


CONSUMPTION and RESPIRATION	
How does carbon move through animals?	Green plans absorb atmospheric carbon dioxide and through photosynthesis create carbohydrates — molecules that contain carbon. When animals feed on green plants, or when animals feed on other animals, they consume these carbon compounds and break them down in a process called cellular respiration. During respiration, some carbon molecules are released as carbon dioxide and others are absorbed by cells and used within the organism. Decomposers, such as fungi, microbes and invertebrates, also release organic compounds and carbon dioxide when they break down dead organisms and waste products.
Activity	
Materials: • notebook • pencil • or camera to record findings	**Instructions:** 1. Find a location near a variety of different layers of plants. 2. Spend time quietly watching and listening for animals in the area. Look for birds and squirrels in tree canopies, flying insects around flower blossoms, ants and other crawling invertebrates on the ground surface. 3. Find evidence of plant consumption, e.g., plant leaves that have been chewed, rolled, or mined by invertebrates, remains of evergreen cones with all the scales and seeds gone, caterpillar frass — small, hard pellets that range in color from brown to black. 4. Search for evidence of animal consumption — bones, insect exoskeletons, pellets or scat. 5. Record your findings with words, images or sketches. Construct a simple food chain from the information you collect.
Debrief:	In what ways is life interconnected through the carbon cycle? What evidence did you find?



GREENHOUSE EFFECT	
What is the greenhouse effect?	Heat from the Earth's surface radiates up to the atmosphere. Gases such as CO_2 and water vapour absorb the heat, slowing its escape into space. The heat energy is then re-radiated out in all directions, with some of it reheating the Earth.
Activity	
Materials: • 1 jar with lid • 2 thermometers • cardboard • rubber band • tape	**Instructions:** 1. Attach each thermometer to a piece of cardboard using rubber bands or tape. (Note: The cardboard should be small enough to fit inside the jar, but large enough to shield the thermometer from direct sunlight.) 2. Place one thermometer and cardboard piece into a jar, ensuring the thermometer can be read and is shaded from direct light by the cardboard. Secure the lid onto the jar and place it in the sun. 3. Place a second thermometer and cardboard piece directly beside the jar, again shading the thermometer from direct light. 4. Observe the temperatures of both thermometers over time.
Debrief:	Are there differences between the air inside and outside of the jar? How is the jar behaving like the Earth's atmosphere? How is it behaving differently? Using this experience as an example, how might you explain the global greenhouse effect?

PHOTOSYNTHESIS	
What is photosynthesis?	Photosynthesis is a chemical process by which green plants — trees, grass, flowers, etc. — use the energy of sunlight to convert carbon dioxide from the air into sugar, releasing oxygen in the process. Green plants then use these sugars to make all the parts of their body structures: leaves, roots, branches, fruits, etc. Sugars like glucose are also stored as the polysaccharide starch. Natural starches are mixtures of amylase (10-20%) and amylopectin (80-90%).
Activity	
Materials: • iodine with dropper • potato slice	**Instructions:** 1. Explain that iodine turns purple if amylase starch is present. (Note: amylopectin starch does not give this colour, nor does cellulose, nor do disaccharides such as sucrose in table sugar.) 2. Drop iodine on a slice of potato, which contains amylase starch. Observe the reaction of the iodine with the potato. 3. Now test a variety of leaves and plant materials found in the school yard. Which parts of plants contain amylase starch?
Debrief:	Using this experience as an example, explain how you and plants are connected in the carbon cycle.



OXIDATION and COMBUSTION

What is oxidation?

Oxidation is a chemical process by which oxygen molecules combine with other molecules. Rust is an example of oxidation where oxygen combines with iron molecules to form iron oxide (rust).

What is combustion?

Combustion is a chemical process by which carbon molecules in a fuel source combine with oxygen and are "oxidized." Combustion requires heat to get it started. Once started, combustion produces heat and light energy. When you burn carbon compounds like sugar (e.g., in marshmallows), water and carbon dioxide are produced. If not enough oxygen is present, black soot (carbon monoxide) is produced.

Activity

Materials:

- candle
- matches
- wooden skewer
- marshmallows

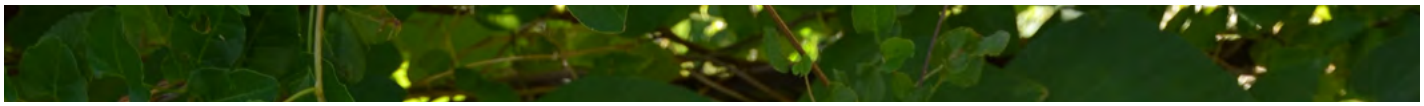
Instructions:

1. Light the candle with the matches.
2. Place a marshmallow on a wooden skewer and heat it over the candle.
3. Watch what happens to the marshmallow over time.

   (Optional) After roasting, eat your marshmallow plain, or make a s'more. For a s'more shortcut, place marshmallow between two chocolate-covered cookies.

Debrief:

Using this experience as an example, explain combustion in your own words.
Why does roasting the marshmallow turn it dark brown and then black?



WATER ABSORPTION of CO_2

How does temperature affect the absorption of CO_2 in water?

Marine and freshwater ecosystems absorb carbon dioxide through photosynthesis by plant-like organisms (phytoplankton) and by simple chemistry: carbon dioxide dissolves in water. In freshwater rivers and streams additional CO_2 is imported from nearby soils and groundwater. As water temperature increases, its ability dissolve and hold CO_2 in solution decreases. If less global CO_2 is absorbed by aquatic ecosystems, more CO_2 is stored in the atmosphere, leading to even higher global temperatures.

Activity

Materials:

- soda or carbonated water
- 2 clear containers
- measuring cups
- ice in a bucket
- thermometer

Instructions:

1. Put equal amounts of carbonated "soda" water into two transparent containers.
2. Keep one container on ice or chilled and the second subject to air temperature.
3. Observe any bubbles forming on the insides or bottoms of the containers and make comparisons between the warm and cold water over time.
4. Discuss the role of water temperature to facilitate the absorption of CO_2.
5. Repeat the experiment a second time, this time adding equal amounts of salt to the soda water.

Debrief:

What future impacts of warmer aquatic ecosystems — both marine and freshwater — do you predict or anticipate?

Carbon Cycle Animals Cards

STATION: Animals

WHAT HAPPENED?
You are stuck inside the intestines of an animal. Oops, a bit of methane leaked out!

PROCESS: Respiration

- When animals breathe, they take in oxygen and exhale carbon dioxide through the respiratory system.
- Respiration in the body is the process of using food for energy. It involves the breaking down of sugar into CO_2 and water when oxygen is present.
- When oxygen is not present, anaerobic respiration occurs (e.g., bacteria in the large intestine) and methane is released.

NEW DESTINATION: Go to Atmosphere

STATION: Animals

WHAT HAPPENED?
You have just been eaten by a big snapping turtle. It will use the stored energy found in an animal's tissues to live.

PROCESS: Respiration

- The aquatic food chain includes plants, animals, or organic material from plants and animals that drifts down from above.
- As aquatic animals break down carbohydrates and other carbon compounds, carbon dioxide and water are released back into the water body.

NEW DESTINATION: Go to Water

STATION: Animals

WHAT HAPPENED?
The animal that you are within has died.

PROCESS: Death and Decomposition

- When animals die, their bodies decay, bringing the carbon into the ground.

NEW DESTINATION: Go to Soils

STATION: Animals

WHAT HAPPENED?
You started in one animal and now you are being eaten by another. Soon you will be absorbed and made into new animal cells and tissues.

PROCESS: Consumption

- Omnivores, carnivores, and scavengers eat animal material for energy and nutrients.
- Some of the carbon is used for energy and some is used to build all the parts of the body — bones, organs, muscles, blood, etc.
- The sugars and starches and nutrients they eat are broken down by the process of metabolism.

NEW DESTINATION: Go to Animals

STATION: Animals

WHAT HAPPENED?
You wanted to make an impression and now you are permanently in rock!

PROCESS: Sedimentation

- When aquatic animals with shells die, their shells sink and build up on the ocean floor, lake bottom or river bed where they accumulate into thick deposits. Over time these carbonate sediments form limestone.
- Some of the animals get stuck in layers of mud. Heat and pressure compress the mud and carbon over millions of years, forming sedimentary rock such as shale.

NEW DESTINATION: Go to Rock Cycle

STATION: Animals

WHAT HAPPENED?
Inside a marine fish, you are forming into solid carbonate crystals soon to be released back into the water.

PROCESS: Excretion

- Fish drink saltwater and get rid of the excess salts by separating inorganic calcium and magnesium carbonate crystals out of the seawater solution in their guts. These solid crystals are then excreted either as pellets or with their feces into the ocean.

NEW DESTINATION: Go to Water

Carbon Cycle Atmosphere Cards

STATION: Atmosphere

WHAT HAPPENED?
Welcome to the emerald city where everything is green. You just entered a plant.

PROCESS: Photosynthesis
- Trees and other green plants such as grass convert carbon dioxide into sugars during photosynthesis, releasing oxygen in the process.
- They use these sugars to make all the parts of their body structure — leaves, roots, branches, etc.

NEW DESTINATION: Go to Plants

STATION: Atmosphere

WHAT HAPPENED?
It was getting too crowded in the air, so you moved below and became part of the cool soil!

PROCESS: Diffusion
- Carbon dioxide is absorbed by the soil when there is more carbon dioxide in the air than in the soil.
- Organic matter (compost, microbes and humus) helps keep the carbon in the soil.

NEW DESTINATION: Go to Soils

STATION: Atmosphere

WHAT HAPPENED?
I hope you like green water beds. Enjoy your stay inside a water plant.

PROCESS: Photosynthesis
- Using energy from the sun, plankton (microscopic organisms in the aquatic ecosystems) combine carbon dioxide and water to form sugar and oxygen.
- Water plants use these sugars to make all the parts of their body structures.

NEW DESTINATION: Go to Plants

STATION: Atmosphere

WHAT HAPPENED?
You and the water drop you just met are causing a rock to break up.

PROCESS: Chemical Weathering
- Carbon dioxide in the air combines with water to form a weak carbonic acid that falls to the surface in the form of rain.
- The acid dissolves rocks, changing the acid to carbonate and releasing minerals from the rock.

NEW DESTINATION: Go to Rock Cycle

STATION: Atmosphere

WHAT HAPPENED?
After floating around in the air, you land on the surface of the ocean. You were quickly absorbed by the water, and fit right in with the rest of the carbon molecules.

PROCESS: Diffusion
- The oceans, and other bodies of water, soak up some carbon dioxide from the atmosphere.
- More carbon is absorbed in cold water than tropical warm water.

NEW DESTINATION: Go to Water

STATION: Atmosphere

WHAT HAPPENED?
Humans have squished you and all the other molecules together under great pressure inside a tall silver cylinder. Whoa! What just happened? You and a bunch of other carbon molecules were sprayed into the air.

PROCESS: Production of Stuff
- Humans created a carbon-based compound called chlorofluorocarbon (CFC) commonly known by the DuPont trade name Freon. CFCs have been widely used in fire extinguishers, refrigerators, and aerosol cans. CFCs contribute to climate change and ozone depletion.

NEW DESTINATION: Go to Atmosphere

Carbon Cycle Combustion Cards

STATION: Combustion

WHAT HAPPENED?
Converting iron ore into steel is a tough job but you have what it takes — lots of carbon and energy. In fact, as coal, you have about 80% more energy potential than an equivalent amount of wood. After burning, you escape with oxygen into the blue sky.

PROCESS: Combustion

- Coal is burned to provide the heat and carbon necessary to convert iron ore into steel.
- Around 770 kg of coal is used to produce 1 tonne of steel, which in turn generates almost 2 tonnes of carbon dioxide gas emissions.

NEW DESTINATION: Go to Atmosphere

STATION: Combustion

WHAT HAPPENED?
You were a part of a stony limestone outcrop for as long as you remember. Now you have been crushed, transported and thrown into a kiln. You don't recall ever being this hot. As the heat increases, you break your bonds and take flight.

PROCESS: Combustion

- To make cement, limestone (calcium carbonate) is heated in kilns, breaking it down into calcium oxide and carbon dioxide.
- Carbon dioxide is also released when fossil fuels are burned to heat the kilns to 1400°C.
- Presently, cement production accounts for approximately 5% of global carbon dioxide emissions.

NEW DESTINATION: Go to Atmosphere

STATION: Combustion

WHAT HAPPENED?
Did you say campfire? I hope you brought s'mores! It takes some time to get started, but once the wood fibres start to burn, the heat and light you give off is breathtaking. As the smoke rises into the clear night sky, so do you.

PROCESS: Combustion

- Large amounts of carbon are released into the atmosphere through the burning of biomass and plant-based fuels *(e.g., wood used for heating or in forest fires, campfires, cigarette smoking, barbeques, and corn based fuels).*

NEW DESTINATION: Go to Atmosphere

STATION: Combustion

WHAT HAPPENED?
Extracted as crude oil, you have been heated, cooled, distilled and mixed to make the perfect blend of gasoline. Now heated again inside a car's engine, you combine with oxygen and make a run for the open skies.

PROCESS: Combustion

- Inside a car's engine, gasoline is burned and the bond between the hydrogen and carbon breaks giving off a large amount of energy to power the engine. The carbon combines with oxygen and enters the atmosphere as carbon dioxide gas.

NEW DESTINATION: Go to Atmosphere

STATION: Combustion

WHAT HAPPENED?
Someone has turned on a gas stove and you are on the job, providing heat for a delicious meal. As the heat escapes, so do you, back into the air, free at last.

PROCESS: Combustion

- Natural gas is made up mostly of the gas methane and is burned as a fuel to produce electricity or directly used in homes to provide heat in cooking, hot water heaters, dryers and furnaces.

NEW DESTINATION: Go to Atmosphere

STATION: Combustion

WHAT HAPPENED?
You have been transported from the forest to the paper mill. As part of the tree bark, your wood fibres are not long enough for paper making. Instead, you are burned for energy to run the large steam rollers in the mill. You leave your ashes behind and head to the clouds.

PROCESS: Combustion

- Papermaking is an energy-intensive endeavor, using both fossil (natural gas, oil) and biomass (wood) fuels.
- Energy is needed to boil wood chips to form a thick wood pulp, run rollers and other machines, and produce steam in the finishing process.

NEW DESTINATION: Go to Atmosphere

Carbon Cycle Plants Cards

STATION: Plants

WHAT HAPPENED?
It's a cloudy dark day and the plant you are in needs some of its own sugar energy to live. Now it's your turn to leave, once the sugar is used.

PROCESS: Respiration in Aquatic Plants
- During the night, plants use some of the sugars they created for energy because there is no sunlight for photosynthesis.
- Respiration involves the breaking down of sugar into carbon dioxide and water. The carbon dioxide is dissolved into the water.
- If no oxygen is available, respiration produces methane.

NEW DESTINATION: Go to Water

STATION: Plants

WHAT HAPPENED?
You knew it was coming, but the snow was much colder than you expected. Your plant assured you that its roots would help it stay alive, but the leaf you are in would have to die. Maybe you will see each other next summer.

PROCESS: Death and Decomposition
- When plants or parts of the plant (e.g., leaves) die, and fall to the soil, fungi, bacteria and invertebrates in the soil break down the parts of the plant into carbon compounds, enriching the soil.

NEW DESTINATION: Go to Soils

STATION: Plants

WHAT HAPPENED?
Shhhh, everyone's sleeping. Your plant host wants a quick night snack. You gladly offer yourself and the rest of the sugar molecule as energy and then head back out into the wide open spaces.

PROCESS: Respiration in Terrestrial Plants
- During the night, plants use some of the sugars they created for energy because there is no sunlight for photosynthesis.
- Respiration involves the breaking down of sugar into carbon dioxide and water. If no oxygen is available, respiration produces methane.

NEW DESTINATION: Go to Atmosphere

STATION: Plants

WHAT HAPPENED?
Oooooh, that tickles. A plant called the Indian Pipe has just combined its roots with yours, taking some of your sugars. You don't mind sharing as long as you both can live!

PROCESS: Parasitism
- A parasitic plant is one that lives on another plant and depends on the host plant for its energy (sugars) and nutrients.

NEW DESTINATION: Go to Plants

STATION: Plants

WHAT HAPPENED?
You have had a wonderful long stay inside a forest tree. Now that your host tree has been cut down to make fuel wood, you wonder where the next adventure will lead you.

PROCESS: Harvesting
- Wood, peat and other plant materials (e.g., corn) are harvested as fuel.
- Forests store 86% of the planet's terrestrial above-ground carbon and 73% of the planet's soil carbon.

NEW DESTINATION: Go to Combustion

STATION: Plants

WHAT HAPPENED?
You didn't remain part of the plant leaf for very long. Before you knew it, you were an insect's meal, and then a bird's. Now inside the bird, your bonds with hydrogen are being broken up to provide energy and then made again with other carbons to help the bird make new feathers.

PROCESS: Consumption
- Herbivores and omnivores eat plants for energy and nutrients. The sugars and starches they eat are broken down by a process of metabolism.

NEW DESTINATION: Go to Animals

Carbon Cycle Plants Cards

STATION: Plants

WHAT HAPPENED?

The plant you are in — you call him Peat — dies and sinks to the bottom of the bog. Over time you are squished and turned into coal.

PROCESS: Carbonification

- Plant material falls to the bottom of swamps and bogs. Because there is little to no oxygen, the dead plant matter builds up faster than it can decay.
- Over time and with lots of pressure, the dead plant matter is changed to fossil fuels such as coal, oil and natural gases.
- Mud and organic compounds from algal and bacterial remains make oil shale. Oil shale is also known as marlstone and contains kerogen, which is an immature precursor to oil and gas.

NEW DESTINATION: Go to Rock Cycle

STATION: Plants

WHAT HAPPENED?

The habitat that you live in is going to be burned to make room for houses. You hope that new plants will grow soon, so you can come back and visit.

PROCESS: Deforestation / Harvesting

- When forests are burned or land is cleared of plants for farms, houses, or other reasons, large amounts of carbon are released forming carbon dioxide when mixed with oxygen. Land use changes are causing just under a billion metric tonnes of carbon to be emitted into the atmosphere.
- Peat is so rich in carbon, it emits carbon dioxide when it is harvested.

NEW DESTINATION: Go to Atmosphere

Carbon Cycle Rock Cycle Cards

STATION: Rock Cycle

WHAT HAPPENED?
You were once peat, but extreme heat and pressure over millions of years have changed you into a dense, carbon-rich rock called coal. Recently, machines scraped the coal you are in from the walls of an underground mine and conveyer belts brought you to the surface. Now you are ready for your new assignment.

PROCESS: Extraction
- Coal is a solid combustible sedimentary rock extracted from the Earth's crust to be burned for fuel. It can be found close to the surface or deep underground.
- Older coal such as anthracite has the highest carbon content whereas lignite, a brown coal, has a lower carbon and higher moisture content.

NEW DESTINATION: Go to Combustion

STATION: Rock Cycle

WHAT HAPPENED?
You are part of the lava that just exploded into the air. You are so hot that you continue as gas.

PROCESS: Volcanic Eruption
- Carbon dioxide is created when volcanoes explode or gas escapes from inside the Earth's interior.
- At present, volcanoes emit between 130 and 380 million metric tonnes of carbon dioxide per year. For comparison, humans emit about 30 billion tonnes of carbon dioxide per year — 100-300 times more than volcanoes — by burning fossil fuels.

NEW DESTINATION: Go to Atmosphere

STATION: Rock Cycle

WHAT HAPPENED?
The hot water bath to help clean the sand from the tar heats you up, so you don't stay around for long. You head back up into the clouds.

PROCESS: Production of Fuels
- Carbon dioxide is released in large amounts as oil is extracted from oil shale.
- Tar sands (also referred to as oil sands) are a combination of clay, sand, water, and bitumen — a heavy black viscous oil. The tar sands mining procedure releases at least three times the carbon dioxide emissions as regular oil production.

NEW DESTINATION: Go to Atmosphere

STATION: Rock Cycle

WHAT HAPPENED?
That really small flakey plant living on your rock has just "broken up" with you. Then to make matters worse, you were minding your own business until some acid rain dissolved you into water.

PROCESS: Rock Weathering
- Extreme storms such as hurricanes and typhoons bury a lot of carbon because they wash so much sediment back into the ocean.
- Carbonic acid in rain and groundwater react with calcium-bearing minerals in rocks. Rivers carry the dissolved calcium and carbonate ions to the ocean.
- Lichens are also able to break down the rocks over thousands of years.

NEW DESTINATION: Go to Water

STATION: Rock Cycle

WHAT HAPPENED?
The warm, shallow waters that were once above you have long dried up. Over time, the limestone rock, which is now your home, has been folded, compressed and changed under heat and pressure. Recently, large chunks have been cut out of the layers of rock and then crushed into smaller pieces. You find yourself loaded into in a large dump truck, excited to be part of whatever adventure awaits.

PROCESS: Extraction
- Limestone is a sedimentary rock that is valued as building material. It is generally mined or extracted in an open quarry, by cutting or splitting it from the limestone deposit once the top layers of soil and vegetation have been removed.

NEW DESTINATION: Go to Combustion

STATION: Rock Cycle

WHAT HAPPENED?
You can't believe your luck: you have been freed from your hard shale rock where you have been trapped for 300 million years. After being purified you are transported through pipes, ready to provide energy wherever you are needed.

PROCESS: Extraction
- Most natural gas has been found in pockets underneath an impervious cap rock layer after migrating through the permeable rock in which it was formed. Shale natural gas, however, remains trapped in the original rock formations.
- Hydraulic fracking opens and widens cracks within the shale's layers by injecting water, chemicals, and sand at high pressure, which releases the trapped natural gas.

NEW DESTINATION: Go to Combustion

Carbon Cycle Soils Cards

STATION: Soils

WHAT HAPPENED?
This forest fire is one of the biggest you've seen and it is burning deep into the soil. All you can do is grab onto a molecule of oxygen as you are whisked up into the atmosphere.

PROCESS: Combustion
- When fire burns in natural areas such as forests or fields, the oxygen combines with the organic (carbon) matter in soil and produces carbon dioxide and water vapour.

NEW DESTINATION: Go to Atmosphere

STATION: Soils

WHAT HAPPENED?
You are so glad to have spring come after the long cold winter. Look, there are some new plants whose roots are looking for you. Enjoy your sweet adventure becoming sugar inside the new plant.

PROCESS: Photosynthesis
- Green plants take in carbon dioxide through their root systems to be used in photosynthesis. The sugars created by photosynthesis can be used to make more roots.

NEW DESTINATION: Go to Plants

STATION: Soils

WHAT HAPPENED?
Once part of a dead leaf, you've been in the soil for hundreds of years. Your final job as an organic carbon compound is to retain water and nutrients for plants. As the last bond is broken, you finally and fully decompose back into the soil.

PROCESS: Decomposition
- Soils store three times as much carbon as plants and the atmosphere. In the soil, carbon is found in living bacteria and fungi, in dead animal and plant carbon compounds (e.g., cellulose and lignin in plants), and in humus carbon compounds such as fulvic acid and humic acid.
- Some forms of organic carbon (e.g., humus) provide very little food for soil organisms, and therefore last for hundreds of years before finally decomposing.

NEW DESTINATION: Go to Soils

STATION: Soils

WHAT HAPPENED?
It's tough living in the soil in a cow pasture. You get stepped on, squished, and now all your plant cover is gone. You can barely hang on the soil any more. As things dry up, you and an oxygen molecule take for the skies.

PROCESS: Oxidation
- Clearing forests, turning soil for crops, draining land of water and overgrazing by animals all expose soil to the air. Mining operations (e.g., pipelines and open pit mines) expose the soil by removing the plant cover. When soil is not covered with growing plants, the carbon from decayed plants mixes with oxygen (oxidation) and forms carbon dioxide.

NEW DESTINATION: Go to Atmosphere

STATION: Soils

WHAT HAPPENED?
Now that winter has come, your home, a plant leaf, has fallen to the ground. You are quickly broken down by fungi and bacteria and then eaten by various other soil animals.

PROCESS: Consumption
- When plants, animals or other forms of life die, living soil organisms such as fungi, microorganisms and invertebrates (e.g., insects, slugs, snails, worms, millipedes) feed on the organic matter for energy and for building their cell structures.
- Soil decomposers play an essential role in the breakdown of organic matter, recycling it and making it available again for other organisms.

NEW DESTINATION: Go to Animals

STATION: Soils

WHAT HAPPENED?
What's that smell? Animal manure has been added to enrich the soil and you are right in the middle of it all. Not to worry. Decomposers are on the job, transforming you into valuable carbon compounds plants can use.

PROCESS: Consumption
- Soil decomposers play an essential role in the breakdown of organic matter, recycling it and making it available again for other organisms.
- Although plants absorb most of the carbon dioxide they need from the atmosphere, small amounts of carbon dioxide and carbonates are absorbed by plant roots.

NEW DESTINATION: Go to Plants

Carbon Cycle Water Cards

STATION: Water

WHAT HAPPENED?
After a little while in the pond singing with the frogs, you passed back up into the air again.

PROCESS: Diffusion
- Dissolved carbon dioxide is released from the surfaces of fresh water ponds, lakes and rivers, back into the atmosphere as water warms up.

NEW DESTINATION: Go to Atmosphere

STATION: Water

WHAT HAPPENED?
As the waves hit the shore, you feel the sun's warmth on the water surface. Before long, you are floating out of the water into the air.

PROCESS: Diffusion
- Dissolved carbon dioxide is released from the ocean's surface back into the atmosphere as water warms up.

NEW DESTINATION: Go to Atmosphere

STATION: Water

WHAT HAPPENED?
Tiny green marine plants floating in the sunlit ocean surface waters, absorb you into their cells.

PROCESS: Photosynthesis
- Using energy from the sun, phytoplankton combine water and carbon dioxide from the water to form sugar and oxygen.
- Sugars are used to make all the parts of their delicate structures.

NEW DESTINATION: Go to Plants

STATION: Water

WHAT HAPPENED?
It's spring and the ice covering the pond begins to thaw. Under the water, a water lily takes you into its cells to begin new growth.

PROCESS: Photosynthesis
- Using energy from the sun, plants combine water and carbon dioxide to form sugar and oxygen.
- Sugars are used to make all the parts of their plant structures: leaves, roots, flowers, etc.

NEW DESTINATION: Go to Plants

STATION: Water

WHAT HAPPENED?
It's time for a snail to make a new shell. No need to go far, all the stuff to make a new one is all right here!

PROCESS: Body Building
- In the oceans, corals and other shell-building animals, use carbon in the form of calcium carbonate to make their shells and structures.
- Calcium carbonate is made by combining dissolved carbonate with dissolved calcium.

NEW DESTINATION: Go to Animals

STATION: Water

WHAT HAPPENED?
Sluuuurrrp! All of a sudden, a mat of green algae appeared floating on the pond you were in. You and all the other carbon molecules were quickly sucked up by all the tiny plants.

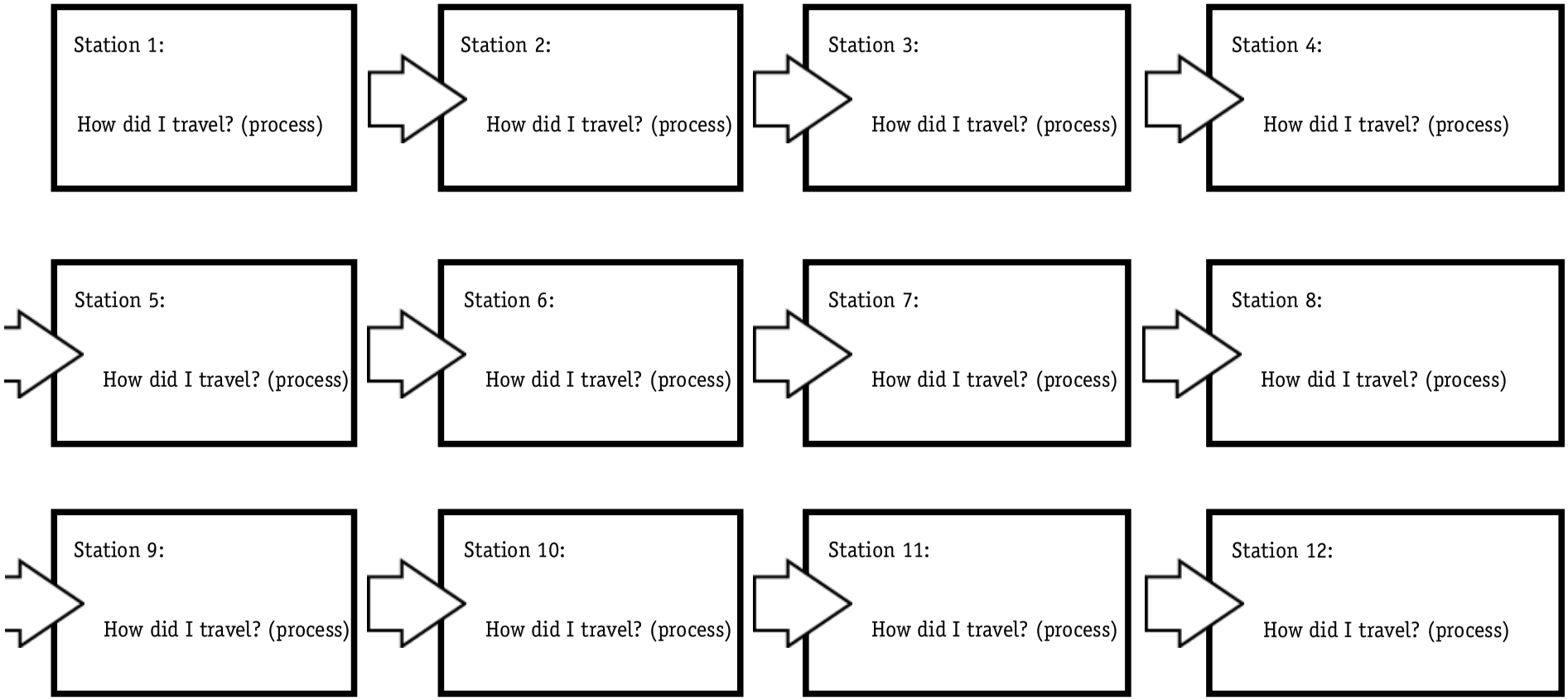
PROCESS: Body Building
- Excess nutrients (nitrogen and phosphorus) from fertilizer, waste water or storm water runoff causes freshwater algae to multiply very quickly especially when the water is warm and shallow.

NEW DESTINATION: Go to Plants

My Life as a Carbon Molecule

Record your journey as a carbon molecule through the carbon cycle

Name (s):_____ Date:_____



Record how many times you visited each station

Animals	Atmosphere	Combustion	Plants	Rock Cycle	Soils	Water