In partnership with Garfield Weston Foundation

EXPLORE: URBAN NATURE

Carbon Cycle Passport

THE URBAN NATURE PROJECT

NATURAL HISTORY MUSEUM

CARBON CYCLE PASSPORT

OBJECTIVE

To increase students' knowledge of the carbon cycle and human impacts on it.

SUMMARY

Students simulate a molecule of carbon's movement through various locations in the carbon cycle, before acting out different human impact scenarios.

INTRODUCTION

The movement of carbon through of the natural environment is the focus of much scientific research. Global warming and climate change can be attributed to increases in heat-trapping gases, such as carbon dioxide.

Students must develop an understanding of how carbon moves through the environment to appreciate how anthropogenic influences disrupt the balance of the carbon cycle. Since anthropogenic influences impact how much carbon is reintroduced to the active carbon cycle, students should recognize that human actions negatively affect the environment.

TIME NEEDED

One lesson

PARTICIPANTS

Whole class

RESOURCES NEEDED

- seven dice
- seven Station signs
- seven Station movement cards
- seven After human interference cards
- carbon passports for each student
- stamps or stickers for each station

LEARNING OUTCOMES

- describe the movement of carbon within the carbon cycle
- classify elements of the carbon cycle as sinks or sources
- evaluate how human activities impact the carbon cycle
- understand that changes in Earth's atmospheric composition impact climate and life on Earth

WARM UP

Discuss where carbon can be found on Earth and its role in each of the places identified. Review the processes that move carbon around in the carbon cycle

Physical processes

- water currents
- settling to the ocean floor or to the ground

Chemical and biological processes

- respiration – exchange of gases through breathing
- photosynthesis – synthesis of complex organic materials, especially carbohydrates, from carbon dioxide, water and inorganic salts, using sunlight as the source of energy
- combustion – the act or process of burning
- dissolving gaseous carbon dioxide into water, where it takes the form of carbonic acid
- carbon dioxide coming out of carbonic acid into the air (like when you open a fizzy drink)
- death and decomposition – breakdown or decay of organic matter

EXTENSION IDEAS

- Ask a few students to tell the story of how their carbon atom moved through the cycle. Who had the most exciting journey as a carbon atom?
- Have each student create a bar graph to show the number of times their carbon atom was at each station.
- Discuss the results – using the bar graphs have the students explain where the most and least amount of carbon was in the cycle?

INSTRUCTIONS

1. Tell the students that they are carbon atoms moving through the carbon cycle.
2. Categorize the places carbon can be found into these seven stations: Atmosphere, Plants, Animals, Soil, Surface Ocean, Deep Ocean, and Fossil Fuels. Point out the areas of the room that are labelled with each station and contain the directions for movement from that station (the Station Movement cards).
3. Explain that for the first round, they will be simulating the carbon cycle before human disturbance, about 6,000 years ago.
4. Assign students to each station randomly and evenly. Ask students to identify the different places carbon could go from their station. Discuss the processes that allow for the transfer of carbon between stations. Identify sources and sinks of carbon.
5. Students take turns to roll the die and to follow the station directions for movement from (or retention at) each station. Remind them that they are representing atoms of carbon moving through the carbon cycle and that they should record their movements in their passport.
6. Allow only a few minutes for this round of the game. Students will quickly realize the routine movements (or non-movements) in the 'natural' carbon cycle. On the whiteboard, record the number of carbon atoms (students) at each station. This is the baseline reading, before human interference.
7. Replace the Station Movement cards with the After Human Interference cards. Have the students start from their present station and continue playing the game. Continue the simulation until all the carbon atoms are eliminated from the Fossil Fuels station.

CLASS DISCUSSION AND ACTION PLAN:

- Have students compare the movement of carbon before and after human interference.
- Discuss what has happened to the Fossil Fuels as well as any changes in the number of atoms in certain stations. Refer back to the carbon atom location record 'before human interference'.
- Discuss the effects that these differences could have on climate change.
- Ask if there are any actions humans could take to help return the carbon cycle to a more natural state. Discuss the actions that returned carbon to plants or sequestered carbon in sinks.
- Develop an action plan that students could follow in their everyday lives to reduce anthropogenic disturbances to the carbon cycle.

BACKGROUND

Most of Earth's carbon is stored in rocks, sediments and soil. The rest is in the ocean, the atmosphere and living organisms. These are the reservoirs through which carbon cycles.

Human impacts on the carbon cycle

Human activities affect the carbon cycle. Burning fossil fuels releases carbon into the atmosphere and changes in land use, such as deforestation, release carbon stored in trees and reduce the amount of carbon that is sequestered (stored away) in soil and vegetation.

While humans emit far less carbon dioxide than nature, the amount we emit exceeds the storage capacity of plants and oceans, as it is on top of the amount they are already absorbing from natural sources. As a result, most of the carbon dioxide we emit remains in the atmosphere and hangs around for a long time, between 300 to 1,000 years. Thus, changes humans make to the atmosphere by emitting carbon dioxide will endure for many generations.

CO2 AND A WARMING PLANET

Background

Carbon dioxide, or CO_2, is one of the primary greenhouse gases. Greenhouse gases are those that can trap thermal radiation or heat that the Earth would otherwise emit to space.

Carbon dioxide is important for life on Earth and integral to maintaining the protective blanket that is our atmosphere. Increases in atmospheric carbon dioxide concentrations, however, adversely alter the global climate.

The Earth system maintains a check and balance on carbon dioxide through the carbon cycle and what we call sources and sinks. A source is any process that releases carbon dioxide into the atmosphere, such as plant and animal decay, deforestation, when we breathe out, or the burning of fossil fuels like coal or gas. A sink is a reservoir that removes carbon dioxide from the atmosphere, such as when vegetation and trees take up carbon dioxide for photosynthesis. The oceans remove carbon dioxide from the atmosphere as well. Phytoplankton in the ocean take up as much CO_2 for photosynthesis as plants on land.

The concentration of carbon dioxide in Earth's atmosphere is currently at nearly 414 parts per million (ppm) and rising. This represents a 48 per cent increase since the beginning of the Industrial Age, when the concentration was near 280 ppm, and an 11 percent increase since 2000, when it was near 370 ppm. Scientists know the increases are caused primarily by human activities because carbon produced by burning fossil fuels has a different ratio of heavy-to-light carbon atoms, so it leaves a distinct 'fingerprint' that can be measure.

A warmer world means melting ice, coastal flooding, more extreme weather events, and this affects animals, plants and food growing.

Reducing impact

Without reversal or mitigation, the continued excess release of carbon dioxide into the atmosphere will eventually warm the planet to the extent that catastrophic changes ensue. The only serious debate at this point is just how quickly those changes will occur, which regions will see them and in what forms.

To reduce the impact of these changes, we need to cut carbon dioxide emissions as fast as possible and find ways of storing away the excess carbon dioxide in the atmosphere. We also need to protecting natural sources that do this (forests, wetlands). All of these measures are needed to keep the level of carbon dioxide and other greenhouse gasses in the atmosphere at a manageable level.

CLIMATE SCIENCE

Discover how carbon dioxide is being monitored from space

The new Orbiting Carbon Obervatory-2 (OCO-2) is NASA's first Earth-orbiting satellite dedicated to studying atmospheric carbon dioxide from space. It will peer into the carbon cycle like never before.

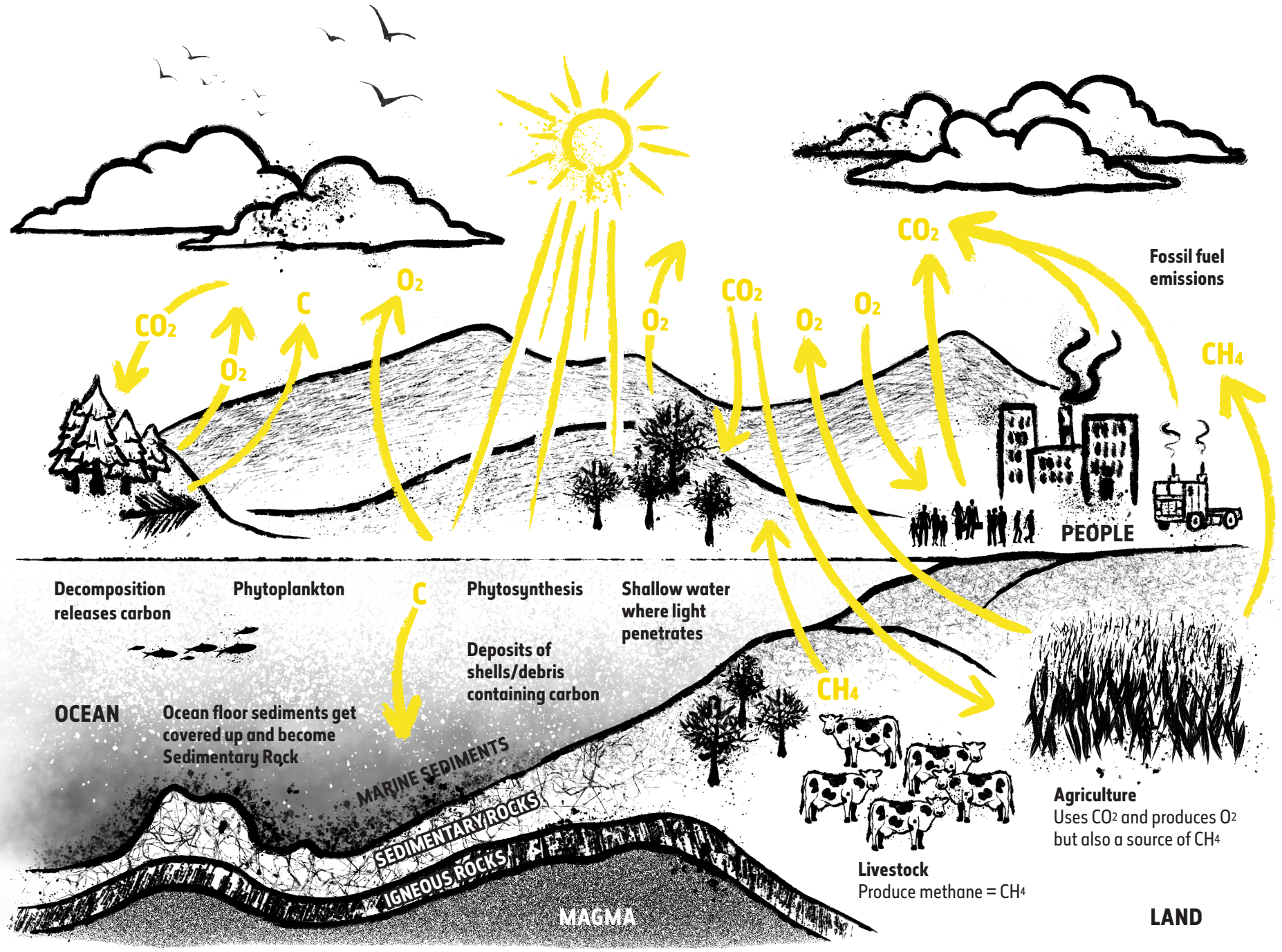
OCO-2 will tell us where carbon is going and give clues to where it will end up.

climate.nasa.gov/climate_resources/99/graphic-measuring-carbon-dioxide-from-space/

THE CARBON CYCLE PASSPORT

Record the places you have traveled as a carbon molecule before human interference.
You may or may not fill up all the spaces.

Student's Name		
BEFORE HUMAN INTERFERENCE		
Station stop	What happens	Destination
1.		
2.		
3.		
4.		
5.		
6.		
AFTER HUMAN INTERFERENCE		
Station stop	What happens	Destination
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		


CO_2
O_2
C
O_2
O_2
CO_2
O_2
O_2
CO_2
Fossil fuel emissions
CH_4
PEOPLE
Decomposition releases carbon
Phytoplankton
C
Phytosynthesis
Deposits of shells/debris containing carbon
Shallow water where light penetrates
CH_4
OCEAN
Ocean floor sediments get covered up and become Sedimentary Rock
MARINE SEDIMENTS
SEDIMENTARY ROCKS
IGNEOUS ROCKS
MAGMA
Agriculture
Uses CO_2 and produces O_2 but also a source of CH_4
Livestock
Produce methane = CH_4
LAND

CARBON CYCLE MOVEMENTS

ATMOSPHERE – BEFORE HUMAN INTERFERENCE (ABOUT 6,000 YEARS AGO)

If you roll...	Then you...
1	Stay in Atmosphere. Much of the carbon dioxide in the atmosphere circulates through the atmosphere and does not interact with other sources or sinks of carbon.
2	Go to Plants. You are used by a plant in photosynthesis. The carbon you provide can be used to create the plant's structures.
3	Stay in Atmosphere. Much of the carbon dioxide in the atmosphere circulates through the atmosphere and does not interact with other sources or sinks of carbon.
4	Stay in Atmosphere. Much of the carbon dioxide in the atmosphere circulates through the atmosphere and does not interact with other sources or sinks of carbon.
5	Go to Surface Ocean. About 12 per cent of carbon in the atmosphere is mixed into the shallow ocean. This carbon dioxide can be used by photosynthetic algae or stored in the water.
6	Go to Plants. You are used by a plant in photosynthesis. The carbon you provide can be used to create the plant's structures.

PLANTS – BEFORE HUMAN INTERFERENCE (ABOUT 6,000 YEARS AGO)

If you roll...	Then you...
1	Go to Soil. The tree shed its leaves, and you are an atom of carbon from those dead leaves that enters the soil.
2	Stay in Plants. You are a carbon atom in the tree's trunk, a part that will not likely be removed or destroyed.
3	Go to Animals. The leaves and berries that the plant produced contain your carbon atom. You will be processed into structures in the animal that consumed you.
4	Stay in Plants. You are a carbon atom in the tree's roots, a part that will not likely be removed or destroyed.
5	Stay in Plants. You are a carbon atom in the tree's branches, a part that will not likely be removed or destroyed.
6	Stay in Plants. You are a carbon atom in the tree's trunk, a part that will not likely be removed or destroyed.

ANIMALS – BEFORE HUMAN INTERFERENCE (ABOUT 6,000 YEARS AGO)

If you roll...	Then you...
1	Stay in Animals. You are consumed by a predator that has a long life. The carbon atom is stored as fat in the animal.
2	Go to Soil. The animal that consumed you died and your carbon atom is returned to the soil.
3	Go to Atmosphere. The animal that consumed you respired (breathed) you out as carbon dioxide.
4	Stay in Animals. You are consumed by a vulnerable prey animal that is, in turn, consumed by a predator. You are stored as protein in the muscles of the predator.
5	Go to Atmosphere. The animal that consumed you respired (breathed) you out as carbon dioxide.
6	Go to Atmosphere. The animal that consumed you respired (breathed) you out as carbon dioxide.

SOIL – BEFORE HUMAN INTERFERENCE (ABOUT 6,000 YEARS AGO)

If you roll...	Then you...
1	Stay in Soil. Much of the carbon in the soil is stored and does not interact with other sources or sinks of carbon.
2	Go to Plants. You are used by a plant in photosynthesis. The carbon you provide can be used to create the plant's structures.
3	Go to Fossil Fuels. Your carbon molecule has been in the soil so long that it binds together with other carbon molecules to create fossil fuels.
4	Go to the Atmosphere. A tiny decomposer uses your carbon atom as it breaks down the detritus in the soil.
5	Stay in Soil. Much of the carbon in the soil is stored and does not interact with other sources or sinks of carbon.
6	Go to Fossil Fuels. Your carbon molecule has been in the soil so long that it binds together with other carbon molecules to create fossil fuels.

SURFACE OCEAN – BEFORE HUMAN INTERFERENCE (ABOUT 6,000 YEARS AGO)

If you roll...	Then you...
1	Go to Deep Ocean. Your carbon atom was part of an ocean organism that has died and has sunk to the bottom of the ocean.
2	Stay in Surface Ocean. Much of the carbon dioxide in the ocean circulates through the surface ocean and does not interact with other sources or sinks of carbon.
3	Go to Deep Ocean. Your carbon atom was part of an ocean organism that has died and has sunk to the bottom of the ocean.
4	Stay in Surface Ocean. Much of the carbon dioxide in the ocean circulates through the surface ocean and does not interact with other sources or sinks of carbon.
5	Go to Atmosphere. Your carbon dioxide atom is used by organisms in the water for respiration.
6	Go to Atmosphere. Your carbon dioxide atom is used by organisms in the water for respiration.

DEEP OCEAN – BEFORE HUMAN INTERFERENCE (ABOUT 6,000 YEARS AGO)

If you roll...	Then you...
1	Stay in Deep Ocean. Much of the carbon dioxide in the deep ocean circulates through the ocean and does not interact with other sources or sinks of carbon.
2	Stay in Deep Ocean. Much of the carbon dioxide in the deep ocean circulates through the ocean and does not interact with other sources or sinks of carbon.
3	Go to Surface Ocean. Some carbon dioxide in the deep ocean moves to the surface through the process of upwelling.
4	Go to Surface Ocean. Some carbon dioxide in the deep ocean moves to the surface through the process of upwelling.
5	Go to Surface Ocean. Some carbon dioxide in the deep ocean moves to the surface through the process of upwelling.
6	Go to Animals. An organism in the water has taken you up as food.

FOSSIL FUELS – BEFORE HUMAN INTERFERENCE (ABOUT 6,000 YEARS AGO)

If you roll...	Then you...
1	Stay in Fossil Fuels. All of the carbon in fossil fuels is accumulated.
2	Stay in Fossil Fuels. All of the carbon in fossil fuels is accumulated.
3	Stay in Fossil Fuels. All of the carbon in fossil fuels is accumulated.
4	Stay in Fossil Fuels. All of the carbon in fossil fuels is accumulated.
5	Stay in Fossil Fuels. All of the carbon in fossil fuels is accumulated.
6	Stay in Fossil Fuels. All of the carbon in fossil fuels is accumulated.

ATMOSPHERE - AFTER HUMAN INTERFERENCE (PRESENT DAY)

If you roll...	Then you...
1	Stay in Atmosphere. Much of the carbon dioxide in the atmosphere circulates through the atmosphere and does not interact with other sources or sinks of carbon.
2	Go to Plants. You are used by a plant in photosynthesis. The carbon you provide can be used to create the plant's structures.
3	Stay in Atmosphere. Much of the carbon dioxide in the atmosphere circulates through the atmosphere and does not interact with other sources or sinks of carbon.
4	Stay in Atmosphere. Much of the carbon dioxide in the atmosphere circulates through the atmosphere and does not interact with other sources or sinks of carbon.
5	Go to Surface Ocean. About 12 per cent of carbon in the atmosphere is mixed into the shallow ocean. This carbon dioxide can be used by photosynthetic algae or stored in the water.
6	Go to Plants. You are used by a plant in photosynthesis. The carbon you provide can be used to create the plant's structures.

PLANTS - AFTER HUMAN INTERFERENCE (PRESENT DAY)

If you roll...	Then you...
1	Go to Soil. The tree shed its leaves, and you are an atom of carbon from those dead leaves that enters the soil.
2	Stay in Plants. You are a carbon atom in the tree's trunk, a part that will not likely be removed or destroyed.
3	Go to Animals. The leaves and berries that the plant produced contain your carbon atom. You will be processed into structures in the animal that consumed you.
4	Go to Atmosphere. Humans have cut down the tree that you were part of and have used it to create lumber. You were part of the excess that was burned.
5	Stay in Plants. You are a carbon atom in the tree's branches, a part that will not likely be removed or destroyed.
6	Go to Soil. Humans have cut down the tree that you were part of and left the bit of stump that you were in to rot in the soil.

ANIMALS - AFTER HUMAN INTERFERENCE (PRESENT DAY)

If you roll...	Then you...
1	Stay in Animals. You are consumed by a predator that has a long life. The carbon atom is stored as fat in the animal.
2	Go to Soil. The animal that consumed you died and your carbon atom is returned to the soil.
3	Go to Atmosphere. The animal that consumed you respired (breathed) you out as carbon dioxide.
4	Stay in Animals. You are consumed by a vulnerable prey animal that is, in turn, consumed by a predator. You are stored as protein in the muscles of the predator.
5	Go to Atmosphere. The animal that consumed you respired (breathed) you out as carbon dioxide.
6	Go to Atmosphere. The animal that consumed you respired (breathed) you out as carbon dioxide.

SOIL - AFTER HUMAN INTERFERENCE (PRESENT DAY)

If you roll...	Then you...
1	Stay in the Soil. Much of the carbon in the soil is stored and does not interact with other sources or sinks of carbon.
2	Go to Plants. You are used by a plant in photosynthesis. The carbon you provide can be used to create the plant's structures.
3	Go to Fossil Fuels. Your carbon molecule has been in the soil so long that it binds together with other carbon molecules to create fossil fuels.
4	Go to Atmosphere. A tiny decomposer uses your carbon atom as it breaks down the detritus in the soil.
5	Stay in Soil. Much of the carbon in the soil is stored and does not interact with other sources or sinks of carbon.
6	Go to Atmosphere. A tiny decomposer uses your carbon atom as it breaks down the detritus in the soil.

SURFACE OCEAN - AFTER HUMAN INTERFERENCE (PRESENT DAY)

If you roll...	Then you...
1	Go to Deep Ocean. Your carbon atom was part of an ocean organism that has died and has sunk to the bottom of the ocean.
2	Stay in Surface Ocean. Much of the carbon dioxide in the ocean circulates through the surface ocean and does not interact with other sources or sinks of carbon.
3	Go to Deep Ocean. Your carbon atom was part of an ocean organism that has died and has sunk to the bottom of the ocean.
4	Stay in Surface Ocean. Much of the carbon dioxide in the ocean circulates through the surface ocean and does not interact with other sources or sinks of carbon.
5	Go to Atmosphere. Your carbon dioxide atom is used by organisms in the water for respiration.
6	Go to Atmosphere. Your carbon dioxide atom is used by organisms in the water for respiration.

DEEP OCEAN - AFTER HUMAN INTERFERENCE (PRESENT DAY)

If you roll...	Then you...
1	Stay in Deep Ocean. Much of the carbon dioxide in the deep ocean circulates through the ocean and does not interact with other sources or sinks of carbon.
2	Stay in the Deep Ocean. Much of the carbon dioxide in the deep ocean circulates through the ocean and does not interact with other sources or sinks of carbon.
3	Go to Surface Ocean. Some carbon dioxide in the deep ocean moves to the surface through the process of upwelling.
4	Go to Surface Ocean. Some carbon dioxide in the deep ocean moves to the surface through the process of upwelling.
5	Go to Surface Ocean. Some carbon dioxide in the deep ocean moves to the surface through the process of upwelling.
6	Go to Animals. An organism in the water has taken you up as food in the deep ocean.

FOSSIL FUELS - AFTER HUMAN INTERFERENCE (PRESENT DAY)

If you roll...	Then you...
1	Go to Atmosphere. Humans have pumped the fuel that you are part of out of the ground and have used it to power their vehicles. You are emitted as a waste from the exhaust.
2	Go to Plants. Humans have pumped the fuel that you are part of out of the ground and have used it to create power at a power plant. You are emitted as dust from the stack pipe.
3	Go to Atmosphere. Humans have pumped the fuel that you are part of out of the ground and have used it to power their airplanes. You are emitted as a waste.
4	Go to Plants. Humans have pumped the fuel that you are part of out of the ground and have used it to create power at a power plant. You are emitted as dust from the stack pipe.
5	Go to Atmosphere. Humans have pumped the fuel that you are part of out of the ground and have used it to power their vehicles. You are emitted as a waste from the exhaust.
6	Go to Atmosphere. Humans have pumped the fuel that you are part of out of the ground and have used it to power their vehicles. You are emitted as a waste from the exhaust.

STATION SIGNS

ATMOSPHERE

You are currently a molecule of carbon dioxide in the atmosphere. The atmosphere is a blanket of gases that surround Earth. Most of these gases, including carbon dioxide, act like a greenhouse. They allow light to pass toward Earth, but they trap heat before it leaves Earth's atmosphere. They are known as 'heat trapping gases'. They are very important to life on Earth, but too much of a good thing isn't always a good thing.

PLANTS

You are currently a carbon compound in the structure of a plant. The plant has taken you in from the air and has created carbohydrates through the process of photosynthesis. Some of the carbon is emitted back to the atmosphere from the plant's leaves through respiration. Sometimes, carbon is stored as carbohydrates within the structure of the plant.

ANIMALS

You are currently a molecule of carbohydrate in an animal. You have been consumed by an animal to help it grow and develop. The animal can either store you away in its body structures or release you back to the atmosphere as it uses the carbohydrate you are stored in as energy.

SOIL

You are currently a molecule of carbon dioxide in the soil. Once you are here, you generally do not move around too much and are stored away. If you're stored long enough, you can join with other carbon molecules to create fossil fuels.

OCEAN SURFACE

You are currently a molecule of carbon dioxide in the surface ocean. The surface ocean mixes around due to ocean currents, but does not mix well with the deeper ocean. Most carbon that enters the surface ocean remains mixed in the surface ocean waters, but can move to different sources or sinks.

DEEP OCEAN

You are currently an atom of carbon in the deep ocean. The deep ocean has little interaction with other parts of the carbon cycle. It is, however, an important carbon sink within the cycle.

FOSSIL FUELS

You are currently an atom of carbon synthesized with other atoms in the soil. Fossil fuels are a rich source of energy created from carbon that has been stored for many millions of years. Since this carbon has been stored for millions of years, it has little effect on the carbon cycle. That is until humans disrupt the cycle.

Explore: Urban Nature is part of the Urban Nature Project

Lead donors

Made possible with Heritage Fund

Evolution Education Trust

THE CADOGAN CHARITY

Garfield Weston FOUNDATION

Supporting donors

The Wolfson* Foundation

CHARLES WILSON AND ROWENA OLEGARIO

Supporting sponsor

workman