The Carbon Cycle Game Data Sheet

1		6	
2		7	
3		8	
4		9	
5		10	

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Atmosphere

Instructions

1. Write the name of this station on the first blank line on your data sheet.
2. Roll the die once.
3. If you roll a MOVE roll, move to the station indicated.
4. If you roll a STAY roll, go back to step 1.

	STAY in Atmosphere. You are part of a CO_2 molecule that stays in the atmosphere for 1,000 years.
	MOVE to Trees. You are used by a tree in photosynthesis.
	STAY in Atmosphere. CO_2 in the atmosphere is measured in parts per million.
	STAY in Atmosphere. CO_2 in the atmosphere acts as a heat-trapping blanket.
	MOVE to Surface Ocean. You become dissolved into ocean water.
	STAY in Atmosphere. A small amount of CO_2 is needed in the atmosphere for life on Earth.

Dice from the Noun Project by Magicon. Atmosphere from Pixabay.

Trees

Instructions

1. Write the name of this station on the first blank line on your data sheet.
2. Roll the die once.
3. If you roll a MOVE roll, move to the station indicated.
4. If you roll a STAY roll, go back to step 1.

	MOVE to Soil. You are in a leaf that is shed during the autumn.
	STAY in Trees. You are in a tree's hard structure, such as the trunk or branches.
	MOVE to Animal. You are in a berry, leaf, bark, or other part of a tree eaten by a grazing animal.
	STAY in Trees. You are in a tree's roots.
	STAY in Trees. A growing forest absorbs more CO_2 than it emits.
	MOVE to Atmosphere. Trees die naturally or are disturbed by logging, forest fire, or storms.

Dice from the Noun Project by Magicon. Tree from Pixabay.

Animals

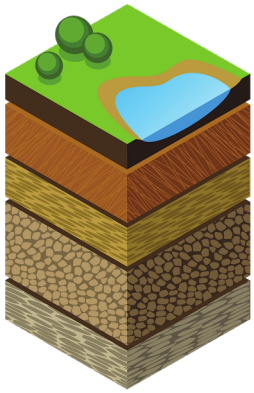
Instructions

1. Write the name of this station on the first blank line on your data sheet.
2. Roll the die once.
3. If you roll a MOVE roll, move to the station indicated.
4. If you roll a STAY roll, go back to step 1.

	STAY in Animals. You are part of the structure of a living thing (bone, muscle, etc.)
	MOVE to Soil. You are part of a land animal that dies and decomposes, mixing with the soil.
	MOVE to Surface Ocean. You are part of a fish that dies and decomposes, and you mix with the water.
	STAY in Animals. The animal you are in is eaten by a predator and used in the predator's body.
	MOVE to Surface Ocean. You are part of plankton that dies and decomposes, and you mix with the water.
	MOVE to Soil. You go through a land animal's digestive system, and then mix with the soil.

Dice from the Noun Project by Magicon. Deer from Pixabay.

Soil



Instructions

1. Write the name of this station on the first blank line on your data sheet.
2. Roll the die once.
3. If you roll a MOVE roll, move to the station indicated.
4. If you roll a STAY roll, go back to step 1.

	STAY in Soil. You're in undisturbed prairies and other grasslands, which store carbon.
	STAY in Soil. You're in permanently-frozen ground, called permafrost, which is a carbon sink.
	STAY in Soil. You're in a peatland, which is full of rich carbon storage.
	MOVE to Atmosphere. The soil was disturbed by agriculture, deforestation, a landslide, or other event.
	STAY in Soil. You're in a salt marsh, which is biologically rich and full of stored carbon.
	STAY in Soil. You're in soil at a no-till farm, which uses agricultural practices to store carbon.

Dice from the Noun Project by Magicon. Soil from Pixabay.

Surface Ocean

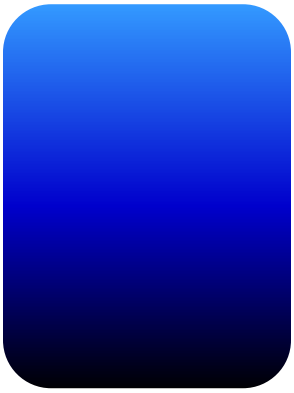
Instructions

1. Write the name of this station on the first blank line on your data sheet.
2. Roll the die once.
3. If you roll a MOVE roll, move to the station indicated.
4. If you roll a STAY roll, go back to step 1.

⚀	STAY in Surface Ocean. You are dissolved as CO_2 from the atmosphere.
⚁	STAY in Surface Ocean. You are in the sunlit zone in the ocean, about 200 meters (650 feet) deep.
⚂	MOVE to Deep Ocean. You are in seaweed that dies and sinks to the bottom of the ocean.
⚃	STAY in Surface Ocean. You are dissolved as CO_2, which makes the ocean more acidic.
⚄	STAY in Surface Ocean. You are dissolved as CO_2, which stays dissolved better in cold water.
⚅	MOVE to Atmosphere. You are in a storm, which releases you from the water to the atmosphere.

Dice from the Noun Project by Magicon

Deep Ocean



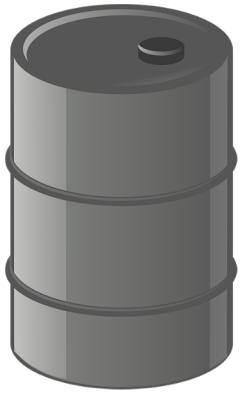
Instructions

1. Write the name of this station on the first blank line on your data sheet.
2. Roll the die once.
3. If you roll a MOVE roll, move to the station indicated.
4. If you roll a STAY roll, go back to step 1.

	STAY in Deep Ocean. You are dissolved in deep ocean, the largest biome on Earth.
	STAY in Deep Ocean. Humans have only explored 5% of the ocean.
	MOVE to Surface Ocean. You are part of upwelling near coasts and islands and during storms.
	STAY in Deep Ocean Some food webs in deep oceans use energy from chemicals instead of the sun.
	STAY in Deep Ocean. The ocean contains more than 95% of all the water on Earth.
	MOVE to Animal. You are used by a shelled animal to make its shell.

Dice from the Noun Project by Magicon

Fossil Fuels



Instructions

1. Write the name of this station on the first blank line on your data sheet.
2. Roll the die once.
3. If you roll a MOVE roll, move to the station indicated.
4. If you roll a STAY roll, go back to step 1.

	STAY in Fossil Fuels. Most fossil fuels are trapped in hard-to-reach places deep in the ground.
	STAY in Fossil Fuels. Most oil in the world formed about 200 million years ago.
	STAY in Fossil Fuels. Most coal in the world formed more than 300 million years ago.
	MOVE to Atmosphere. You are part of oil drilled out of the ground, which releases CO_2.
	MOVE to Atmosphere. You are in coal, which is burned to generate electricity.
	STAY in Fossil Fuels. The carbon in fossil fuels is from from plants and algae millions of years ago.

Dice from the Noun Project by Magicon. Barrel from Pixabay.

Today I Learned About Planting Trees

"One way to think about the terrestrial carbon cycle is that you've got this uptake and this release, and the system likes to find a state where the two are equal to each other."
Charles Harvey, Environmental Engineering, MIT
TILclimate podcast: Today I Learned About Planting Trees

The Carbon Cycle Game

Just like water, nitrogen, and other key life support, carbon moves through parts of the Earth system. In this game, you will represent one carbon atom and you will cycle through Earth ten times. Watch where you and your classmates end up over the course of the game.

The Parts of the System

Atmosphere: In the form of carbon dioxide (CO_2) carbon makes up about 0.04% of Earth's atmosphere. Even at this tiny concentration, it acts as a key part of the heat-trapping blanket that keep's the Sun's heat inside the atmosphere and warms Earth.

Trees: Trees, crops, and other land plants take in CO_2. Through photosynthesis, they convert the carbon into wood, roots, and leaves. When plants die, carbon is released through decomposition.

Animals: Animals consume the carbon in their food and use it to build muscle, bone, and energy. They release CO_2 as they breathe and other forms of carbon in their digestive processes.

Soil: Healthy, undisturbed soil stores carbon. If soils are disturbed by tilling, deforestation, or weather events, they release CO_2 to the atmosphere

Surface Ocean: The top level of the ocean absorbs CO_2 from the atmosphere. Through wave action and other ocean processes, it may release that carbon back to the atmosphere or move it to the Deep Ocean.

Deep Ocean: Deeper ocean areas (below about 650 feet) take in carbon from the surface ocean. It may stay there, be cycled back up, or used by ocean animals as food or to build their shells.

Fossil Fuels: When carbon has been stored in the soil for millions of years, it can become energy-rich fossil fuels such as coal, oil, and natural gas. When fossil fuels are burned, they release CO_2 into the atmosphere.

All images from Pixabay

Today I Learned About Planting Trees

"We know that deforestation releases CO_2. So we adjust our practices, to not deforest or to extract lumber in a more sustainable way. And then, in the long term, turn that around and start to pull carbon dioxide out of the atmosphere. I think it has a lot more potential in the long-term, after we've eliminated fossil fuel emissions, to actually lower atmospheric concentrations."

Charles Harvey, Environmental Engineering, MIT

TILclimate podcast: Today I Learned About Planting Trees

Can Trees Help?

Carbon cycles through our world. We need a regular amount of it in the atmosphere in the form of carbon dioxide (CO_2) to keep Earth warm enough to sustain life. However, rampant CO_2 from fossil fuel emissions (burning coal, oil, and natural gas) is acting like a blanket around Earth, trapping heat. This trapped heat is warming our air, ocean, and land, causing dramatic changes to weather patterns.

Forests are part of the carbon cycle. As they grow, trees absorb CO_2 from the atmosphere and use it to build their bark, wood, leaves, and roots. Mature trees store large amounts of carbon in their wood. Decaying leaves and deep roots add carbon to the soil. However, when trees die, or are cut down or burned, their carbon is released back into the atmosphere.

Scientists who study the climate and forests talk about carbon *flux*. A carbon flux is the amount of carbon exchanged between two (or more) carbon *pools* (such as the atmosphere, the ocean, soils, and living things.) Since these systems exchange carbon back and forth between them all the time, the amount of carbon in any given pool will fluctuate (flux) up and down.

For example, a forest in the Northern Hemisphere in the winter is mostly dormant, so it is not absorbing very much CO_2 from the atmosphere. In the summer, that same forest is growing quickly and may absorb much more CO_2 than it releases.

Image from Pixabay

Today I Learned About Planting Trees

Investigate Forests

Forests are large and complex. Scientists still don't have exact measures for precisely how much CO_2 they are "breathing" in and out. However, using satellite data, direct measurement tools, and models, scientists can approximate the effect of planting, protecting, or demolishing forests on the climate. You will investigate the current state of forests around the world and ask questions about what can and should be done to help forests pull carbon dioxide out of the atmosphere.

1. Visit https://www.globalforestwatch.org/map/
2. Turn off the three layers that are automatically on when you first visit the site. (Click **legend** and the **x** next to each layer to do this.)
3. Click through the options under Forest Change, Land Cover, Land Use, Climate, and Biodiversity.

Explore

As you see different datasets, what are you curious about? What questions do you have?

4. Under **Land Cover**, turn on **Tree Cover.**
5. Choose a region of the world of interest. This dataset is best viewed zoomed in to 8 or more (zoom level is found in the bottom right corner.)
6. Change the **canopy density** to 10%, 50%, and 75%.

Describe

What do you notice? How would you describe the forest in the area you chose?

Canopy Density?

Forest canopy density is a measurement of the ratio of vegetation (trees) to ground as seen from the air. A satellite or LIDAR image can be used to measure this.

Class	Canopy density
Very Dense Forest	70%+
Dense Forest	40% - 70%
Open Forest	10% - 40%
Scrub	<10%

7. Turn **Tree Cover** off and zoom back out to the world view.
8. Under **Forest Change**, turn on **Tree cover loss by dominant driver**. (For definitions of the drivers, hover your cursor over "Hover for details on drivers classes.")
9. Choose a region of the world of interest. This data set is best viewed zoomed to 3-5.

Describe

What do you notice? What are the dominant drivers of forest loss in this area? Why do you think this is? Are the dominant drivers of forest loss the same around the world?

Today I Learned About Planting Trees

Investigate Forests, cont'd

10. Turn off **Tree cover loss by dominant driver** and turn on **Tree cover gain** for the same region.

Describe

What do you notice? Is there growth in the same areas that had also lost tree cover? Why do you think this is?

10. Turn off **Tree cover gain** and zoom back out to the world view.

11. Under **Climate**, turn on **Forest greenhouse gas net flux**.

Describe

What do you notice? Does it look like most forests are *sinks* (absorb more CO_2 than they emit) or *sources* (emit more CO_2 than they absorb)?

12. On the legend, click the **Analysis** tab at the top.

13. Click on one country or state and click the **Analyze** button that comes up.

Analyze

Was this forest area a sink or a source during the study period?

Which other layers could you turn on to help you understand why this is?

14. Click the back arrow on the **Analysis** tab**.** Click the **Legend** tab and turn **Net forest GHG flux** off by clicking the x in the top right corner.

15. Under **Climate**, turn on **Potential carbon sequestration rate**

Describe

What do you notice? What regions could absorb the most CO_2 if they were reforested?

Consider

To reduce the amount of CO_2 in our atmosphere, should we plant trees? If so, where?

Extend

What other questions do you have? How could you use this tool to answer them?

Model

Any model, such as the carbon flux model used here, has certain assumptions built in. Different forest types absorb and release CO_2 at different rates. This depends on latitude (tropics vs temperate,) tree type (evergreen vs deciduous,) how the forest was lost (fire, logging, etc.), and many other factors. Some of these factors cannot be measured with satellite images, and so they can only be approximated in the model. To read more about the model, click the information button on the **Analysis** tab.