Modeling the Carbon Cycle

 In this activity, you will use a virtual lab. With the computer model in the lab, you will explore how changes to the **carbon cycle** affect the Earth's **biosphere**, **atmosphere**, **hydrosphere**, and **geosphere**.

You will model how both natural processes and human activities affect the carbon cycle and thus the global **climate**. Finally, you will try to reduce or reverse human impact on the carbon cycle.

The Carbon Cycle and Earth's Spheres

Carbon can be found in all four spheres of Earth: the **biosphere**, **atmosphere**, **hydrosphere**, and **geosphere**. Each sphere is a reservoir, or "pool," that carbon can move into or out of. The amount of carbon in a reservoir is called the **carbon stock**. Carbon moves between reservoirs via the **carbon cycle**.

Together, **photosynthesis** and **cellular respiration** allow living things to capture energy from the Sun and change it into a form they can use to power their cellular activities. In this way, energy is constantly changing form and flowing within and between living systems. And at the same time, these two processes are also causing matter to change form and flow between systems.

Explore the activity to learn more about the carbon cycle and the **biotic** and **abiotic** components that serve as carbon reservoirs in Earth's spheres.

Biosphere

Carbon is part of the matter that makes up all living things. Some **autotrophs**, such as plants, take in carbon dioxide from the air or water. They use the Sun's energy to convert it into food via photosynthesis. Other autotrophs use **chemosynthesis** to make food from carbon dioxide without sunlight. **Heterotrophs**, such as animals, get the carbon they need by consuming other organisms. All living things return carbon to the oceans and atmosphere during cellular respiration and **decomposition**.

Atmosphere

Atmospheric carbon is found in gases such as carbon dioxide and methane. The rate at which carbon moves into and out of the atmosphere depends on many factors. For example, changes in temperature and rainfall can affect the growth of plants, which affects the rate of photosynthesis, which removes carbon from the atmosphere. Meanwhile, volcanic activity and wildfires move carbon back into the atmosphere. The amount of carbon in the atmosphere can also affect other spheres. For example, an increase in atmospheric carbon can cause an increase in the rate of photosynthesis.

Hydrosphere

Earth's oceans make up most of the hydrosphere. The ocean stores carbon in the form of dissolved rock — mainly limestone — that has gone through **weathering**. Layers of sediment and shells that contain calcium carbonate settle to the bottom of the ocean in a process called **sedimentation**. The sediment is gradually cemented together into limestone rock. This process returns carbon to the geosphere. The ocean also absorbs and releases carbon dioxide through gas exchange at the water's surface.

Geosphere
Plants release some excess carbon into the soil through their roots during cellular respiration. But most of the carbon in the geosphere comes from decaying plant and animal materials buried in the ground. **Fossil fuels** — oil, natural gas, and coal — form over millions of years from the remains of living things. Carbon is stored in these fossil fuels. It is released into the atmosphere when the fuels are burned.

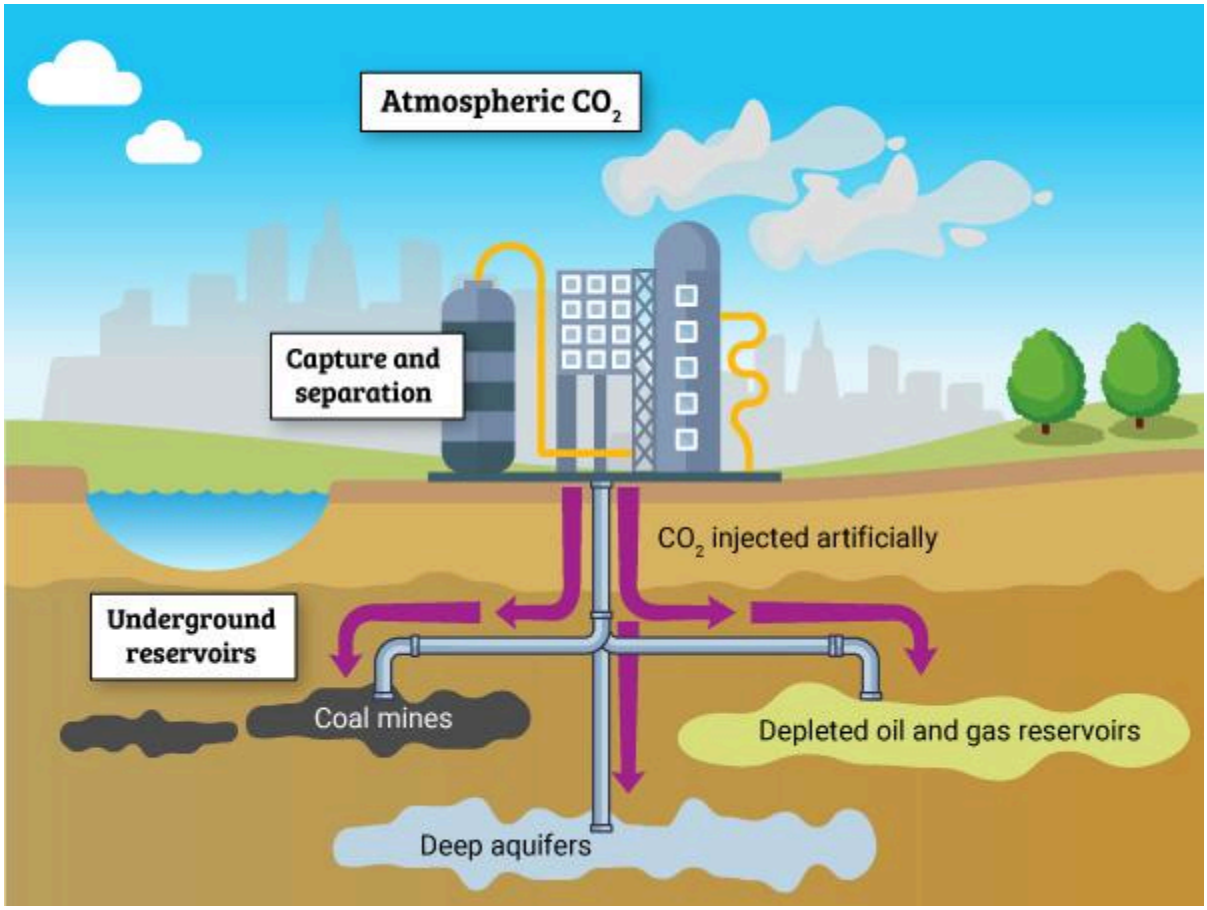
Remediation Tactics

Remediation involves stopping activities that damage the environment. It can also refer to reversing damage that has already occurred. In terms of the carbon cycle, remediation focuses on slowing the rate at which carbon is released into the atmosphere. This can be done by making changes to human activities. For example, people can reduce the amount of fossil fuels they burn. Another way to keep carbon out of the atmosphere is by storing it in other spheres.

This diagram describes one method of remediation: **geologic carbon sequestration**.

Explore the image to learn about geologic carbon sequestration.

visibility



Atmospheric CO_2

Carbon dioxide is released from factories and power plants that use fossil fuels. It also exists in the atmosphere as a result of many other human activities and certain natural processes.

Capture and separation

A method called *carbon capture technology* is used to separate carbon dioxide from the other gases that make up air. The technology can be used on the waste exhaust from factories to prevent the carbon from

entering the atmosphere. It can also be used to capture carbon directly from air in order to reduce the atmosphere's carbon stock.

Underground reservoirs

After the gas is captured, it is compressed into a liquid. The liquid is injected into porous rock deep underground, where it cannot easily escape. The liquid replaces oil, gas, and coal that was removed from the geosphere at an earlier time.

The liquid can also be injected into deep aquifers, which are natural pools of saltwater. The water has no economic value due to its salt content. Therefore, the aquifers are a good candidate for storing carbon.

Instructions

Virtual lab

Open the lab worksheet by selecting the link at right. Then select the simulation below. Complete the activity by following the steps in the worksheet. **Be sure to follow any instructions given by your lab supervisor.** Record your data and answer all the questions on the worksheet.

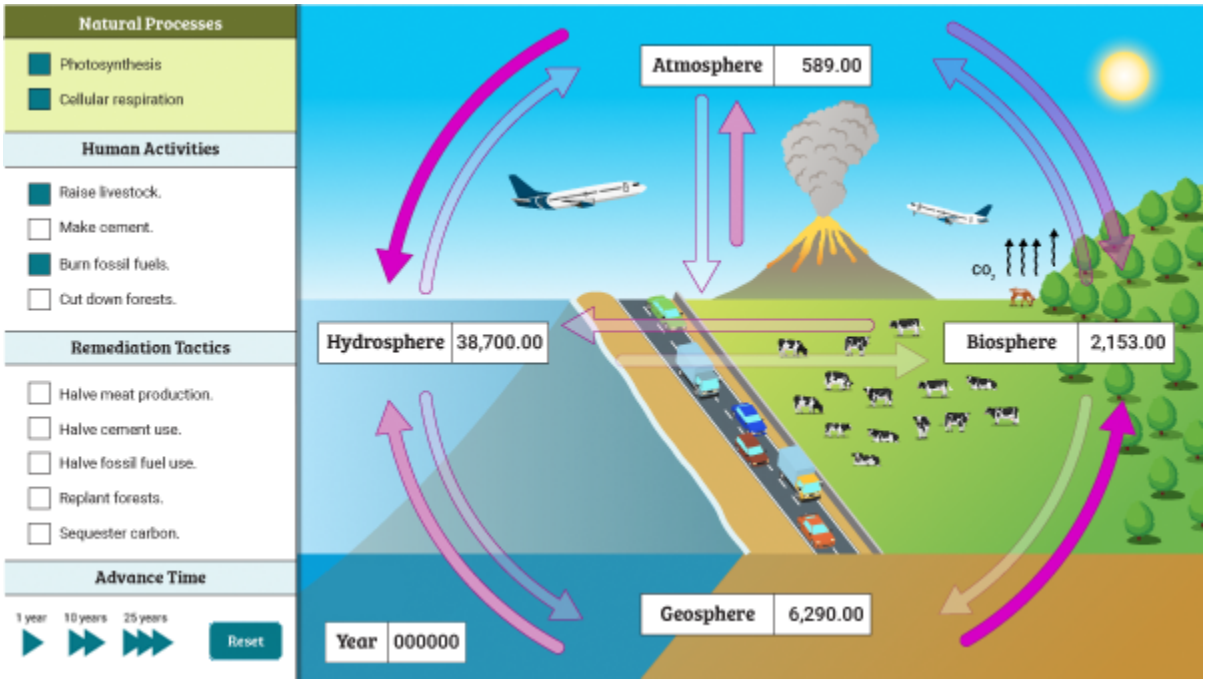
Directions

1. Open the lab worksheet by selecting the icon on the right.

2. After you complete the lab worksheet, turn in all lab work to your teacher.

Scoring

This activity is worth 50 points.



2.1.7 Lab: Modeling the Carbon Cycle

Lab

Biology Prescriptive Sem 1

Name: _____

*Points Possible:*50

Date: _____

Part 1: Modeling the Carbon Cycle (10 points)

In this part of the lab, you will model the effects of photosynthesis and cellular respiration on Earth's spheres.

1. In the Natural Processes section of the virtual lab, check that both "Photosynthesis" and "Cellular respiration" are selected.

2. In the first row of data table 1, record each sphere's carbon stock at the beginning of the simulation. Then copy these data into the first rows of data tables 2 and 3.

3. Run the simulation for one year by selecting the arrow labeled "1 year." In data table 1, record each sphere's carbon stock at the end of the year.

4. Calculate the change in each sphere's carbon stock over the course of one year. Record these values in the bottom row of data table 1.

5. Select "Units: PgC" at the bottom right of the simulation and read the information in the pop-up window.

6. Select each arrow that describes the movement of carbon between different spheres. Make notes in your lab worksheet under data table 1.

7. Deselect "Cellular respiration." Run the simulation for one year again to identify the effect of photosynthesis alone on carbon stocks. Record each sphere's final carbon stock in data table 2. Then calculate the change per year for each sphere and record it in the table.

8. Deselect "Photosynthesis," and then reselect "Cellular respiration." Run the simulation for one year to identify the effect of cellular respiration alone on carbon stocks. Record each sphere's final carbon stock in data table 3. Then calculate the change per year for each sphere and record it in the table.

9. Answer the questions below about the effects of photosynthesis and cellular respiration on the carbon cycle.

<u>Data</u> (3 points)

Year	**Carbon stock (PgC)**			
	Atmosphere	**Biosphere**	**Geosphere**	**Hydrosphere**
0				
1				
Change per year				

Notes:

Year	Carbon stock (PgC)			
	Atmosphere	Biosphere	Geosphere	Hydrosphere
0				
1				
Change per year				

Year	Carbon stock (PgC)			
	Atmosphere	Biosphere	Geosphere	Hydrosphere

0				
1				
Change per year				

<u>Analysis and Conclusions</u> (7 points)

1. Which sphere contains the largest stock of carbon? Which sphere contains the smallest stock? (1 point)

2. Explain how photosynthesis and cellular respiration are related. Use data you gathered from the simulation to support your explanation. (2 points)

3. Considering only the natural processes of photosynthesis and cellular respiration, where is carbon stored over the course of the simulation? Use the calculations in data table 1 to support your answer. (1 point)

4. How is energy stored, released, and transferred on Earth through photosynthesis and cellular respiration? (2 points)

5. The length of the simulation is limited to 250 years. What other processes in the carbon cycle might you see if the simulation were to run for millions of years? (1 point)

Part 2: Modeling the Impact of Human Activities on the Carbon Cycle (16 points)

In this part of the lab, you will model the impact of human activities on the carbon cycle.

1. In the Natural Processes section of the virtual lab, check that both "Photosynthesis" and "Cellular respiration" are selected.

2. In the first row of each section of data table 4, record each sphere's carbon stock at the beginning of the simulation.

3. Select a human activity, and then run the simulation for one year. Record each sphere's carbon stock at the end of the year. Then calculate and record the change in each sphere's carbon stock over the course of that year.

4. Calculate the change in each sphere's carbon stock caused by the human activity alone (in other words, if photosynthesis and cellular respiration did not occur). To do this, take the change per year you calculated in Step 3 and subtract the change per year from data table 1.

5. Reset the simulation and repeat Step 3 with each of the human activities.

6. Select all human activities. Run the simulation until the end by clicking the arrows to advance 1, 10, or 25 years. When alerts appear, note them in data table 5.

7. Answer the questions below about the impact of human activities on the carbon cycle.

Data (7 points)

	Year	Carbon stock (PgC)			
		Atmosphere	Biosphere	Geosphere	Hydrosphere
Burn fossil fuels.	0				
	1				
	Change per year				
	Change per year without photosynthesis and cellular respiration				
Make cement.	0				
	1				

	Change per year				
	Change per year without photosynthesis and cellular respiration				
Raise livestock.	**0**				
	1				
	Change per year				
	Change per year without photosynthesis and cellular respiration				

Cut down forests.	**0**				
	1				
	Change per year				
	Change per year without photosynthesis and cellular respiration				

Atmosphere carbon stock	**Summary of alert description**

<u>Analysis and Conclusions</u> (9 points)

1. Compare the amounts of carbon released into the atmosphere by the various human activities. How much carbon is released into the atmosphere each year by all human activities in the simulation combined? (2 points)

2. What are the effects of increasing atmospheric carbon on natural ecosystems? (2 points)

3. Nearly half of Earth's land consists of agricultural ecosystems. Of this, approximately one-third is used for planting crops, while two-thirds are open fields of grasses for livestock to graze. How might agricultural ecosystems be affected by an increase in atmospheric carbon dioxide? (2 points)

4. The burning of fuel releases carbon dioxide. Based on the current rate at which humans burn fossil fuel, a theoretical 8 PgC should be released into the atmosphere annually. How does this number compare with those from the simulation? Where else does the carbon go, and what processes cause this movement of carbon? (2 points)

5. Aside from the release of carbon dioxide, how else do human-caused pollution and habitat destruction affect the carbon cycle and the health and sustainability of an ecosystem? (1 point)

Part 3: Simulating Remediation Tactics (12 points)

In this part of the lab, you will model the effects of remediation tactics on Earth's spheres.

1. In the Natural Processes section of the virtual lab, check that both "Photosynthesis" and "Cellular respiration" are selected.

2. Select both "Burn fossil fuels" and its remediation tactic, "Halve fossil fuel use." Run the simulation for one year. Record the atmosphere's carbon stock at the beginning and end of the year. Calculate the change per year in atmospheric carbon stock, and record your calculation in data table 6.

3. Repeat Step 2 for each activity and remediation tactic. Record your calculations in data table 6.

4. Run the simulation with various combinations of human activities and remediation tactics. Record each combination in data table 7, and calculate the change per year in atmospheric carbon stock for each combination. Your goals are to

    a. find a combination that stabilizes atmospheric carbon stock, and then
    b. find a combination that reduces atmospheric carbon stock.

<u>Data</u> (7 points)

Remediation tactic	Atmospheric carbon stock (PgC)		
	Beginning of year	After 1 year	Change per year
Replant forests.			
Halve fossil fuel use.			
Halve cement use.			
Halve meat production.			
Sequester carbon.			

Remediation tactics	Change per year in atmospheric carbon stock (PgC)

<u>Analysis and Conclusions</u> (5 points)

1. Current carbon sequestration technologies remove approximately 1 PgC from the atmosphere every year and move that carbon to the geosphere. How does this real-world rate compare with the rate shown in the simulation? What do you think accounts for the difference? (2 points)

2. What combination of remediation tactics stabilized and reduced the atmospheric carbon stock in the simulation? What can individuals do to stabilize and reduce atmospheric carbon stocks? (2 points)

3. What other remediation tactics can you think of that were not in the simulation? (1 point)

Part 4: Developing a Model (12 points)

1. Use your data and observations from the simulation to develop a diagram or graphic organizer to model how carbon cycles among Earth's spheres. In your model:

a. Include the amount of carbon that is moved by photosynthesis and cellular respiration and the spheres that are involved. (3 points)

b. Include the human activities depicted in the simulation and the spheres that are involved. (3 points)

c. List the other natural processes involved in the carbon cycle. (2 points)

d. Include factors that might affect the carbon cycle on a much longer timescale, such as millions of years. (1 point)

2. Evaluate your model. What parts of the cycling of carbon among Earth's spheres does it show well? What parts could be improved? Briefly describe two ways you could improve your model. (3 points)

Submit this completed worksheet to your teacher.

Rubric

Each question in this activity is worth a specific number of points. The possible point value is stated at the end of each question. The length of your response will depend on the type of question. Responses should be written in complete sentences, illustrated with labeled diagrams, and/or calculated with all work shown.

You can use this general rubric for guidance on how your responses will be scored by your teacher. Once scoring is complete, your teacher will provide you with feedback on your performance.

Points awarded	Description
Full points	The response addresses all parts of the question completely and correctly.
Partial points	The response is incomplete or partially incorrect.
No points	The response is incorrect, it does not match the question, or no response is given.

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