TEACHER GUIDE

THE CARBON CYCLE

MATERIALS PER GROUP:

Activity 1

- Carbonated water (clear soda or seltzer water)
- Hot water (50°C)
- Cold water (5°C)
- Two 12 oz. plastic bowls
- Two small (3 oz.) clear plastic cups

Activity 2

- Vinegar
- Baking soda
- Universal indicator
- Water
- Water and indicator cup
- Baking soda and vinegar
- Mini spoon
- Universal indicator pH color chart

Activity 3

- Bubble generator*
- Dry ice (8 oz.)
- 9 oz. plastic cup
- Water (enough to fill bubble generator half-full)
- Plastic spoon
- Dish soap (5 mL)
- Cotton glove

**A bubble generator can be purchased from Steve Spangler, or a homemade one can be built from simplet materials (e.g., plastic pickle jar or large plastic container and rubber tubing).*

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LESSON OVERVIEW:

The carbon cycle is the biogeochemical cycle by which carbon is exchanged among the biosphere, pedosphere, geosphere, hydrosphere and atmosphere of Earth. Along with the nitrogen cycle and the water cycle, the carbon cycle comprises a sequence of events key to making Earth capable of sustaining life; it describes the movement of carbon as it is recycled and reused throughout the biosphere.

LESSON OBJECTIVES:

Students will be able to:

1. Observe the density of carbon dioxide.
2. Demonstrate the effect of temperature on the amount of carbon dioxide that will dissolve in water.
3. Test the effect of carbon dioxide on the pH of water.
4. Describe how these properties of carbon dioxide relate to the carbon cycle.

ESSENTIAL QUESTION:

How does matter cycle through an ecosystem?

TOPICAL ESSENTIAL QUESTION:

What is carbon's role in life on Earth?

TOTAL DURATION:

15-20 min. pre-lab prep time; 40-50 min. class time

SAFETY PRECAUTIONS:

- Avoid contact of all chemicals with eyes and skin. Wear safety glasses, lab coat and gloves when performing the experiment.
- Universal indicator is flammable and is a mild eye and skin irritant.
- Baking soda and vinegar are not considered hazardous. However, prudent safety procedures should always be observed when handling chemicals in the laboratory.
- Dry ice is extremely cold and can quickly freeze skin; avoid contact with skin.
- Use caution when handling hot water.
- Do not eat, drink or chew gum while in the laboratory.
- Wash hands thoroughly with soap and water before leaving the laboratory.

OKLAHOMA STANDARDS:

Middle School

*MS-LS2-3

Students who demonstrate understanding will be able to:

Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

MS-PS1-4

Students who demonstrate understanding will be able to:

Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-ESS2-4

Students who demonstrate understanding will be able to:

Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

MS-LS2-3

Students who demonstrate understanding will be able to:

Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

**As written, this lesson is designed to fully meet this standard. The other standards are touched upon but are not covered in sufficient depth to be fully met by this lesson alone.*

TEXAS STANDARDS:

TEKS:

7.6A

Distinguish between physical and chemical changes in matter.

8.11C

Recognize human dependence on ocean systems and explain how human activities such as runoff, artificial reefs, or use of resources have modified these systems.

B12C

Analyze the flow of matter through the carbon and nitrogen cycles and explain the consequences of disrupting these cycles.

E.4C

Diagram abiotic cycles, including the rock, hydrologic, carbon, and nitrogen cycles.

E.5E

Analyze and evaluate the economic significance and interdependence of resources within the environmental system.

Science and Engineering Practices:

1. Asking questions
2. **Developing and using models**
3. **Planning and carrying out investigations**
4. **Analyzing and interpreting data**
5. **Using mathematics and computational thinking**
6. **Constructing explanations and designing solutions**
7. **Engaging in argument from evidence**
8. **Obtaining, evaluating and communicating evidence**

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E.6E
Investigate and identify energy interactions in an ecosystem.

AS.4A
Identify key features and characteristics of atmospheric, geological, hydrological, and biological systems as they relate to aquatic environments.

AS.6A
Identify the role of carbon, nitrogen, water, and nutrient cycles in an aquatic environment including upwellings and turnovers.

ESS.15D
Explain the global carbon cycle, including how carbon exists in different forms within the five subsystems and how these forms affect life.

HS.A.REM.3A
Describe ecology, photosynthesis, energy flow, and climax vegetation.

Crosscutting Concepts:

1. **Patterns**
2. **Cause and Effect: Mechanisms and explanations**
3. Scale, Proportion and Quantity
4. **Systems and System Models**
5. **Energy and Matter: Flows, cycles and conservation**
6. Structure and Function
7. **Stability and Change**

KEY VOCABULARY:

Biosphere
Hydrosphere
Sequester
Carbon source
Pedosphere
Photosynthesis
Carbon cycle
Geosphere
Greenhouse gas
Carbon sink

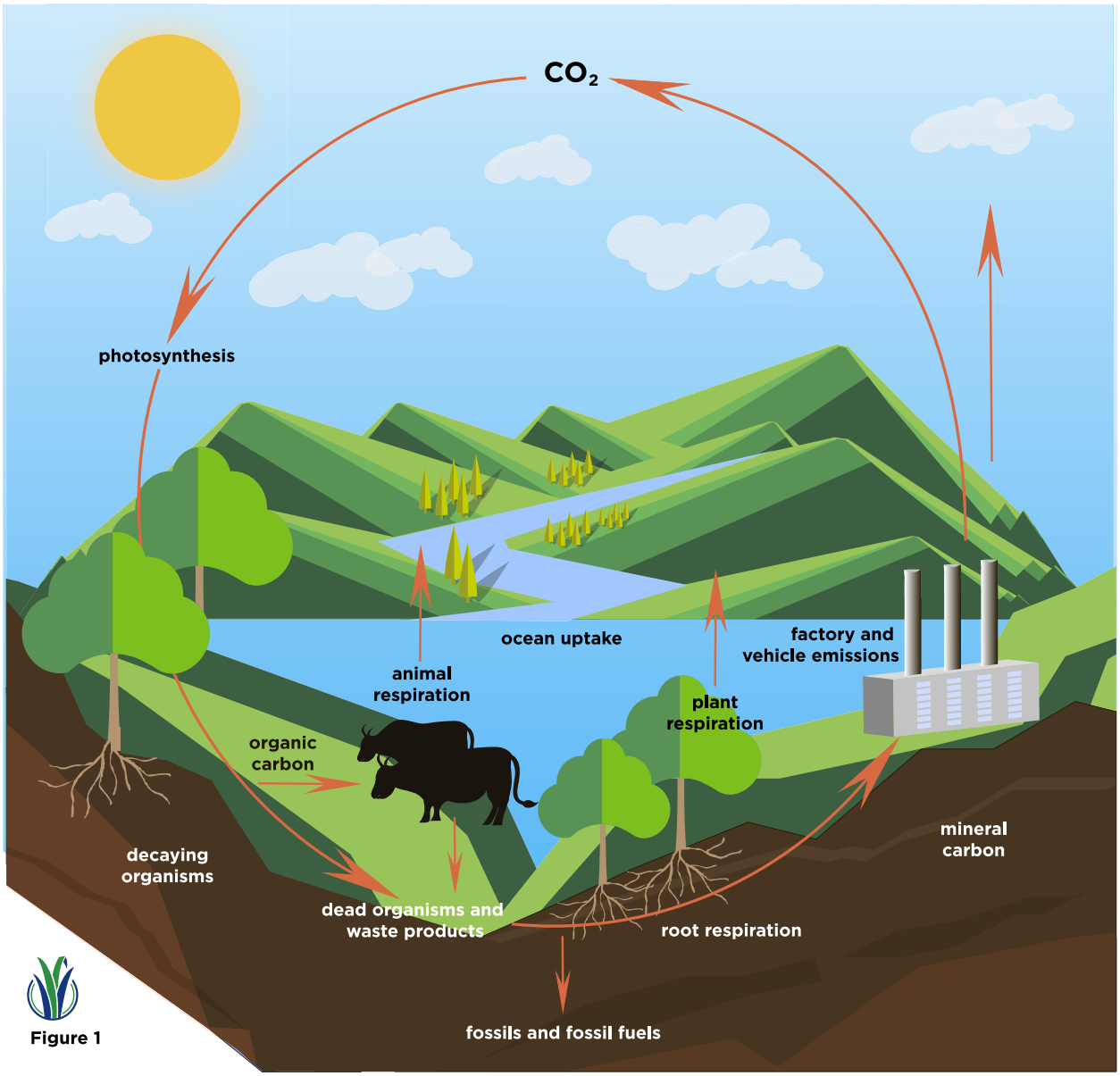


Figure 1

LAB BACKGROUND INFORMATION:

NOTE: This is background information for the teacher to assist in facilitating learning and will be explained to the students after the Explore section.

Carbon is an essential element for life on Earth. All living organisms require carbon for either their structure or energy; humans use it for both. Carbon is the fourth most abundant element in the universe and is found in many forms on Earth. The forms range from carbon dioxide (CO_2) gas, which is also termed a **greenhouse gas**, to solids such as diamonds or graphite.

The **carbon cycle** (Figure 1) is the biogeochemical cycle by which carbon is exchanged among the **biosphere, pedosphere, geosphere, hydrosphere** and atmosphere of Earth. Along with the nitrogen cycle and

the water cycle, the carbon cycle comprises a sequence of events key to making Earth capable of sustaining life; it describes the movement of carbon as it is recycled and reused throughout the biosphere.

In the cycle, anything storing more carbon that it releases is called a **carbon sink**. A **carbon source** is anything releasing more carbon than it absorbs.

The cycle starts with carbon dioxide in the atmosphere. It not only dissolves directly into the oceans but is utilized by plants in a process called **photosynthesis**. This process occurs in the chloroplasts of plant cells and allows them, with help from the sun's energy and water, to produce their own food (glucose) and produce oxygen (O_2).

Humans and other animals cannot make their own food like plants do. They eat plants and/or other animals to get their energy. Most of the food we eat is derived from plants. Plants also serve as carbon sinks, trapping atmospheric carbon in their root systems and **sequestering** it underground.
Animals use oxygen released by plants during photosynthesis to break down sugar for energy. During cellular respiration, they release CO_2 back into the atmosphere to be used again by plants. When plants or animals die, they decompose, releasing carbon back into the atmosphere. However, under certain conditions, plants and animals do not decompose and become buried deep beneath Earth's surface. Over time (millions of years), intense heat and pressure transformed this carbon into fossil fuels. As fossil fuels are used (combustion), sequestered carbon returns to the atmosphere.

ENGAGE:

Place an X beside each of the following things that have carbon in them.

X	A cat	X	Motor oil
X	A cactus	X	A worm
X	A rock	X	Ocean water
X	The air you breathe	X	A wooden board

Introduction
In this activity, you will observe the density of CO_2, learn how CO_2 affects the pH of water, and learn how temperature affects the amount of CO_2 water is able to dissolve (hold). As each activity is performed, you will determine how the results of each activity relate to the carbon cycle.

EXPLORE:

Activity 1: The Hot and Cold of CO_2 Absorption

In this activity, students will investigate how temperature affects the amount of CO_2 that a liquid can hold. Have students make a prediction: Which do you think will hold more CO_2, hot soda or cold soda? Why?

1. Fill one plastic bowl half full with cold water and the other plastic bowl half full with hot water.
2. Fill two 3 oz. clear plastic cups three-fourths full with carbonated water (clear soda or seltzer water).
3. Place one 3 oz. cup filled with the carbonated water into the bowl with cold water and the other 3 oz. cup into the bowl with hot water.
4. Observe the surface of the carbonated water. Which has more bubbles? What do these observations tell you about the temperature at which water absorbs CO_2?

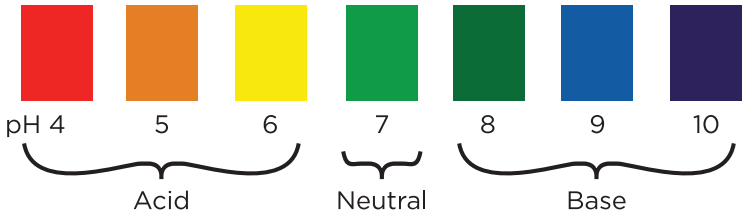
Real-World Application
The world's oceans, one of the largest carbon sinks, are heating up. They are able to hold less carbon dioxide, releasing it into the atmosphere and compounding the greenhouse effect aiding in the warming of the planet.

Activity 2: The Effect of CO_2 on the pH of H_2O

In this activity, students will investigate the relationship between the amount of CO_2 dissolved in water (H_2O) and the pH of H_2O. Have students make a prediction: As the amount of CO_2 increases in a solution, does the pH increase or decrease? Why?

1. To prepare the pH indicator solution, add 0.5 mL (10 drops) of universal indicator to 20 mL of water in a 90 mL (3 oz.) clear plastic cup labeled "Water and Indicator" and gently swirl the mix. Use the indicator chart to determine the pH at the start.
2. To the reaction vessel labeled "Baking Soda and Vinegar," add ¾ teaspoon baking soda.
3. Quickly add 10 mL of vinegar to the reaction vessel.
4. Quickly place the small plastic cup containing the indicator solution into the reaction vessel.
5. Place the lid on the reaction vessel.
6. Gently swirl the set of cups and observe the color of the solution. Using the indicator chart below, determine if adding CO_2 to the system produces an acidic, basic or neutral solution.

Universal Indicator pH Color Chart



Real-World Application
When carbon dioxide enters the ocean water, it forms carbonic acid, which lowers the pH of the water. In the last 200 years, the pH level of the oceans has gone from 8.2 to 9.1, a 25 percent increase in acidity (pH scale is logarithmic). In addition to lowering pH, the increased levels of carbon dioxide pose a threat to shellfish and coral reefs. In the past, calcium carbonate has been readily available for bivalves, shellfish and coral reefs to use to construct their shells and skeletons. However, as more carbon dioxide enters the oceans it is binding with carbonate ions to form bicarbonate. This process makes the calcium unavailable to the bivalves, shellfish and coral reefs, which inhibits their ability to grow and replace shells or skeletons.

Activity 3: The Density of CO_2

In this activity, students will investigate the density of CO_2. Have students make a prediction: Do you think the CO_2 bubbles will float or sink?

1. Add 120 mL of water and 15 drops of dish soap to a 9 oz. plastic cup.
2. Fill the bubble generator with warm water until it is half full.
3. Put a cotton glove on over your latex glove.

4. Add five to 10 pieces of dry ice to the warm water in the bubble generator and put on the lid. NOTE: For safety reasons, do not allow students to handle or touch dry ice.
5. Briefly dip the tip of the rubber tubing attached to the bubble generator into the soapy water, and watch as a bubble filled with CO_2 forms.
6. When the bubble drops from the tip, catch it in your gloved hand. You should be able to bounce the CO_2-filled bubble in your hands a few times before it breaks.
7. When the bubble breaks, observe the CO_2. Does it rise, fall or float in the same place? What does your observation tell you about the density of CO_2?

EXPLAIN: (SEE LAB BACKGROUND):

The Lab Background Information from the Teacher Guide is repeated in the Explain section of the Student Guide.

ELABORATE:

Optional Extension Activities

Dinosaur Breath: Did you know that the carbon we exhale is never destroyed? Instead, it becomes part of the carbon cycle. As part of this cycle, the carbon atoms continually move through living organisms, the oceans, the atmosphere and Earth's crust. This movement can take millions of years to complete. Just as we are part of the carbon cycle, other animals are, too; even dinosaurs that roamed Earth millions of years ago. As the dinosaurs exhaled, some of the carbon atoms in their breath was absorbed by the oceans.

The White Cliffs of Dover off of the coast of England are made of calcium carbonate sediment, or chalk. This sediment is made of ancient seashells. These shells were created by sea creatures millions of years ago using the carbon found in Earth's oceans, possibly the same carbon atoms from exhaled dinosaur breath. It is possible ancient carbon from dinosaur breath may be in some of the chalk used today.

Try extracting carbon from chalk using the following procedure:

1. Using a rolling pin, crush three or four pieces of chalk (not the dustless kind) in a plastic bag.
2. Measure 25 grams of crushed chalk and place it in a small glass jar. Make sure the end of a balloon can fit around the mouth of the jar.
3. Add 5 grams of baking soda to the glass jar with the crushed chalk. The baking soda is used to accelerate the reaction because most chalk is not pure calcium carbonate.
4. Next, add approximately 25 mL of vinegar to the glass jar and quickly cover the mouth of the jar with a balloon.
5. The reaction releases carbon in the form of CO_2 gas, which is the gas filling the balloon. The carbon atoms in the CO_2 may be from dinosaur breath exhaled millions of years ago!
6. For more information about this experiment please visit: http://www.teachengineering.org/view_activity.php?url=http://www.teachengineering.com/collection/cub_/activities/cub_carbon/cub_carbon_lesson01_activity1.xml.

Try your knowledge with the carbon cycle interactive game: http://www.windows2universe.org/earth/climate/carbon_cycle.html

EVALUATE:

1. What gaseous form of carbon is taken from the atmosphere by plants and dissolves into oceans?
   CO_2

2. For what two purposes do living organism require carbon?
   Plants use carbon to build sugar molecules.
   Organisms use energy contained in carbon compounds during cellular respiration.

3. What is the difference between a carbon source and a carbon sink?
   In the carbon cycle, anything that stores more carbon than is used is a carbon sink. A carbon source is anything that releases more carbon that it absorbs.

4. Carbon dioxide is taken from the atmosphere in what two ways?
   Plants take CO_2 from the atmosphere through photosynthesis.
   CO_2 is also dissolved into water bodies such as the ocean.

5. Do you think warm water or cold water holds more CO_2? Why?
   Cold water can hold more CO_2 than warm water because cold water has less energy and the particles have less motion.

6. When CO_2 was dissolved into water, did the water become acidic, basic or neutral?
   The water became more acidic.

7. Since CO_2 is able to dissolve into the ocean and the ocean acts as a carbon sink, predict the change in pH of oceans over time if the current atmospheric conditions continue. Do you think this could affect aquatic organisms like fish, lobsters and coral reefs?
   If increasing amounts of CO_2 are dissolved into ocean water, the oceans will become more acidic. A change in the pH can dramatically affect the health of the organisms present in an ocean ecosystem.

8. When the bubble filled with CO_2 burst, did the CO_2 rise, sink or float? Why?
   The CO_2 sank because it has a greater density than the surrounding air.

Noble Academy would like to thank the following people for their contributions to this lesson:

- Quentin Biddy
- Janie Herriott
- Susie Edens
- Fiona McAlister
- Kay Gamble
- Julie Smiley-Foster

STUDENT GUIDE

THE CARBON CYCLE

MATERIALS PER GROUP:

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- Hot water (50°C)
- Cold water (5°C)
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Activity 2

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LESSON OVERVIEW:

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ESSENTIAL QUESTION:

How does matter cycle through an ecosystem?

TOPICAL ESSENTIAL QUESTION:

What is carbon's role in life on Earth?

LESSON OBJECTIVES:

You will be able to:

1. Observe the density of carbon dioxide.
2. Demonstrate the effect of temperature on the amount of carbon dioxide that will dissolve in water.
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KEY VOCABULARY:

Biosphere
Hydrosphere
Sequester
Carbon source
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Photosynthesis
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Greenhouse gas
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_____ A cactus
_____ A rock
_____ The air you breathe
_____ Motor oil
_____ A worm
_____ Ocean water
_____ A wooden board

INTRODUCTION:

In this activity, you will observe the density of CO_2, learn how CO_2 affects the pH of water, and learn how temperature affects the amount of CO_2 water is able to dissolve (hold). As each activity is performed, you will determine how the results of each activity relate to the carbon cycle.

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Activity 1: The Hot and Cold of CO_2 Absorption

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_____

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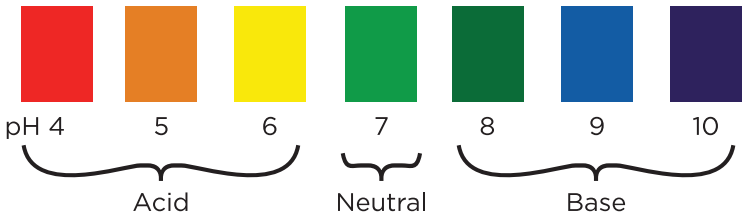

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_____

What does your observation tell you about the density of CO_2?

_____

_____

_____

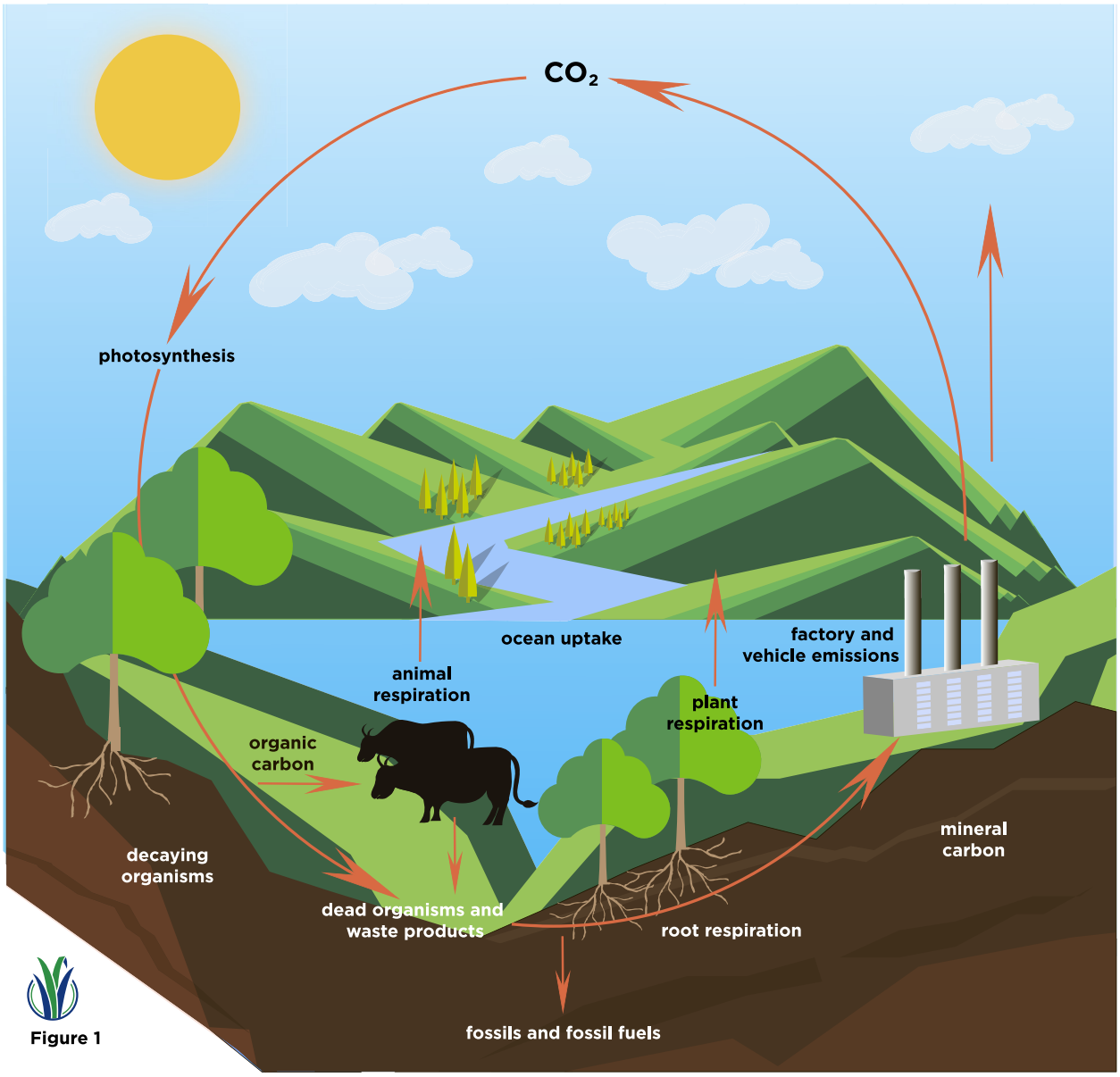

Figure 1

EXPLAIN:

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In the cycle, anything storing more carbon that it releases is called a **carbon sink**. A **carbon source** is anything releasing more carbon than it absorbs.

The cycle starts with carbon dioxide in the atmosphere. It not only dissolves directly into the oceans but is utilized by plants in a process called **photosynthesis**. This process occurs in the chloroplasts of plant cells and allows them, with help from the sun's energy and water, to produce their own food (glucose) and produce oxygen (O_2).

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ELABORATE:

Optional Extension Activities

Dinosaur Breath: Did you know that the carbon we exhale is never destroyed? Instead, it becomes part of the carbon cycle. As part of this cycle, the carbon atoms continually move through living organisms, the oceans, the atmosphere and Earth's crust. This movement can take millions of years to complete. Just as we are part of the carbon cycle, other animals are, too; even dinosaurs that roamed Earth millions of years ago As the dinosaurs exhaled, some of the carbon atoms in their breath was absorbed by the oceans.

The White Cliffs of Dover off of the coast of England are made of calcium carbonate sediment, or chalk. This sediment is made of ancient seashells. These shells were created by sea creatures millions of years ago using the carbon found in Earth's oceans, possibly the same carbon atoms from exhaled dinosaur breath. It is possible ancient carbon from dinosaur breath may be in some of the chalk used today.

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6. For more information about this experiment please visit:
   http://www.teachengineering.org/view_activity.php?url=http://www.teachengineering.com/collection/cub_/activities/cub_carbon/cub_carbon_lesson01_activity1.xml.

Try your knowledge with the carbon cycle interactive game:
http://www.windows2universe.org/earth/climate/carbon_cycle.html

EVALUATE:

Name: _____

Use knowledge gained from this lesson to complete the questions.

1. What gaseous form of carbon is taken from the atmosphere by plants and dissolves into oceans?

_____

_____

_____

2. For what two purposes do living organism require carbon?

_____

_____

_____

3. What is the difference between a carbon source and a carbon sink?

_____

_____

_____

4. Carbon dioxide is taken from the atmosphere in what two ways?

_____

_____

_____

5. Do you think warm water or cold water holds more CO_2? Why?

_____

_____

_____

6. When CO_2 was dissolved into water, did the water become acidic, basic or neutral?

_____

_____

_____

7. Since CO_2 is able to dissolve into the ocean and the ocean acts as a carbon sink, predict the change in pH of oceans over time if the current atmospheric conditions continue. Do you think this could affect aquatic organisms like fish, lobsters and coral reefs?

_____

_____

_____

8. When the bubble filled with CO_2 burst, did the CO_2 rise, sink or float? Why?

_____

_____

_____