A Study of Matter and Energy in Systems

Lesson 2: An Isolated Plant

Grade: 9-10 General Biology

Length of lesson: 130 minutes

Placement of lesson: Lesson 2 of 7

Unit Overarching Goal

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixedinto organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemicalenergy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

Unit Central Question

How do matter and energy move through a system as living things interact with each other and the environment?

Lesson 2 Main Learning Goal

As a system, plants use inputs of water and carbon dioxide to create outputs of sugar (glucose and starch) and oxygen through the process of photosynthesis. Matter is conserved throughout this process.

Lesson 2 Focus Question

Where do the atoms that a plant uses in photosynthesis come from? Where do they go?

Ideal student response

Plants use carbon, oxygen, and hydrogen in the chemical reactions of photosynthesis. Inputs of carbon and oxygen atoms come from carbon dioxide in the air. Inputs of hydrogen and oxygen atoms come from water which the roots of the plants take up from the soil. During photosynthesis, carbon dioxide and water molecules are separated. The oxygen atoms from water are released into the air. The hydrogen atoms from water are combined with the carbon and oxygen atoms from carbon dioxide and glucose molecules are formed.

Science Content Storyline

A plant, such as the one in the terrarium, is a system. Plants use a series of chemical reactions called photosynthesis to separate the atoms of water and carbon dioxide molecules and connect those atoms in different arrangements to make glucose and oxygen molecules. We can trace the atoms used in photosynthesis because matter is conserved in a system.

Glucose molecules ($C_6H_{12}0_6$) are composed of carbon, hydrogen, and oxygen atoms which form the backbone of other large carbon molecules (such as starch). The oxygen produced as an output comes from the breakdown of the water molecules input into the system.

Materials

Bromothymol Blue Demonstration

- Safety goggles (1/teacher)
- 250 ml Erlenmeyer flask or beaker
- Distilled water
- 0.04% bromothymol blue solution
- Drinking straw with a hole punched near the top

Bromothymol Blue and *Elodea*

- Safety goggles (1/student)
- 2 test tubes with stoppers (per team)
- 2 test tubes/stoppers to serve as controls (1/class)
- Tape and marker for labeling test tubes (or grease pencil) (1/team)
- Test tube rack or clear container to hold test tubes upright
- Drinking straw with a hole punched near the top (1/team)
- 250 ml Erlenmeyer flask or beaker (1/team)
- Distilled water
- 0.04% bromothymol blue solution
- 2 healthy sprigs of *Elodea* (per team)
- Light source (window or lamps with LED 65W spotlights or fluorescent bulbs)

Leaf Disk Investigation

- Clear plastic cups (2/team)
- Permanent markers and tape to label cups
- Single hole punch or drinking straw (1 per team)
- Fresh spinach leaves (bagged baby spinach works well)
- Distilled water
- 0.2% Sodium bicarbonate solution (baking soda) (300 ml/team)
- 10 ml plastic syringe, needle removed (1/team)
- Light source (window or lamps with LED 65W spotlights or fluorescent bulbs)

Other materials

- Lesson 2 slide deck
- Chart markers
- Charts with terrarium diagrams from Lesson 1

Advance Preparation

- Make sure you have all materials prepared for use and distribution before class to be efficient with time. You may not be able to complete the lesson in one class period because students will need time to think, read, write, and talk.

Bromothymol Blue Demonstration

- Use a hole punch to make a hole near the end of a drinking straw. This prevents accidental sucking in of the solution while still allowing blowing bubbles in the solution.

Bromothymol blue and *Elodea*

- Prepare materials for each team and determine how common materials will be accessed.
- Prepare the bromothymol blue (BTB) solution.
    - Determine the total amount of BTB needed by multiplying the number of test tubes for the class (each team will use two test tubes) by the volume needed to fill one test tube ¾ full.
    - The ratio of BTB to distilled water is 2.5 ml of 0.04% BTB to 125 ml of distilled water. Prepare enough solution for your class with some extra for accidental spillage. The solution should be blue. This diluted solution can be made a day in advance and kept at room temperature in a sealed bottle.
- Determine the best light source for the investigation. Test tubes can be placed in test tube racks or glass beakers, so the *Elodea* is exposed to light. The light source should be strong enough that the *Elodea* will photosynthesize, but not heat up the solution.

Leaf Disk Investigation

- Place fresh spinach leaves in water under a light source prior to the investigation. As a point of reference, twenty minutes under an LED 65W equivalent flood light at a height of 1 foot above the leaves was adequate for good results.
- Prepare 0.2% sodium bicarbonate solution: dissolve 1 teaspoon (6 grams) of baking soda per 2400 ml of distilled water). This solution should be made just prior to conducting the investigation.
- Determine the best light source for the investigation. Ideally, the light source comes from above the cups, however, good light from a window will work as well. The light source should be strong enough that the leaf disks will photosynthesize, but not heat up the solution. Using the LED 65W flood light at 1 foot above the cups, the disks will often rise within 3-5 minutes.

- Save several test tubes with bromothymol blue and *Elodea* for Lesson 4.
- Additional background information on the Leaf Disk Investigation can be found at https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/3/1009/files/2015/09/Floating-Leaf-Disk-Brad-Williamson.pdf and https://youtu.be/vw8baZO89oc

Lesson 2 General Outline

Time (min)	Phase of lesson	How the science content storyline develops
10	**Where do the atoms that a plant uses in photosynthesis come from? Wheredo they go? (Lesson focus question)** The teacher makes links to the prior lesson and introduces the lesson focus question.	
10	**A Plant as a System** Activity 1-2 Setup Students complete a chart to consider a plant as a system. The teacher leads a class discussion about how a component of a system can itself be a system at a different scale. leads a class discussion about how the terrarium represents a system.	A system has boundaries, components, interactions, and inputs and outputs. In a closed system, you can identify the inputs and outputs as matter or energy. A terrarium represents a closed system with all identifiable characteristics of a system.
30	**A Plant as a System, Part 1** Activity 1 Setup Students observe a demonstration showing that bromothymol blue changes color in the presence of carbon dioxide. Activity 1 Student teams set up and diagram the investigation of *Elodea* in bromothymol blue. They add the results of their investigation to the diagram. Activity 1 Follow-up Students complete a reading about how plants use carbon dioxide and draw a diagram showing important ideas of the reading.	Plants use a series of chemical reactions called photosynthesis to separate the atoms of water and carbon dioxide molecules and connect those atoms in different arrangements to make glucose and oxygen molecules. We can trace the atoms used in photosynthesis because matter is conserved in a system.
50	**A Plant as a System, Part 2** Activity 2 Setup Students read the procedure for the leaf disk investigation. Activity 2 Student teams conduct the leaf disk investigation, recording and graphing their data. They complete the Identify and Interpret protocol to interpret their graph. Activity 2 Follow-up Students complete a reading about where the oxygen produced by photosynthesis comes from and complete a chart identifying which input molecules contribute atoms to the output molecules. The teacher leads a class discussion of the reading.	Glucose molecules ($C_6H_{12}0_6$) are composed of carbon, hydrogen, and oxygen atoms which form the backbone of other large carbon molecules (such as starch). The oxygen produced as an output comes from the breakdown of the water molecules input into the system.

25	**Synthesize and Summarize** Students revise and add a plant system to their initial model drawing, adding labels showing the key features of a plant system. They revise and add to their initial response to the focus question.	
5	**Summarize and Link** In this lesson, students have considered how matter moves through the terrarium's plant, and how the plant represents a subsystem of the terrarium. In the next lesson, students will consider the role of energy in these matter transformations.	

Lesson 2: An Isolated Plant

Phase of Lesson: *Lesson Focus Question*

Main Learning Goal: As a system, plants use inputs of water, and carbon dioxide to create outputs of small carbon-based molecules (glucose) and oxygen through the process of photosynthesis. Matter is conserved throughout this process.

Focus Question: Where do the atoms that a plant uses in photosynthesis come from? Where do they go?

Unit Overarching Goal:

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

Notes:

Time: 10 Minutes

STeLLA Strategies

- Strategy 1: Ask questions to elicit student ideas and predictions.
- Strategy 2: Ask questions to probe student ideas and predictions
- Strategy B: Set the purpose with a focus question

Science Ideas

- A plant, such as the one in the terrarium, is a system.

Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
- During photosynthesis, energy from sunlight is transformed into sugar.
- Plants increase mass by taking up chemicals from the soil.
- Fertilizer is food for plants.
- Plants undergo cellular respiration to provide CO_2 tomake sugars.
- Photosynthesis takes place in plants while cellular respiration takes place in animals.
- Cellular respiration is the opposite of photosynthesis.
- Cellular respiration and breathing are the same thing.
- Cellular respiration and fermentation are unrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
- Energy can be recycled.

Lesson 2: An Isolated Plant

Introduction

In the last lesson, you explored a terrarium system that has been sealed from the outside world, yet the plant inside the terrarium has continued to grow and fill the bottle with healthy leaves. In this lesson, you will continue to think about how the plant interacts with its environment to stay alive.

Lesson Question

Where do the atoms that a plant uses in photosynthesis come from? Where do they go?

Process and Procedure

1. Write your best ideas about the lesson focus question in the space below. Leave space to revise your ideas as you learn throughout this lesson. As you have new ideas, record them in a different color.

Focus on Student Thinking

- Ask students to share their ideas with the whole group. The purpose is for you and the studentsto get a sense of the class's thinking about the focus question. Use STeLLA Strategy 1: Ask questions to elicit student ideas and predictions. Make it clear to students that, like the beginning of Lesson 1, we are gathering a lot of ideas and you are not going to tell which predictions are right or wrong at this point.
- Sample student responses follow:
  - The plants take in carbon dioxide from the air.
  - Plants use carbon dioxide from the air to make oxygen. The oxygen is released backinto the air.
  - The plants take in water and nutrients from the soil.
  - Nutrients from the soil are turned into food (sugar) for the plant.
- Be sure to probe ideas to ensure that a depth of student thinking surfaces. Use STeLLA Strategy 2: Ask questions to probe student ideas and predictions. Again, the purpose here is to get a quick, public snapshot of what students are thinking. The goal is not to interrogate one student for an extended period of time. If interesting misconceptions emerge, note them on the board and come back to them at the end of the lesson. Examples of probe questions include:
  - I wonder if you have any ideas about how the plant turns carbon dioxide into oxygen.
  - Tell us more about the nutrients that the plant gets from the soil.
  - Do you have any ideas about what happens to the water that the plant takes in?

Implementation	Notes
Link to Previous Lesson • Remind students that in the last lesson, they considered the characteristics of a system and how the sealed terrarium could be considered a system. Share that in this lesson, they will think about how the terrarium plant interacts with its environment to stay alive. *Lesson Focus Question* • **STEP 1:** Introduce the lesson focus question: “ Where do the atoms that a plant uses in photosynthesis come from? Where do they go?” Write this question on the board so students can write it in the box on step 1 and refer to the question throughout the lesson. • Ask students to write the Lesson 2 focus question in the box in their notebooks and, keeping in mind what they learned in the previous lesson, write their best ideas in the space below the box, leaving room so they can modify their response as needed. • Invite several students to share their ideas with the whole class. Use Strategy 1: Ask questions to elicit student ideas and predictions and Strategy 2: Ask questions to probe student ideas and predictions to make student thinking visible. Use the information in “Focus on Student Thinking” in the SE key to see examples of ways to elicit and probe student ideas.	

Lesson 2: An Isolated Plant

Phase of Lesson: *A Plant as a System Part 1*
Activities Part 1 and 2 Setup, Activity Setup, Activity Part 1, Activity Follow-up

Main Learning Goal: As a system, plants use inputs of water, and carbon dioxide to create outputs of small carbon-based molecules (glucose) and oxygen through the process of photosynthesis. Matter is conserved throughout this process.

Focus Question: Where do the atoms that a plant uses in photosynthesis come from? Where do they go?

Unit Overarching Goal:

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas and predictions
- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy 3: Ask questions to challenge student thinking
- ❖ Strategy 5: Engage students in analyzing and interpreting data and observations
- ❖ Strategy F: Make explicit links between science ideas and activities

Time: 40 Minutes

Science Ideas

- A system has boundaries, components, interactions, and inputs and outputs. In a closed system, you can identify the inputs and outputs as matter or energy. A plant represents a closed system with all identifiable characteristics of a system.
- Plants use a series of chemical reactions called photosynthesis to separate the atoms of water and carbon dioxide molecules and connect those atoms in different arrangements to make glucose and oxygen molecules.
- We can trace the atoms used in photosynthesis because matter is conserved in a system.
- Glucose molecules (C6H1206) are composed of carbon, hydrogen, and oxygen atoms which form the backbone of other large carbon molecules (such as starch).
- The oxygen produced as an output comes from the breakdown of the water molecules input into the system.

Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
- During photosynthesis, energy from sunlight is transformed into sugar.
- Plants increase mass by taking up chemicals from the soil.
- Fertilizer is food for plants.
- Plants undergo cellular respiration to provide CO_2 tomake sugars.
- Photosynthesis takes place in plants while cellular respiration takes place in animals.
- Cellular respiration is the opposite of photosynthesis.
- Cellular respiration and breathing are the same thing.
- Cellular respiration and fermentation are unrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
- Energy can be recycled.

A Plant as a System

2. Just as the terrarium can be considered a system, a plant can be considered a system. Thinking about the plant sealed in the terrarium as a system can help us figure out how it has stayed alive for so long.

   In the table below, write your ideas about how the terrarium plant can be considered a system

Feature of a System	Feature of a Plant
Boundary	The edge (outer cells) of the leaf or stem
Components	Examples may include cells, leaves, stem, chloroplasts, roots,
Processes	Photosynthesis
Inputs and Outputs	Inputs: Carbon dioxide, water, light energy Outputs: oxygen, glucose

   Add ideas from the class discussion in the space below.

3. To stay alive, a plant requires inputs of carbon dioxide (CO_2) and water (H_2O) from its environment. Because carbon dioxide is a clear gas, it is impossible to observe directly, so we will use an indicator to detect its presence or absence in the system. The indicator we will use is bromothymol blue (BTB), which changes color in the presence of carbon dioxide.

   Observe the demonstration and record the color of the indicator in the table below.

Color of Bromothymol Blue (BTB) in the Presence of Carbon Dioxide (CO_2)

	Carbon dioxide (CO_2) Absent	Carbon dioxide (CO_2) Present Low Concentration	Carbon dioxide (CO_2) Present High Concentration
Color	Blue	Green	Yellow

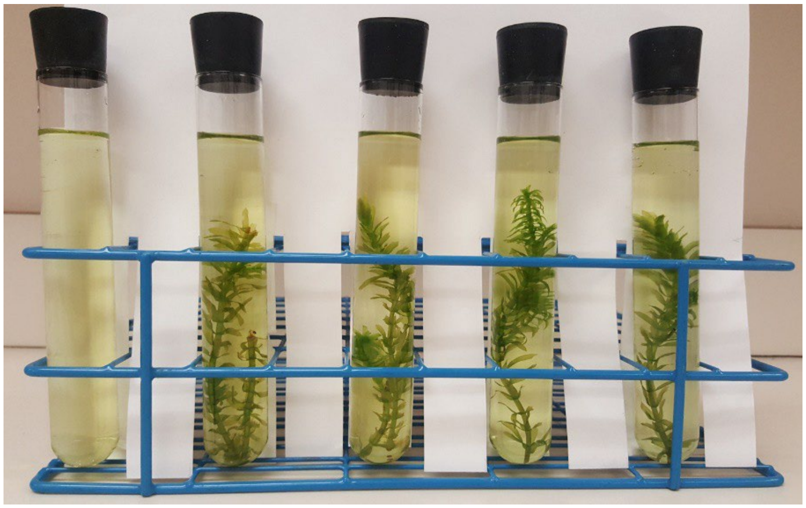
#3 ON SE L2-3

Implementation	Notes

Setup for Activities Parts 1 and 2
• Introduce the idea of a plant as a system.
• **STEP 2:** Direct students to complete the chart. This can be accomplished in a variety of ways to best meet the needs of the class. Some options include:
  ○ Complete the first row as a class and have groups complete the rest of the chart.
  ○ Complete the chart in groups and have groups share ideas with the whole class
  ○ Complete the chart in pairs and have groups compare their ideas
  ○ Individuals complete the chart and compare their ideas as a group
• After completing the chart, have a whole group discussion to ensure students understand that the plant can be considered a system. Highlight that a component of a system (the plant is a component of the terrarium system) can be considered its own system at a smaller scale.
Activity Setup: Bromothymol Blue Demonstration
• **STEP 3**: Invite students to read the paragraph individually. Ask several students to summarize what they read. Make sure that students understand the chemical formulas for carbon dioxide and water (CO2 indicates that a single molecule of carbon dioxide contains one carbon atom and two oxygen atoms; H2O indicates that a molecule of water contains one oxygen atom and two hydrogen atoms).
• Wearing safety goggles, pour 125 ml of distilled water into a 250ml Erlenmeyer flask and add 2.5 ml of 0.04% bromothymol blue. The solution should be blue. Using a straw with a hole punched in the top, gently and steadily blow bubbles into the solution. The solution should gradually turn from blue to green to yellow.
  ○ Note that at this point in the lesson, it is important to understand that BTB serves as an indicator of the presence of carbon dioxide. Students will learn that BTB is a pH indicator in the following reading.
• After the demonstration, ask students to complete the chart. It is important that students understand that a BTB solution is yellow in the presence of carbon dioxide.
  ○ Ask students what color they predict the solution would be if the carbon dioxide could be removed from the flask. Students should be able to predict that the solution would return to blue in the absence of carbon dioxide.	

4. Follow your teacher's directions to observe how a common aquatic plant, *Elodea*, uses carbon dioxide as an input of matter. Draw a labeled diagram of the investigation setup in the space below.

A sample investigation setup:



Focus on Student Thinking

- Use appropriate elicit (STeLLA Strategy 1) and probe questions (STeLLA Strategy 2) as you discuss predictions with small groups.
- Following are some example conversations:
    - T: So, what color do you predict the BTB in the tube with CO_2 will be at the end of the experiment? (ELICIT)
    - S1: I think green.
    - S2: I think it will go back to blue.
    - S3: I think green also.
    - T: Okay. Can each of you tell me why you predicted the color that you did? (PROBE)
    - S1: Well, if there is carbon dioxide in the tube, then the plant will take in some of that carbon dioxide and use it to make oxygen. So, the carbon dioxide will come out of the liquid and make the BTB greener.
    - T: I see. And is there a way to know if the carbon dioxide was used to make oxygen?(PROBE)
    - S3: No, not necessarily.
    - T: So if the BTB does turn green, what will we be able to say for sure? (PROBE)
    - S2: That the plant used some of the carbon dioxide in the water.
    - T: I like your thinking. Can you tell me why you think the BTB will go back to blue? (PROBE)
    - S2: Because I think that the plant will use up all the CO2 in the tube to do photosynthesis,so none of it will be left in the tube.
    - T: And how will that affect the color of the BTB? (PROBE)
    - S3: It would turn it back to blue.
    - T: I see. Do others agree or disagree with that explanation? (ELICIT)

Implementation	Notes
Activity: Bromothymol Blue and <u>*Elodea*</u>	

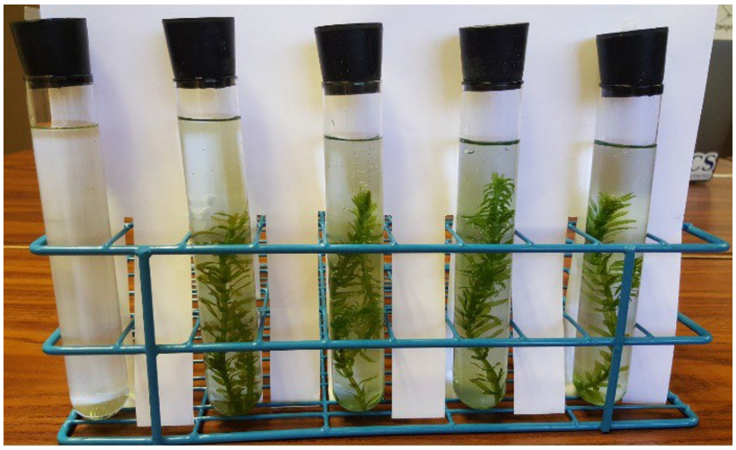
- **STEP 4:** Provide directions and materials locations for setting up the Bromothymol Blue and Elodea investigation:
    - To demonstrate the process, set up one test tube as a control. Label one tube "no CO_2" and the other "CO_2". Wearing safety goggles, add the BTB solution to each test tube until it is ¾ full. Stopper the test tube labeled "no CO_2" and place it in the test tube rack. Pour the BTB solution from the test tube labeled "CO_2" into the Erlenmeyer flask and blow bubbles through the solution until it turns yellow. Pour the yellow BTB solution back into the "CO_2" test tube, stopper the tube, and place it in the test tube rack. Mark that these tubes will serve as controls for the investigation.
    - Have teams label one test tube "no CO_2" and the other "CO_2". Following the procedure demonstrated above, each group should prepare the BTB solution for each test tube.
    - Once the solutions for each test tube are prepared, have teams add one sprig of *Elodea* to each test tube, making sure the sprig is fully submerged in the BTB solution. Enough space should remain at the top of the tube so that the stopper can be inserted without the solution overflowing. Test tubes should be placed in a test tube rack or clear container and placed in the light.
- Once student teams have set up the investigation, they should draw a labeled diagram of the setup in their notebooks. As students are setting up the investigation and recording the setup in their notebooks, circulate through the room asking elicit and probe questions to determine what students predict will happen in each tube.

> Refer to "Focus on Student Thinking" in the SE key for possible questions to elicit and probe student ideas.

- Once all groups have completed setting up the investigation, share that they will leave the test tubes in the light while they continue with part 2 of the activity. Teams will record the results of the investigation later in the lesson.
    - The time needed for this investigation will vary depending on environmental conditions that influence photosynthesis, primarily light. If you will be collecting results in the following class period, it may be necessary to leave the test tubes under a light source overnight.

On the diagram above, use a different color to show the results of the investigation.

After 30 minutes. Note the bubbles of oxygen on the plant leaves.



Use the space below to record important ideas from your class discussion.

Implementation	Notes

Activity Follow-up: Bromothymol Blue and Elodea

- Student teams should examine their test tubes and record their observations in a different color on their original diagram of the lab setup.
  - Important Note: Save several tubes containing healthy sprigs of Elodea for Lesson 4. Keep these tubes in the light until Lesson 3, then put the tubes in a dark place or cover the test tubes with foil. In the dark, the *Elodea* should undergo cellular respiration and the blue solution should turn yellow.
- Students should disassemble their materials. Provide a central collection container for the BTB solution and another container for the *Elodea*. The *Elodea* can be kept indefinitely in a tank with spring water (do not use distilled or chlorinated tap water) with a light source.
- Have a class discussion about how the results of the investigation matched, or not, their predictions. Key points to highlight in the discussion include:
  - The "CO_2" test tube turned from yellow to blue. This is a result of the *Elodea* taking in CO2 from the water to use in photosynthesis.
  - The "no CO_2" test tube remained blue throughout the investigation. The tube may have turned even darker blue as the Elodea took in CO_2 from the water during photosynthesis.
  - One of the inputs to the plant system is CO_2, which the plant uses in the chemical reactions of photosynthesis.

5. Read and annotate *Where Does the Carbon Go?* to learn more about how a plant uses carbon dioxide. As you read, stop and discuss the questions with your group.

Where Does the Carbon Go?

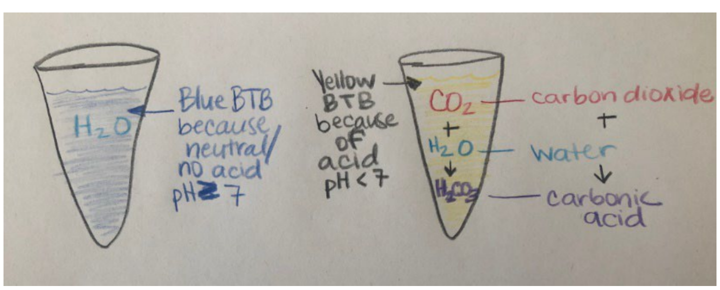
Carbon dioxide is a colorless, odorless gas that is present in the Earth's atmosphere. A single molecule of carbon dioxide, CO_2, is composed of two oxygen atoms attached to one carbon atom by chemical bonds. Carbon dioxide (CO_2) can dissolve in water (H_2O) to form carbonic acid (H_2CO_3). As its name suggests, carbonic acid is an acid. Acids have a pH value less than the neutral value of 7.0. The pH of a substance can be determined by the use of an indicator such as Bromothymol Blue (BTB).

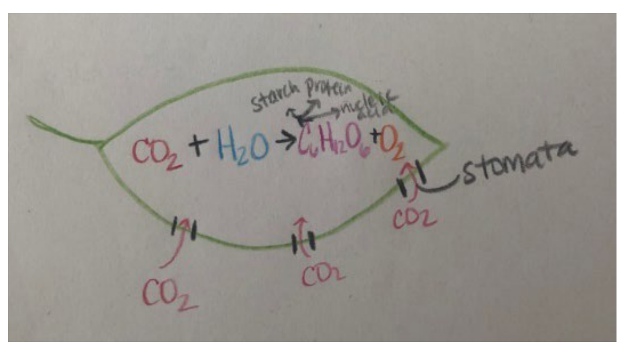
STOP **Stop and Think**
In the demonstration you observed, why did the Bromothymol Blue solution change color when air was bubbled through it by blowing through a straw? Why did the Bromothymol Blue solution change color when *Elodea* was added, and the test tube left in the light?

Plants use carbon dioxide in the process of photosynthesis. Photosynthesis is a series of chemical reactions in which the atoms of carbon dioxide (CO_2) and water (H_2O) molecules are separated and recombined to form glucose ($C_6H_{12}O_6$) and oxygen (O_2) molecules. Carbon dioxide in the air enters a plant through small openings in their leaves called stomata. In a cycle of chemical reactions, carbon dioxide molecules are separated into carbon and oxygen atoms. These atoms then form chemical bonds with hydrogen atoms to make glucose. Glucose is a type of sugar that a plant can use to form other molecules such as starch, proteins, and nucleic acids. Plants also use glucose as fuel in other chemical reactions.

STOP **Stop and Think**
Elodea is an aquatic plant that lives underwater. Where does *Elodea* get the carbon dioxide it needs for photosynthesis?

6. Draw a diagram showing the important ideas in the article.





Implementation	Notes

- **STEP 5:** Invite students to read the article, *"Where Does the Carbon Go?"* Students should read and annotate the article, stopping to discuss the questions after each paragraph.
- **STEP 6:** After reading the article, students should draw a diagram showing the important ideas in the article.
    - Invite several students to share what they have drawn. If a document camera is available, have students project their drawings for the class to observe.
    - Students should understand that when carbon dioxide dissolves in water, carbonic acid is formed. This causes the BTB solution to turn from blue to yellow. BTB is yellow in the presence of acids and blue in the absence of acids (or in the presence of a base).
    - Students should realize that the carbon dioxide the Elodea needs to photosynthesize is dissolved in water, forming carbonic acid. As the *Elodea* photosynthesizes, it takes up carbon dioxide, reducing the amount of carbonic acid in solution. This increases the pH (the solution becomes less acidic), turning the BTB blue.

Lesson 2: An Isolated Plant

Phase of Lesson: *A Plant as a System Part 2*
Activity Setup, Activity Part 2, Activity Follow-up

Main Learning Goal: As a system, plants use inputs of water, and carbon dioxide to create outputs of small carbon-based molecules (glucose) and oxygen through the process of photosynthesis. Matter is conserved throughout this process.

Focus Question: Where do the atoms that a plant uses in photosynthesis come from? Where do they go?

Unit Overarching Goal:

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas and predictions
- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy 3: Ask questions to challenge student thinking
- ❖ Strategy 5: Engage students in analyzing and interpreting data and observations
- ❖ Strategy F: Make explicit links between science ideas and activities

Time: 50 Minutes

Science Ideas

- Plants use a series of chemical reactions called photosynthesis to separate the atoms of water and carbon dioxide molecules and connect those atoms in different arrangements to make glucose and oxygen molecules.
- We can trace the atoms used in photosynthesis because matter is conserved in a system.
- Glucose molecules (C6H1206) are composed of carbon, hydrogen, and oxygen atoms which form the backbone of other large carbon molecules (such as starch).
- The oxygen produced as an output comes from the breakdown of the water molecules input into the system.

Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
- During photosynthesis, energy from sunlight is transformed into sugar.
- Plants increase mass by taking up chemicals from the soil.
- Fertilizer is food for plants.
- Plants undergo cellular respiration to provide CO_2 to make sugars.
- Photosynthesis takes place in plants while cellular respiration takes place in animals.
- Cellular respiration is the opposite of photosynthesis.
- Cellular respiration and breathing are the same thing.
- Cellular respiration and fermentation are unrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
- Energy can be recycled.

In the last investigation, you explored how a plant uses inputs of carbon dioxide and water to produce outputs of glucose and oxygen. In this investigation, you will think more about the oxygen a plant produces through the reactions of photosynthesis.

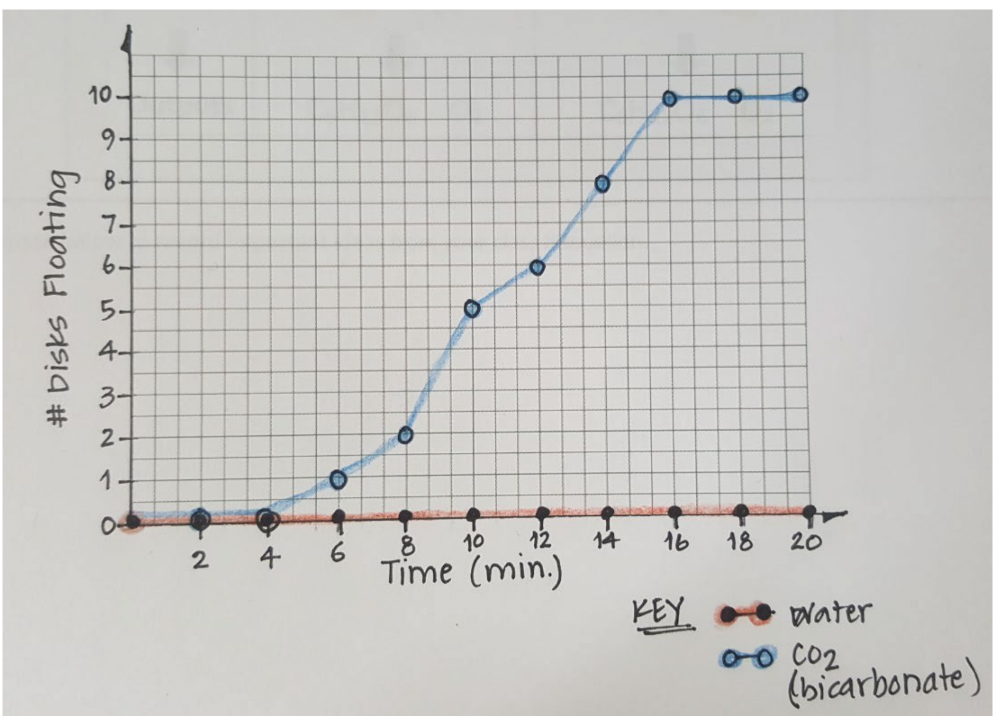
7. Read the procedure for conducting the leaf disk investigation with your group, making sure that everyone in your group understands the purpose for each step.

   Follow your teacher's directions to set up the leaf disk investigation.

8. Record the number of leaf disks floating in each solution in the table below. Sample results are shown.

Time / Solution	2 min	4 min	6 min	8 min	10 min	12 min	14 min	16 min	18 min	20 min
H_2O	0	0	0	0	0	0	0	0	**0**	0
CO_2	0	0	1	2	5	6	8	10	10	10

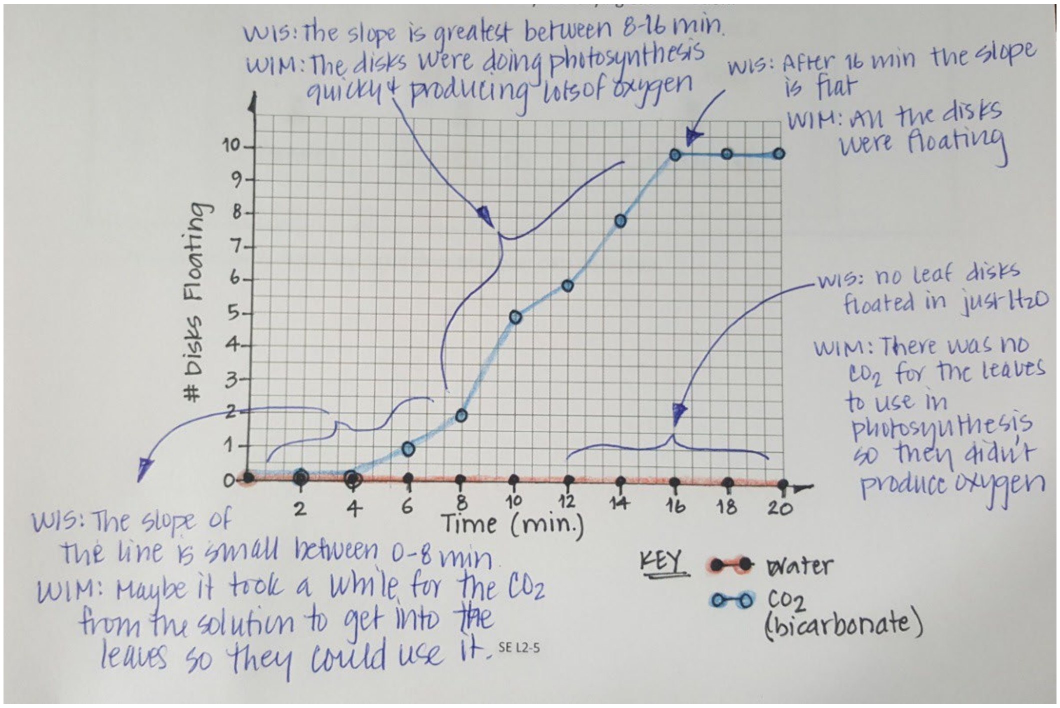
9. Graph your data. Be sure to label the axes and include a key identifying each solution.



Implementation	Notes

Activity Setup: Leaf Disk Investigation
 	
• Invite a student to read the introductory paragraph out loud to the class. Highlight that in this investigation, students will be investigating the output of oxygen produced during the chemical reactions of photosynthesis.
 	
• **STEP 7:** Distribute the handout and have students read the background information.
  ○ In teams, have one student read the step of the procedure and another student read the purpose for the step. The team should discuss the step and its purpose, making sure that everyone in the group understands both.
 	
• Demonstrate the procedure for the class. Alternatively, you may show students the procedure using the video found at this link:
  https://youtu.be/vw8baZO89oc
  Note that sometimes small bubbles remain attached to the disks during the vacuum process. If this occurs, physically sinking the disks in the cup will fix the problem.
 	
Activity: Leaf Disk Investigation
 	
• **STEP 8:** Provide directions and materials locations for setting up the leaf disk investigation.
 	
• Once groups have completed setting up the investigation, they should place their cups under the light source and begin timing and collecting data. Note that each student should record the data collected by the group.
  ○ The time needed for this investigation will vary depending on environmental conditions that influence photosynthesis, primarily light and the freshness of the spinach.
  ○ All the disks in the bicarbonate solution should float in a reasonable amount of time. Leaf disks in only water should have few, if any, disks floating. Depending on the time required for disks in the bicarbonate solution to float, you may have students stop recording data for both solutions. If the leaf disks in the bicarbonate solution float quickly, students may continue to collect data for the disks in water for a period of time after.
 	
• **STEP 9:** After all data has been collected, students should graph their data using the grid in their notebooks. Make sure students are labeling the axes of their graph correctly and including a key to identify each solution.	

10. Use Identify and Interpret (I[2]) on the graph by writing "What I see" and "What it means" statements. Be sure to include arrows from the "What I see" statements to the trend, pattern, high-point, or low-point on the graph.



Focus on Student Thinking

- Use appropriate elicit (STeLLA Strategy 1), probe (STeLLA Strategy 2), and challenge questions (STeLLA Strategy 3) as you discuss students' interpretations of their graphs.
- Following are some example conversations:
  - T: What was something interesting that you noticed in your graph? (ELICIT)
  - S1: I noticed that the disks with the bicarbonate rose a lot quicker than the ones in justwater.
  - S2: I noticed that too, and not as many rose in just water.
  - T: Great observations. Who might be able to explain why the disks in bicarbonate would have risen more quickly? (PROBE)
  - S3: I think because they could do photosynthesis and the ones in just water couldn't.
  - T: Can you explain your thinking a little further? (PROBE)
  - S3: Well, plants need carbon dioxide to do photosynthesis, so with the bicarbonate, they had carbon dioxide, so they did photosynthesis. But in just water, they didn't have carbon dioxide, so they couldn't do photosynthesis.
  - T: So how does 'doing photosynthesis' make them float? (PROBE)
  - S3: Because there was carbon dioxide gas in there then. And gases are light.
  - T: I see. I'm a little confused, though, because I thought we read that the atoms of carbon dioxide are separated during photosynthesis. (CHALLENGE)
  - S4: Yeah. Carbon dioxide and water get broken down to make glucose and oxygen.
  - T: So, if the carbon dioxide has been broken down, what caused the disk to float? (CHALLENGE)
  - S1: Oh, because there's oxygen made. And oxygen is a gas, too. So the oxygen is making it float.

Implementation	Notes

- **STEP 10:** Teams should then use the Identify and Interpret process to interpret their graph. Review the directions for this process with the class.
- Invite several groups to share their graphs and interpretations. If a document camera is available, have students project their drawings for the class to observe. As students share their interpretations of the graph, ask elicit, probe and challenge questions to make student thinking visible. Students should be able to link their data to the information from the "Purpose for the Step" column of their procedure handout.
- Key points to highlight in the discussion include:
    - The leaf disks initially sink because they are more dense than the solution. The vacuum created by the syringe removed the air between the leaf cells of the disk.
    - The leaf disks rose in the bicarbonate solution because the leaf disks were able to conduct photosynthesis. The input of carbon dioxide came from the bicarbonate dissolved in the water. As the leaf photosynthesized, it produced oxygen which collected between the leaf cells. This caused the disk to become less dense than the solution and the disk floated.
    - Leaf disks in water did not have a source of carbon dioxide to use in the chemical reactions of photosynthesis. Therefore, they did not produce oxygen and float. Some disks may have had some residual carbon dioxide between their cells to use in photosynthesis, and eventually floated.

Refer to "Focus on Student Thinking" in the SE key for possible questions to elicit and probe and challenge student ideas and predictions.

Activity Follow-up: Leaf Disk Investigation

- Students should disassemble their materials. The solution can be disposed of in sink drains after leaf disks have been removed. Leaf disks should be thrown in the trash and not dumped down the sink drains.
- Remind students that the inputs of photosynthesis are carbon dioxide and water. Both these molecules contain oxygen. Ask for a show of hands for which molecule they think contributes the oxygen that made the leaf disks float: carbon dioxide, water, or both.

11. Read the article, *Where Does the Oxygen Come From?* As you read, underline important ideas.

Where Does the Oxygen Come From?

In the chemical reactions of photosynthesis, the atoms of carbon dioxide (CO_2) and water (H_2O) are separated and recombined into glucose ($C_6H_{12}O_6$) and oxygen. (O_2). The overall reaction for photosynthesis can be written as:

carbon dioxide + water → glucose + oxygen

A molecule of glucose is composed of carbon, hydrogen, and oxygen atoms. From the overall reaction, we can see that the carbon atoms of a glucose molecule come from carbon dioxide, and the hydrogen atoms come from water. However, both carbon dioxide and water contain oxygen atoms. Do the oxygen atoms in glucose come from the oxygen atoms in carbon dioxide or the oxygen atoms in water?

To answer this question, scientists used radioactive isotopes to follow the atoms as they move through chemical reactions. An isotope is a different form of an element that behaves identically in chemical reactions. Because it is radioactive, the isotope can be detected using a Geiger counter or other detection device. Scientists used radioactive isotopes of oxygen atoms to follow their movement through the reactions of photosynthesis as shown in the table below:

The Path of Radioactive Oxygen Isotopes in Photosynthesis

Key
O = non-radioactive oxygen
O = radioactive oxygen isotopes

	Experiment 1	Experiment 2
Inputs	C**O**₂ → CO_2 (radioactive O), H_2O	CO_2, H_2**O** (radioactive O)
⬇	⬇	⬇
Outputs	C_6H_{12}**O**$_6$ (radioactive O), O_2	$C_6H_{12}O_6$, **O**$_2$ (radioactive O)

Use the space below to record important ideas from your class discussion.

Implementation	Notes

• **STEP 11:** Have students read the article, “Where Does the Oxygen Come From?” using an appropriate literacy strategy.
• Have a class discussion about how the article supported, or not, their predictions. Key points to highlight in the discussion include:
  ○ When carbon dioxide is labeled with radioisotopes of oxygen, the glucose produced by the chemical reactions of photosynthesis is radioactive. The oxygen produced is not radioactive. This means the oxygen from carbon dioxide is incorporated into the glucose and not the oxygen.
  ○ When water is labeled with radioisotopes of oxygen, the glucose produced by the chemical reactions of photosynthesis is not radioactive; however, the oxygen produced is radioactive. This means the oxygen from water is released as oxygen.	

12. Place a check mark in the appropriate column to show which input molecule is the source of the atoms in glucose and oxygen - the output molecules of photosynthesis.

Inputs		**Outputs**	
Carbon dioxide (CO2)	**Water (H2O)**	**Atom of output molecule**	**Output molecule**
✓		Carbon (C)	**Glucose ($C_6H_{12}O_6$)**
	✓	Hydrogen (H)	
✓		Oxygen (O)	
	✓	Oxygen (O)	**Oxygen (O_2)**

Implementation	Notes
• **STEP 12:** Have students individually complete the table showing where the atoms of carbon dioxide and water can be found in the output molecules of glucose and oxygen. Students should compare their ideas with others in their group and make sure that everyone agrees.	

Lesson 2: An Isolated Plant

Phase of Lesson: *Synthesize and Summarize*

Main Learning Goal: As a system, plants use inputs of water, and carbon dioxide to create outputs of small carbon-based molecules (glucose) and oxygen through the process of photosynthesis. Matter is conserved throughout this process.

Focus Question: Where do the atoms that a plant uses in photosynthesis come from? Where do they go?

Unit Overarching Goal:

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

Notes:

Time: 25 Minutes

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas and predictions.
- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy 9: Engage students in making connections by synthesizing and summarizing key science ideas
- ❖ Strategy H: Highlight key science ideas and focus questions throughout

Science Ideas

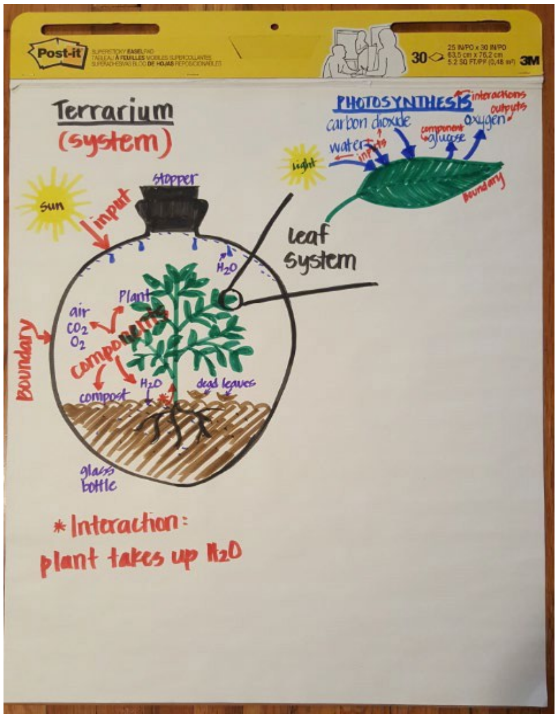
- A system has boundaries, components, interactions, and inputs and outputs. In a closed system, you can identify the inputs and outputs as matter or energy.
- A plant represents a closed system with all identifiable characteristics of a system.

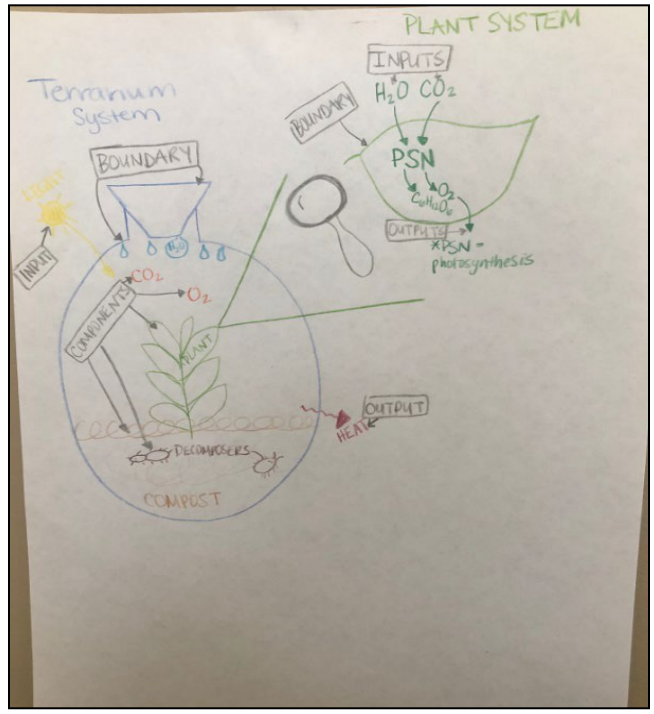
Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
- During photosynthesis, energy from sunlight is transformed into sugar.
- Plants increase mass by taking up chemicals from the soil.
- Fertilizer is food for plants.
- Plants undergo cellular respiration to provide CO_2 to make sugars.
- Photosynthesis takes place in plants while cellular respiration takes place in animals.
- Cellular respiration is the opposite of photosynthesis.
- Cellular respiration and breathing are the same thing.
- Cellular respiration and fermentation areunrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
- Energy can be recycled.

Synthesize and Summarize Ideas

13. Following your teacher's directions, create a drawing, or model, that shows how the plant in the terrarium is a system. Add labels showing characteristics, or key features of a system to your model.





14. Reread your initial response to the lesson focus question. Consider the ideas from the activities you completed. If you would like to add to or revise your ideas, do so in a different color.

Focus on Student Thinking

- Use appropriate elicit (STeLLA Strategy 1) and probe questions (STeLLA Strategy 2) as you discuss predictions with small groups.
- Following are some example conversations:
    - T: Would anyone like to share how their ideas have changed since the beginning of this lesson?(ELICIT)
    - S1: Well at the beginning of the lesson, I said that plants took in nutrients from the soil and used itfor food.
    - T: I noticed quite a few people who mentioned that. Were there others who also thought this?(ELICIT)
    - T: Can someone who raised their hand tell me how their ideas have changed now? (PROBE)
    - S2: Well now I know that they actually use carbon dioxide from the air and mostly water from the soil to make glucose.
    - T: That's an awesome revision of your ideas. Who else had a change in their ideas? (ELICIT)
    - S3: At the beginning, I thought that plants used carbon dioxide to make oxygen, but that's actually not true.
    - T: Okay. And what do you think now? (PROBE)
    - S3: Plants take in carbon dioxide and water and rearrange the atoms to make glucose, and the oxygen they release is actually from water, not carbon dioxide.
    - T: That is a great explanation. Thank you for sharing.

Implementation	Notes
Synthesize and Summarize Science Ideas • **STEP 13:** Provide directions for adding a labeled drawing of the plant system to their original terrarium system model. Mark that teams should make sure they have added labels to show the characteristics of a system to their drawing. • As teams construct their drawing, circulate through the room asking probe and challenge questions to make student thinking visible. • When groups have finished their drawing of a plant system, have teams hang their charts in a space where others can observe them. Have several teams share the thinking that contributed to their drawing. • **STEP 14:** Have students reread their initial response to the lesson focus question. After considering the activities they completed in this lesson, students should add to or revise their answer to the focus question in a different color. • Invite several students to share how their thinking changed over the course of the lesson. Refer to "Focus on Student Thinking" in the SE key to see examples of ways to elicit and probe student ideas.	

Lesson 2: An Isolated Plant

Phase of Lesson: *Summarize and Link*

Main Learning Goal: As a system, plants use inputs of water, and carbon dioxide to create outputs of small carbon-based molecules (glucose) and oxygen through the process of photosynthesis. Matter is conserved throughout this process.

Focus Question: Where do the atoms that a plant uses in photosynthesis come from? Where do they go?

Unit Overarching Goal:

In a closed system, matter is conserved and cycles within the system. Energy is conserved, but can enter and leave a closed system, thus flowing through the system. Through the processes of photosynthesis and cellular respiration, carbon molecules cycle between living and nonliving components. Through biological processes, carbon atoms are fixed into organic molecules that are rearranged into other organic molecules by organisms. Energy is transferred and transformed from solar to chemical energy during photosynthesis. Through the process of cellular respiration, chemical energy is transformed into kinetic and heat energy by living organisms. Because heat energy leaves the system, a continual input of solar energy is required to sustain the system. Using models, we can predict how changes in components affect the systems.

Notes:

Time: 25 Minutes

STeLLA Strategies

- Strategy I: Summarize key science ideas

Science Ideas

Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
- During photosynthesis, energy from sunlight is transformed into sugar.
- Plants increase mass by taking up chemicals from the soil.
- Fertilizer is food for plants.
- Plants undergo cellular respiration to provide CO_2 to make sugars.
- Photosynthesis takes place in plants while cellular respiration takes place in animals.
- Cellular respiration is the opposite of photosynthesis.
- Cellular respiration and breathing are the same thing.
- Cellular respiration and fermentation areunrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
- Energy can be recycled.

Implementation	Notes
Summarize • Close the lesson by sharing that, in this lesson, we learned that a plant can be considered a system. The inputs a plant uses for photosynthesis include carbon dioxide and water. The outputs of photosynthesis are glucose and oxygen. The oxygen produced comes from the input molecules of water. *Link to the Next Lesson* • Link to the next lesson by sharing that, in the next lesson, we will consider the role of energy in the chemical reactions of photosynthesis.	