A Study of Matter and Energy in Systems

Lesson 4: Food For Plants

Grade: 9-10 General Biology

Length of lesson: 145 minutes

Placement of lesson: Lesson 4 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 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.

Unit Central Question

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

Lesson 4 Main Learning Goal

The process of cellular respiration is a series of chemical reactions that both require and release energy. These reactions yield a net release of energy that can be used to form large carbon-based molecules that can be used for growth and reproduction as well as fuel in chemical reactions.

Lesson 4 Focus Question

How do plants use the outputs of photosynthesis?

Ideal student response

Plants use glucose and oxygen, the outputs of photosynthesis, as the inputs for cellular respiration. The glucose that a plant makes through photosynthesis becomes food for the plant. In cellular respiration, there is an overall input of energy because it takes less energy to break the bonds of glucose and oxygen molecules than the energy released when carbon dioxide and water are formed. This energy can be used by the plant to run other chemical reactions, making molecules like starch that will become part of the plant's body, or for reproduction. Because mass is conserved, the number and type of input atoms is the same as the output atoms.

Science Content Storyline

The process of cellular respiration is a series of chemical reactions that both require and release energy. Plants use cellular respiration reactions to separate the atoms of glucose and oxygen and connect those atoms in different arrangements to form larger carbon-based molecules such as starch. An input of energy is required to separate the atoms of the reactant molecules (glucose and oxygen), and energy is released as atoms connect to form new product molecules (carbon dioxide and water). Because the energy required to separate the atoms of the reactant molecules is less than the energy released in the formation of product molecules, the reactions of cellular respiration result in a net output of energy. Some of this energy is used in other chemical reactions, and some energy leaves the plant as heat.

Plants use some large carbon-based molecules to grow by organizing the molecules into roots, stems, leaves, and reproductive structures. They use other large carbon-based molecules and oxygen molecules as fuel in chemical reactions. The products of these chemical reactions are simple molecules of carbon dioxide and water which are returned to the environment.

Materials

Leaf Starch Demonstration

- Goggles
- Ethanol
- 250 ml beaker
- Boiling water (do not heat over an open flame with ethanol present)
- Iodine Potassium Iodide (IKI) solution (also called Lugols solution)
- Beaker or jar labeled “waste ethanol”
- Geranium leaves or other leaves, one that has been in the dark for 24 hours and one that has been in thelight
- Forceps or tweezers
- 2 large test tubes, 1/leaf used
- Glass stirring rod

Other materials

- Computer access to conduct simulation, either as a class or ideally per student

Advance Preparation

- At least 24 hours before the lesson, cover one geranium leaf with foil or heavy paper so it cannot photosynthesize.
- Determine how students will access the online simulation (individually, in pairs or small groups, or as a whole class)
- Make sure you have all the materials prepared for use before class to be efficient with time. You may not be able to complete the lesson in one class period because students need more time to read, talk, think, or write.

Lesson 4 General Outline

Time (min)	Phase of lesson	How the science content storyline develops
10	**How do plants use the outputs of photosynthesis? (Lesson focus question)** The teacher makes links to the prior lesson and introduces the lesson focus question.	
60	**Matter and Energy Interactions in Cellular Respiration** Activity Setup Students read and discuss an article about plant growth. They observe a demonstration showing the presence of starch in photosynthetic leaves. Activity Students observe the results of *Elodea* in BTB left in the dark and a cup of floating leaf disks left in the dark. They use the Identify and Interpret process to interpret their observations. Students then read an article about seed germination and use a simulation showing the growth of radish seeds in various conditions and suggest reasons for mass changes over time. Activity Follow-up Students read about cellular respiration and the Law of Conservation of Mass and manipulate pop beads to account for the atoms in the reactants and products of cellular respiration. They revise their explanations for the mass changes in the radish seed simulation.	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.
15	**Synthesize and Summarize** Students revise and add to their initial model drawing, adding labels showing the flow of energy and cycling of matter involved in plant cellular respiration. They revise and add to their initial response to the focus question.	
5	**Summarize and Link** In this lesson, students have considered the flow of energy and cycling of matter in the chemical reactions of cellular respiration in a plant. In the next lesson, students will consider the chemical reactions of photosynthesis in other organisms.	

Lesson 4: Food for Plants

Phase of Lesson: *Lesson Focus Question?*

Main Learning Goal: The process of cellular respiration is a series of chemical reactions that both require and release energy. These reactions yield a net release of energy that can be used to form large carbon-based molecules that can be used for growth and reproduction as well as fuel in chemical reactions.

Focus Question: How do plants use the outputs of photosynthesis?

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

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.

Lesson 4: Food for Plants

Introduction

In the last lesson, you explored how inputs of matter and energy interact in the process of photosynthesis to produce glucose and oxygen. In this lesson, you will continue to think about additional interactions of matter and energy that are needed to keep the plant alive.

Lesson Question

How do plants use the outputs of photosynthesis?

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

- Use STeLLA Strategy 1: Ask questions to elicit student initial ideas and predictions to get a variety of ideas out. Make it clear to students that at this point in the lesson, we are gathering a lot of ideas and that you are not going to tell which ideas about how plants use the outputs of photosynthesis are right or wrong at this time.
- Sample student responses follow:
    - Plants use the outputs of photosynthesis to do photosynthesis again.
    - Plants use the outputs of photosynthesis for energy for the plant.
    - Plants use the outputs of photosynthesis for food for the plant.
    - Plants use the outputs of photosynthesis to continue the cycle.
- 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. 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 the following:
    - Tell us more about…
    - What do you mean when you say…?
    - What would a plant need energy for?

Implementation	Notes

Link to Previous Lessons
• Remind students that the unit central question is "How do matter and energy move through a system as living things interact with each other and the environment?"
• Ask students to summarize what they have figured out in previous lessons that will help answer the unit central question. Ideas to highlight in the discussion include:
  ○ Both the terrarium and the plant in the terrarium are considered to be systems because they display the characteristics of a system: boundaries, components, inputs and outputs, and interactions.
  ○ Plants use the chemical reactions of photosynthesis to break the bonds of carbon dioxide and water and recombine the atoms into products of glucose and oxygen. These reactions require the input of light energy.
  ○ The oxygen produced by photosynthesis comes from the breakdown of water molecules.
  ○ Light energy is required for the chemical reactions of photosynthesis. This energy is required because the energy required to separate the reactant molecules is greater than the energy released when the product molecules are formed.
Lesson Focus Question
• **STEP 1:** Introduce the lesson focus question: "How do plants use the outputs of photosynthesis?" 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.
• Allow time for students to write the focus question in the box in their notebooks. Remind them that we are just beginning the lesson, so they may not know the full answer, but they should think about their best ideas in response to the question. Share that they will have a chance to revise their ideas as they work through the lesson.
• Invite several students to share their ideas about the focus question.
 	
Use the information in "Focus on Student Thinking" in the SE key to see examples of ways to elicit and probe student ideas.	

Lesson 4: Food for Plants

Phase of Lesson: *Matter and Energy Reactions in Cellular Respiration*

Main Learning Goal: The process of cellular respiration is a series of chemical reactions that both require and release energy. These reactions yield a net release of energy that can be used to form large carbon-based molecules that can be used for growth and reproduction as well as fuel in chemical reactions.

Focus Question: How do plants use the outputs of photosynthesis?

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
- ❖ Strategy G: Link science ideas to otherscience ideas

Time: 60 Minutes

Science Ideas

- The process of cellular respiration is a series of chemical reactions that both require and release energy.
- Plants use cellular respiration reactions to separate the atoms of glucose and oxygen and connect those atoms in different arrangements to form larger carbon-based molecules such as starch. An input of energy is required to separate the atoms of the reactant molecules (glucose and oxygen), and energy is released as atoms connect to form new product molecules (carbon dioxide and water).
- Because the energy required to separate the atoms of the reactant molecules is less than the energy released in the formation of product molecules, the reactions of cellular respiration result in a net output of energy. Some of this energy is used in other chemical reactions, and some energy leaves the plant as heat.
- Plants use some large carbon-based molecules to grow by organizing the molecules into roots, stems, leaves, and reproductive structures. They use other large carbon-based molecules and oxygen molecules as fuel in chemical reactions. The products of these chemical reactions are simple molecules of carbon dioxide and water which are returned to the environment

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.
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- Energy is released whenever chemical bonds are broken.
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Matter and Energy Interactions in Cellular Respiration

2. Read and annotate Plant Growth to begin to think about how a plant uses matter and energy to stay alive. As you read, stop and discuss the questions with your group.

Plant Growth

Plants, like all living organisms, require an input of matter (food) that is used for growth and reproduction. Some of the matter becomes part of the plant's body structure, including roots, stems, leaves, and reproductive structures such as flowers, fruit, and seeds. Some of the matter is used as fuel in chemical reactions.

Stop and Think
What types of matter might a plant use as food for growth and reproduction?

A plant might use nutrients from the soil for its food.
A plant might use the glucose from photosynthesis for food.

The atoms of the input food molecules include carbon, hydrogen, and oxygen. These atoms are rearranged through chemical reactions to form new molecules such as carbohydrates (starch), amino acids and proteins, lipids (fats), and nucleic acids. These large carbon-based molecules are found throughout a plant's body structures.

Stop and Think
How are the large carbon-based molecules found throughout a plant's body structures the same as, or different than, those found in animal body structures?

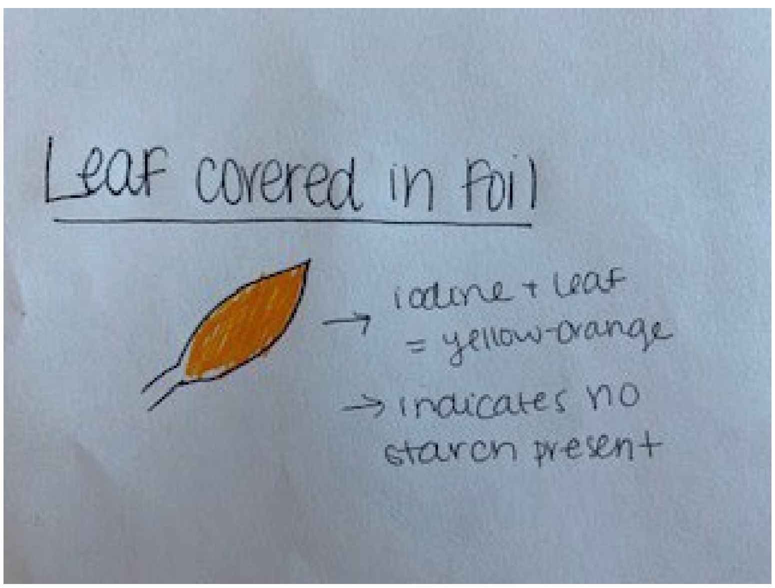
Animals have protein, fat, and nucleic acids in their body. I don't know if animals have starch in their bodies.

A plant needs energy all the time to power the chemical reactions it needs to stay alive. The reactions of photosynthesis require a net input of light energy. However, a plant cannot get energy from the sun at night and, in many climates, the amount and intensity of sunlight is limited in winter. To obtain energy at all times, the plant needs chemical reactions with a net output of energy. In these reactions, the reactant molecules require less energy to break their bonds than the energy released when the product molecules' bonds are formed. Glucose is a molecule that, in reactions with oxygen, provides a net output of energy.

I know that animals can use glucose as food. Maybe plants and animals can both use glucose as food for energy.

Implementation	Notes
Activity Setup • Remind students that the plant in the terrarium has been alive for over fifty years in isolation from the external environment. To stay alive and grow, the plant needs both matter and energy. • **STEP 2:** Have students read and annotate the article, "Plant Growth." As they complete each paragraph, they should discuss the questions in their team to make sure that everyone understands the information in the text.	

3. Plants often use chemical reactions to join glucose molecules together to form starch molecules. This allows the plant to store more glucose molecules in a smaller space within the plant's cells. Watch your teacher's demonstration of a chemical test for the presence of starch in a plant's leaves. Draw a labeled diagram of your observations below.



Implementation	Notes

• **STEP 3:** Ask a student to read the introductory text of this step. If students have prior experience with the IKI test for starch, ask several students if they recall how to test for the presence of starch.
• Engage students in the Starch in Leaves demonstration, sharing the purpose for each of the steps:
  ○ Pour boiling water into a large beaker. Using forceps, place each leaf in the boiling water for one minute. This step breaks down the cell membranes.
  ○ Remove the leaves from the boiling water and put each in a large, labeled test tube, pushing it to the bottom with a glass stirring rod.
  ○ Add enough ethanol to cover the leaves and place the test tube in the beaker of hot water. The ethanol will boil even though the water may not be boiling as ethanol has a lower boiling point (78.7oC) than water. Boil the leaves in ethanol for several minutes until the green chlorophyll is removed from the leaf. This makes it easier to see the color change when IKI is added to the leaf.
    ▪ Note: replace the hot water in the beaker with boiling water if the leaves are still green after 5 minutes.
  ○ Remove the leaves from the test tube and rinse carefully in cold water. This step ensures the ethanol will not interact with the IKI solution.
  ○ Place the leaves on a white surface, such as paper. Add a few drops of iodine potassium iodide (IKI) solution, covering the leaf surface. IKI is orange-brown and will turn blue-black in the presence of starch.	

4. The reading, *Plant Growth*, stated a plant could obtain energy by reacting glucose with oxygen. If glucose and oxygen are the reactants in the chemical reaction, what molecules might be the products of this reaction? To begin to answer this question, at the end of Lesson 2, a test tube containing *Elodea* and Bromothymol Blue was placed in the dark. Similarly, at the end of Lesson 3, a cup with all the leaf disks floating was placed in the dark. Observe both and complete the chart below.

Investigation Set up	Observation (What I See)	Interpretation (What it means)
A test tube with *Elodea* in water with Bromothymol Blue was left in the dark.	The Bromothymol Blue solution has turned yellow.	There is an increase in carbon dioxide in the test tube. Carbon dioxide turns the BTB solution yellow because carbon dioxide dissolves in water to make carbonic acid.
A cup in which all the spinach leaf disks were floating was left in the dark.	All the leaf disks are laying on the bottom of the cup.	The oxygen in the disks was the reactant and was used up. This would make the leaf disk more dense than the solution and it would sink.

Use the space below to add ideas from the class discussion.

Focus on Student Thinking

- Use appropriate probe (STeLLA strategy 2) and challenge questions (STeLLA strategy 3) as students share their ideas in the class discussion or in small groups.
- Below is an example conversation.
  - T: Why is the test tube yellow? (ELICIT)
  - S: It means carbon dioxide is present.
  - T: Where do you think that carbon dioxide could have come from? (PROBE)
  - S: I think it would have had to come from the plant?
  - T: Say more about that. (PROBE)
  - S: Well, the Elodea was the only thing in the test tube, so it had to come from the plant
  - T: How do these results compare to the results when the test tube was left in the light? (CHALLENGE)
  - S: Well in the light, the plant was doing photosynthesis so maybe in the dark it wasn't. In the last lesson, we learned that light is needed for photosynthesis to occur. Maybe some different chemical reactions are happening.

Implementation	Notes

• **STEP 4:** Have table groups read the introductory text from step 4 in their notebooks. Ask several students to summarize what they read. The purpose of this step is to link science ideas from prior lessons with the observations they make of plants left in the dark. These connections will help students think about how plants use the products of photosynthesis during cellular respiration.
  ○ Show students the test tubes containing Elodea in the Bromothymol Blue solution and the cups with floating leaf disks that have been in the dark for 24- 48 hours.
    ▪ Have students individually record their observations in the middle column of the chart in their notebooks.
    ▪ After students have made their observations, invite teams to discuss what their observations mean. Circulate among teams asking elicit, probe and challenge questions as needed to make student thinking visible and move their thinking forward.
  ○ Have a class discussion about what their observations mean. Encourage students to link their interpretation of their observations to science ideas from previous lessons. Encourage students to add new ideas from the discussion in the space below the chart.
 	
Use the information in "Focus on Student Thinking" in the SE key to see examples of ways to elicit, probe, and challenge student ideas as well as to help students link science ideas to other science ideas.	

5. To think more about how a plant gets energy from reacting glucose with oxygen, we will explore the growth of seeds. Before starting the simulation, read the following information about seeds and germination.

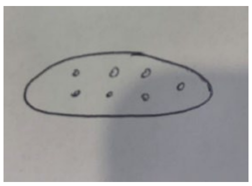
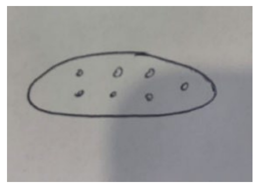
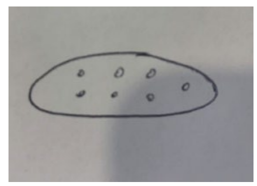
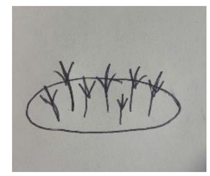
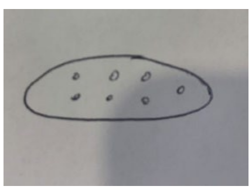
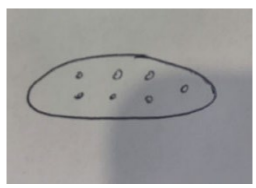
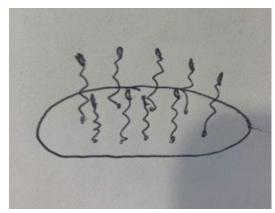
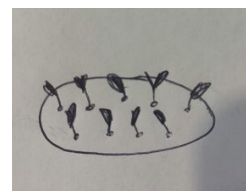
Seed Germination

Seeds are living organisms. A fully developed seed contains an embryo, a store of food reserves, and a tough protective outer layer called a seed coat. The food reserves of a seed are composed primarily of starch. This starch was produced by the seed's parent plant. Until they are in the proper environmental conditions, seeds are dormant – the chemical reactions within the cells of the seed are extremely limited.

For a seed to come out of dormancy and germinate, it needs to take up water. As the seed absorbs water, it swells and the seed coat softens. The swelling seed breaks open the softened seed coat. The absorbed water also activates the chemical reactions in the cells of the seed. Starch molecules are broken down into glucose molecules. Some of the glucose molecules combine with oxygen in chemical reactions with a net output of energy. Some of the glucose molecules are used in chemical reactions to make other large carbon-based molecules that will form the new plant's body structures.

Implementation	Notes
Activity • **STEP 5:** Note that, to think more about how a plant gets energy from reacting glucose with oxygen, they will explore the growth of seeds. Use an appropriate literacy strategy to support students as they read the article, “Seed Germination.”	

6. Follow your teacher's directions to access the simulation.
   - Read the directions in the box titled, "Setup the Experiment."
   - In the first row of the chart below, make a labeled drawing of your predictions.
   - After making your predictions, click the "Run Experiment" button and add a labeled diagram of the experimental results in the second row.
   - Predict whether the mass of plant material has increased, decreased, or stayed the same by placing a check in the appropriate column.
   - Click the "Get Results" button and record the results of the experiment.

	Experimental Setup 1 **Light: NO Water :NO**			**Experimental Setup 2** **Light: YES Water :NO**			**Experimental Setup 3** **Light: NO Water :YES**			**Experimental Setup 4** **Light: YES Water :YES**		
Drawing of Your Prediction												
Drawing of Experimental Results												
Prediction of Mass Change	Increase	Decrease	No change	Increase	Decrease	No change	Increase	Decrease	No change	Increase	Decrease	No change
			✓			✓	✓					
Initial dry mass of seeds (g)	1.00 grams			1.00 grams			1.00 grams			1.00 grams		
Final Dry Mass of Seeds (g)	1.00 grams			0.99 grams			0.81 grams			1.10 grams		
Change in Dry Mass (g)	0.00 grams			-0.01 grams			-0.19 grams			+ 0.10 grams		

Implementation	Notes
• **STEP 6:** Provide directions about how students will access the online simulation. The link to the simulation is: Growth needs of Plants Simulator or https://media.bscs.org/emat/bio_unit/interactives/2_XPLR_C-growth-needs-plants/index.html Because there are four experimental setups, students will need to run the simulation twice. Alternatively, you may lead experimental setup 1 as a demonstration to model the process and have students conduct experimental setups 2-4 in teams. Encourage students to make predictions about what will happen to the seeds as well as predictions about the changes in mass they might observe.	

7. Write your best ideas about why the mass of the plant material increased, decreased or stayed the same for each experimental condition in the chart below.

	Experimental Setup 1 **Light: NO Water: NO**	**Experimental Setup 2** **Light: YES Water: NO**	**Experimental Setup 3** **Light: NO Water: YES**	**Experimental Setup 4** **Light: YES Water: YES**
My ideas about the change in the mass of plant material	The mass did not change because there was no water for the seed to use to germinate. Because there was no sunlight, there could be no photosynthesis.	The mass did not change because there was no water for the seed to use to germinate. Even though there was light for photosynthesis to happen, because the seed hadn't absorbed any water, it didn't matter that there was light for photosynthesis. Water seems more important than light for a seed to start to grow.	The mass decreased even though there was water added to the seed. The water allowed the seed to germinate and start to grow by breaking down the stored energy in the seed. Because there wasn't any light, there was no photosynthesis and the seedling couldn't produce glucose to use as food. Because the seed was using up the food that was stored in the seed and not making any new food, the mass decreased.	The mass increased because the seed absorbed water and germinated. In this case, the seedling was able to do photosynthesis with sunlight, water and the carbon dioxide from the air. The seedling photosynthesized and produced glucose and used that glucose for energy or to make new molecules. As the seedling added these new molecules, the mass increased.

Focus on Student Thinking

- Ask appropriate probe (STeLLA strategy 2) and challenge questions (STeLLA strategy 3) as students share their ideas in the class discussion.
- A sample conversation is below:
  - T: Say more about what happened to the seed that only had water. (PROBE)
  - S1: The plant lost mass because it was using what was in the seed to grow.
  - T: What do you mean by using what was in the seed? (PROBE)
  - S1: The reading says that there is food storage in the seed.
  - T: What do others think about what S just said? (Elicit)
  - S2: I agree with that. I think it used the food storage to grow and as it used up the food storage, it lost mass.
  - T: Why do you think that is important? (Challenge)

Implementation	Notes
• **STEP 7:** Working in teams, students should write their best ideas about why the mass of plant material increased, decreased, or stayed the same. ○ After students have added their ideas to the chart, have students share their ideas with the whole class. As students share their ideas, ask probe and challenge questions to make student thinking visible and support their ideas with science ideas from prior lessons. Use the information in “Focus on Student Thinking” in the SE key to see examples of ways to elicit, probe, and challenge student ideas as well as to help students link science ideas to other science ideas.	

8. As you read earlier, plants get energy from the reaction of glucose and oxygen. Actually, ALL organisms require energy and get it in the same basic way – the process of cellular respiration. To learn and think more about this process and how that energy is used, read the science ideas in the left column of the table below. In the right column, draw a labeled diagram that represents that idea.

Energy and Cellular Respiration

Science Idea	Labeled Drawing of the Idea
Cellular respiration is a chemical reaction. The reactant (input) molecules are glucose and oxygen. The product (output) molecules are carbon dioxide and water.	D
During cellular respiration, energy is required to break the bonds between the atoms of the reactants (glucose and oxygen). Unlike photosynthesis, however, this energy input is chemical, not light.	F
During cellular respiration, energy is released when atoms bond to form the product molecules (water and carbon dioxide).	E
In cellular respiration, the amount of energy required to break the bonds of the reactant molecules ($C6H12O6$ and $O2$) is less than the amount of energy released when the product molecules ($CO2$ and $H2O$) form. Therefore, the chemical reaction of cellular respiration produces a NET OUTPUT of energy.	B
This NET OUTPUT of energy is required to carry out life's functions and sustain life's processes (ex: movement, building body structures, reproduction, maintaining body temperature)	G
Some of the glucose made during photosynthesis is used as a reactant for cellular respiration. The oxygen reactant comes from the air. The carbon dioxide produced is released into the atmosphere. Some of the water produced is also released into the atmosphere, while some is retained in the plant cells.	A
Plants require oxygen as a reactant to carry out cellular respiration, and they also produce oxygen during photosynthesis. However, plants produce approximately ten times more oxygen during photosynthesis than they use in cellular respiration.	C

9. Now that you have drawn representations of the statements above, cut and sort the card set on the next page and tape the appropriate card beside each statement. Compare your representation to the card and discuss with a partner. Your representation may not be exactly the same, but does it reflect the same idea as that on the card? If not, reread the statement together to clarify your understanding.

Implementation	Notes
Activity Follow-up • **STEP 8:** Have students read the paragraph above the chart in their notebooks. • Working in pairs, students should read each science idea and discuss what they think the idea means in their own words. Then they should make a labeled drawing of the idea in the right-hand column. • Once pairs have completed discussing the science ideas and adding labeled drawings, they should share their drawings with the rest of their group, noting similarities and differences between their drawings. • As students are working, circulate among teams asking elicit and probe questions to make student thinking visible. • **STEP 9:** Have students cut the Card Sort drawings in their student notebook apart. Then they should work with an elbow partner to read one card and determine which statement they think it represents. • Once pairs have decided which statement the card represents, have them compare their own representations with the card. Ask them to discuss whether all are representing the same basic idea. Remind them that their drawings may not look exactly like the card. The goal is to look for similarities and differences. • When students have completed the comparison of all cards to their own drawings, have a class discussion about similarities and differences found and clarify thinking. Teacher Note: Avoid the terminology that the reactions are opposites of each other. While the inputs of photosynthesis are the outputs of cellular respiration, and the outputs of photosynthesis are the inputs of cellular respiration, the chemical reactions are very different. The incomplete idea that photosynthesis and cellular respiration are opposites of each other becomes problematic when trying to balance the chemical equations.	

Energy and Cellular Respiration

photosynthesis atmosphere cells Glucose + oxygen → carbon dioxide + water	**A**
Energy in Energy out NET Energy	**B**
O_2 (photosynthesis product) **X 10** = O_2 (CR reactant)	**C**
Cellular respiration: glucose + oxygen → carbon dioxide + water $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_20$	**D**
Carbon, oxygen, hydrogen atoms → Carbon dioxide + water + energy out	**E**
energy in glucose and oxygen molecules break apart into carbon atoms, oxygen atoms, and hydrogen atoms	**F**
NET Energy Life processes: Movement, building, reproduction, body temp. regulation	**G**

Implementation	Notes

10. In this lesson, you have explored the energy input and output of cellular respiration. Now consider the input and output of molecules of matter during cellular respiration. You have observed the types of atoms (carbon, hydrogen, and oxygen) that make up the input molecules are the same as those of the output molecules. Does the amount of each type of atom change during the reactions of cellular respiration? In other words, are there the same number of each type of atom at the end of cellular respiration as there are at the beginning?

To think more about this question, read the article, *Conservation of Mass*. As you read, underline important ideas.

Conservation of Mass

The atoms of most naturally occurring elements are very stable at the conditions found in our environment and are not converted to other elements during chemical reactions. Atoms themselves are neither created nor destroyed during chemical reactions. As a result, the number of atoms of one element at the beginning of a chemical reaction will be the same at the end of the reaction. In a closed system, the total number of atoms of each element will stay the same. Scientists refer to these ideas as the Law of Conservation of Mass.

The overall reaction for cellular respiration can be written as:

Glucose + oxygen → carbon dioxide + water

Using the pop beads provided to your group, assemble one glucose molecule. Note the color of each type of atom in the key your teacher gives you. Use the Law of Conservation of Mass to determine the number of oxygen molecules needed to produce the output molecules of carbon dioxide and water.

	Glucose $C_6H_{12}O_6$	**Oxygen** O_2		**Carbon dioxide** CO_2	**Water** H_2O
Number of Molecules	1	**6**	→	**6**	**6**

Implementation	Notes
• **STEP 10:** Use a formative assessment tool, such as “thumbs up – thumbs down” to assess students’ prior knowledge of the Law of Conservation of Mass. Invite students to read the introductory text of this step and the article, “Conservation of Mass.” Ask students to share their understanding of the text with an elbow partner. • While students are discussing, distribute pop beads to each team. Write the key for the color of pop bead representing each type of atom on the board. • Teams should assemble the correct number and color of pop beads to represent a molecule of glucose. Mark that, the pop beads will serve only to represent the types and numbers of atoms in each molecule. They will not represent the precise arrangement of atoms within the molecules. • After assembling the pop beads representing the atoms in a single glucose molecule, teams should use the glucose pop beads as well as the remaining pop beads in their baggie to determine the number of oxygen molecules needed to produce complete output molecules of carbon dioxide and water. • Invite teams to pair with another team and share their findings and how those findings support the Law of Conservation of Mass. <u>Teacher Note:</u> The balanced chemical equation for cellular respiration is as follows: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6\ H_2O$ However, the balanced chemical equation for photosynthesis is as follows: $6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$ This equation reflects the fact that oxygen molecules produced through photosynthesis originate solely from the input of water. Water molecules are broken during the light dependent reactions of photosystem II while carbon dioxide molecules are broken down during the light independent reactions of the Calvin-Benson cycle. The six output water molecules are often referred to as “new water” to show that they are different water molecules than the reactant water molecules. This is one reason to avoid the terminology that the two reactions are opposites of each other. For this reason, the Law of Conservation of Mass was not introduced in prior lessons and the equation for photosynthesis was represented in words only. Consider how you will handle this discussion if students attempt to balance the chemical equation for photosynthesis.	

11. Based on the reading and pop bead calculation, use a different color to revise or add to your ideas in Step 7 about why the mass of the plant material increased, decreased or stayed the same for each experimental condition. Use a different color to show how your thinking changed.

Focus on Student Thinking

- Ask appropriate probe (STeLLA strategy 2) and challenge questions (STeLLA strategy 3) as students share their ideas in the class discussion.
- A sample conversation is below.
    - T: Tell me what you mean when you say that the plant lost mass because it released something. (PROBE)
    - S: Well, the equation shows that cellular respiration produces carbon dioxide and water.
    - T: And where did that carbon dioxide and water come from?
    - S: It comes from the glucose molecule and the oxygen being used in cellular respiration.
    - T: Say more about cellular respiration (PROBE)
    - S: During cellular respiration, the glucose reacts with oxygen and releases carbon dioxide and water and energy.
    - T: Okay. How can you relate that back to what we saw with the seed germination? (CHALLENGE)
    - S: Well, the seed with no light lost mass because it was breaking down the stored starch which is made of glucose.
    - T: Why do you think that happened? (PROBE)

Implementation	Notes

- **STEP 11:** After students have completed their pop bead calculations, teams should return to their ideas about changes in the mass of radish seeds under different environmental conditions. They should revise or add to their ideas in a different color.
- Invite several teams to share how their thinking changed. Key ideas to highlight in the class discussion include:
    - The seeds contain starch which was produced from glucose made by the parent plant through photosynthesis.
    - The seed itself cannot photosynthesize until it has developed into a seedling.
    - The seed needs an input of water to come out of dormancy. The seed also needs an input of water when it begins to photosynthesize.
    - The seed uses the chemical reactions of cellular respiration to provide energy for the seed to produce new cells for growth.
    - The outputs of cellular respiration are carbon dioxide and water. Carbon dioxide is a gas which would leave the cells of the new plant and go into the air.
    - When carbon dioxide leaves the plant system, the plant will lose mass even though water has been added to the system. (Carbon dioxide molecules have a greater mass than water molecules.)
    - If light energy and water are present, the growing plant will begin to photosynthesize. The inputs of photosynthesis are water and carbon dioxide. The carbon dioxide comes from the atmosphere into the plant system. Thus, the plant gains mass.
    - If light is present, but water is not, the seed will not germinate.
    - If water is present, but light is not, the seed will germinate and undergo cellular respiration. The seedling will not turn green but will lose mass due to the loss of carbon dioxide molecules from the system.

> Use the information in "Focus on Student Thinking" in the SE key to see examples of ways to elicit, probe, and challenge student ideas as well as to help students link science ideas to other science ideas.

Lesson 4: Food for Plants

Phase of Lesson: *Synthesize and Summarize*

Main Learning Goal: The process of cellular respiration is a series of chemical reactions that both require and release energy. These reactions yield a net release of energy that can be used to form large carbon-based molecules that can be used for growth and reproduction as well as fuel in chemical reactions.

Focus Question: How do plants use the outputs of photosynthesis?

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: 15 Minutes

STeLLA Strategies

- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy 3: Ask questions to challenge student thinking
- ❖ Strategy 9: Engage students in making connections by synthesizing and summarizing key science ideas

Science Ideas

- A system is an organized group of related objects or components that form the whole. Systems have boundaries, components, processes, and inputs and outputs. Often parts of a system are interdependent, and each one depends on or supports the functioning of the system's other parts.
- A terrarium can be considered a closed system in which matter cycles and through which energy flows.

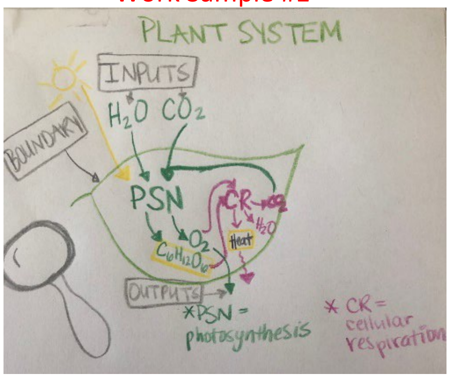
Common Student Ideas

- 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.

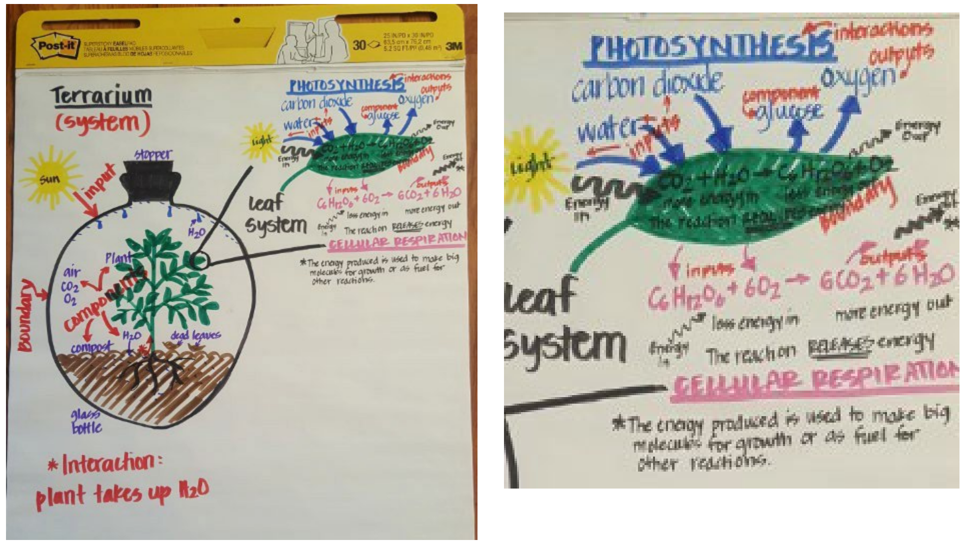
Synthesize and Summarize Ideas

12. Add your ideas about cellular respiration to your model of the terrarium plant system. Add labels to help others understand your model.

Work Sample #1



Work Sample #2



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

Implementation	Notes
Synthesize and Summarize Science Ideas • **STEP 12:** Provide directions for students to add ideas about the interactions of matter and energy to their drawing of the plant system. • As teams construct their drawing, circulate through the room asking probe and challenge questions to make student thinking visible. • **STEP 13:** 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.	

Lesson 4: Food for Plants

Phase of Lesson: *Synthesize and Summarize*

Main Learning Goal: The process of cellular respiration is a series of chemical reactions that both require and release energy. These reactions yield a net release of energy that can be used to form large carbon-based molecules that can be used for growth and reproduction as well as fuel in chemical reactions.

Focus Question: How do plants use the outputs of photosynthesis?

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: 5 Minutes

STeLLA Strategies

- Strategy I: Summarize key science ideas

Science Ideas

- A system is an organized group of related objects or components that form the whole. Systems have boundaries, components, processes, and inputs and outputs. Often parts of a system are interdependent, and each one depends on or supports the functioning of the system's other parts.
- A terrarium can be considered a closed system in which matter cycles and through which energy flows.

Common Student Ideas

- Photosynthesis occurs during the day and cellular respiration occurs at night.
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- 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.

Implementation	Notes
Summarize • Share that in this lesson, we learned that plants need inputs of matter and energy to stay alive. Glucose can be rearranged and linked together to form starch and other molecules that become part of the plant's body. Glucose can also serve as fuel in chemical reactions. The chemical reactions known as cellular respiration use inputs of glucose and oxygen with outputs of carbon dioxide and water. Throughout the chemical reactions of cellular respiration, matter is conserved. Cellular respiration provides energy used for movement, building body structures, and reproduction. *Link to the Next Lesson* • Link to the next lesson by sharing that, in the next lesson, we will explore how other organisms use cellular respiration to stay alive.	