A Study of Matter and Energy in Systems

Lesson 3: A Closer Look at Photosynthesis

Grade: 9-10 General Biology

Length of lesson: 145 minutes

Placement of lesson: Lesson 3 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 3 Main Learning Goal

The process of photosynthesis is a series of chemical reactions that both require and release energy. However, a net input of light energy is required. The amount of light energy can affect the rate of photosynthesis.

Lesson 3 Focus Question

What is the role of energy in the chemical reactions of photosynthesis?

Ideal student response

In chemical reactions, bonds between atoms are broken and new bonds form to make new molecules. When the bonds between atoms of the reactants are broken, it requires energy. When new bonds form between atoms to make the product molecules, energy is released. Whether a chemical reaction takes energy or produces energy depends on the amount of energy required to break the bonds of the reactants compared to the amount of energy released when the product bonds are made. Photosynthesis requires an input of light energy because it takes more energy to break the bonds of carbon dioxide and water than the energy that is released when glucose and oxygen are made.

Science Content Storyline

An input of energy is required to separate the atoms of the reactant molecules of carbon dioxide and water. Energy is released as atoms connect to form products of glucose and oxygen. Because the energy required to separate the atoms of the reactant molecules (carbon dioxide and water) is greater than the energy released in the formation of product molecules (small carbon-based molecules), the reactions of photosynthesis require a net input of energy. This input of energy comes from light energy.

Materials

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 3 slide deck
- Chart markers
- Charts with terrarium diagrams from Lesson 1
- Colored cellophane sheets (red, blue, yellow, green)

Advance Preparation

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.

Other

- Identify several ways that students can change the distance between the cups and the light source. For example, stacks of books, empty petri plates, or other materials might be used.
- Determine where teams will place their cups in the dark.
- Save several cups with floating leaf disks for Lesson 4. At the end of Lesson 3, while the disks are still floating, place the cup in a dark cupboard.

Lesson 3 General Outline

Time (min)	Phase of lesson	How the science content storyline develops
10	**What is the role of energy in the chemical reactions of photosynthesis? (Lesson focus question)** The teacher makes links to the prior lesson and introduces the lesson focus question.	
120	**The Role of Energy in Photosynthesis** <u>Activity Setup</u> Students consider the role of energy in chemical reactions, creating labeled drawings of key science ideas. <u>Activity</u> Student teams use the floating leaf disk protocol to design an investigation about the effects of light quality or intensity on the rate of photosynthesis. Teams conduct the investigation and graph their results. <u>Activity Follow-up</u> Teams develop a scientific explanation for their investigation. They use the CCCR process to give and get feedback on their explanations.	An input of energy is required to separate the atoms of the reactant molecules of carbon dioxide and water. Energy is released as atoms connect to form products of glucose and oxygen. Because the energy required to separate the atoms of the reactant molecules (carbon dioxide and water) is greater than the energy released in the formation of product molecules (small carbon-based molecules), the reactions of photosynthesis require a net input of energy. This input of energy comes from light energy.
10	**Synthesize and Summarize** Students add their ideas about energy to their plant system model. They revise and add to their initial response to the focus question.	
5	**Summarize and Link** In this lesson, students have considered the role of energy in photosynthesis. In the next lesson, students will consider how plants use the glucose produced by photosynthesis in the chemical reactions of photosynthesis.	

Lesson 3: A Closer Look at Photosynthesis

Phase of Lesson: *Lesson Focus Question*

Main Learning Goal: The process of photosynthesis is a series of chemical reactions that both require and release energy. However, a net input of light energy is required. The amount of light energy can affect the rate of photosynthesis.

Focus Question: What is the role of energy in the chemical reactions 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 areunrelated to each other.
- Energy is released whenever chemical bonds are broken.
- Energy is fuel.
- Energy can be recycled.

Lesson 3: A Closer Look at Photosynthesis

Introduction

In the last lesson, you explored how the plant uses carbon dioxide and water as the inputs of matter in the chemical reactions of photosynthesis to produce glucose and oxygen. In this lesson, you will take a closer look at the role of energy in the chemical reactions of photosynthesis.

Lesson Question

What is the role of energy in the chemical reactions 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 Strategies 1 (ELICIT) and 2 (PROBE) to get a variety of ideas out. Make sure you emphasize to the students that just like in Lesson 1, we are gathering a lot of ideas and that you are not going to give them the answers to the questions.

Ask students to share their ideas with the entire group, using STeLLA Strategy 2 (PROBE) to make their thinking visible and allow other students to respond and pose additional questions.
Example teacher and student dialogue is shown below:

- T: What is the role of energy in the chemical reactions of photosynthesis? (ELICIT) S1: Plants use sunlight as an input for energy.
- T: What do others think? (ELICIT) S2: They use it for photosynthesis.
- T: Can you tell me more about that? (PROBE)
- S2: It must take energy to run the chemical reactions. Maybe it's like needing a match to start a fire. You need the energy from the match to start a fire.
- T: Thank you for adding to your idea. What other ideas did others write? (ELICIT)

Implementation	Notes
Link to Previous Lesson • Share that, in the previous 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. • In this lesson, we will think about the role of energy in creating the outputs of photosynthesis. *Lesson Focus Question* • **STEP 1:** Introduce the lesson focus question: "What is the role of energy in creating 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. • Ask a student to read the focus question aloud. Then ask another student to paraphrase what the focus question is asking. • 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 about the question. Share that they will have a chance to revise their ideas as they work through the lesson. • Once students have written the focus question in their workbooks, provide time for teams to discuss their ideas. This is not a time to challenge their ideas, but rather to make their current thinking about the focus question visible through the use of Strategy 1: Ask questions to elicit student ideas and predictions and Strategy 2: Ask questions to probe student ideas and predictions. Use the information in "Focus on Student Thinking" in the SE key to see examples of ways to elicit and probe student ideas.	

Lesson 3: A Closer Look at Photosynthesis

Phase of Lesson: *Energy Transfer in Photosynthesis*

Main Learning Goal: The process of photosynthesis is a series of chemical reactions that both require and release energy. However, a net input of light energy is required. The amount of light energy can affect the rate of photosynthesis.

Focus Question: What is the role of energy in the chemical reactions 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 4: Engage students in communicating in scientific ways
- ❖ Strategy 5: Engage students in analyzing and interpreting data and observations
- ❖ Strategy 7: Engage students in constructing explanations and arguments
- ❖ Strategy F: Make explicit links between science ideas and activities
- ❖ Strategy G: Link science ideas to other science ideas

Time: 120 Minutes

Science Ideas

- An input of energy is required to separate the atoms of the reactant molecules of carbon dioxide and water.
- Energy is released as atoms connect to form products of glucose and oxygen.
- Because the energy required to separate the atoms of the reactant molecules (carbon dioxide and water) is greater than the energy released in the formation of product molecules (small carbon-based molecules), the reactions of photosynthesis require a net input of energy. This input of energy comes from light energy.

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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Energy Transfer in Photosynthesis

2. In the leaf disk investigation, you placed the solution with submerged leaf disks under a light source. As a result of photosynthesis, oxygen was produced, and the leaf disks floated to the surface of the solution. What is the role of light energy in the chemical reactions of photosynthesis?

   To think more about energy in photosynthesis, read the science ideas in the left column of the table below. In the right column, draw a labeled diagram that represents that idea.

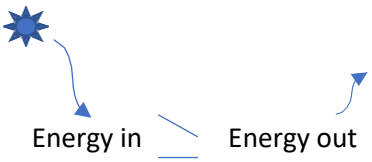
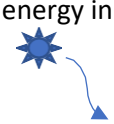
Energy in Photosynthesis

Science Idea	Labeled Drawing of the Idea
A chemical reaction involves breaking the bonds between the atoms of the reactant (input) molecules and forming new bonds between those atoms to create product (output) molecules.	**B**
Photosynthesis is a chemical reaction. The reactant (input) molecules are carbon dioxide and water. The product (output) molecules are glucose and oxygen.	**D**
During photosynthesis, absorption of light energy is required to break the bonds between the atoms of the reactant molecules (carbon dioxide and water).	**F**
During photosynthesis, energy is released when atoms bond to form the product molecules (glucose and oxygen).	**C**
In photosynthesis the amount of energy required to break the bonds of the reactant molecules (CO_2 and H_2O) is ***greater than*** the amount of energy released when the product molecules ($C_6H_{12}O_6$ and O_2) form. Therefore, the chemical reaction of photosynthesis requires a NET INPUT of energy.	**A**
In photosynthesis, the light energy that is absorbed is transformed into stored chemical energy.	**E**

3. Now that you have drawn representations of the statements above, cut out and sort the card set provided by your teacher 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 Setup • **STEP 2:** Have students read the paragraphs 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 3:** 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. • As students are working, circulate among teams asking elicit and probe questions to make student thinking visible. • 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.	

Energy in Photosynthesis Card Sort

	**A**
Chemical reaction: reactants (inputs) ⟶ products (outputs)	**B**
Carbon, oxygen, hydrogen atoms ⟶ glucose, oxygen + energy out	**C**
Photosynthesis: Carbon dioxide + water ⟶ glucose + oxygen	**D**
 transforms to chemical energy (stored)	**E**
energy in  Carbon dioxide + water molecules break apart into carbon atoms, oxygen atoms, hydrogen atoms	**F**

Implementation	Notes

4. We have seen that photosynthesis requires an input of light energy to power the chemical reactions. Does the type or intensity of light energy affect the rate of the photosynthesis reactions? To explore this question, you will use the leaf disk procedure from lesson 2.

   Your teacher will show you the materials available to change either the quality or intensity of light energy. After considering the materials available, discuss possible questions you could test with your group and complete the table below. Put a star next to the question your group would most like to test.

Question to test	How we will collect evidence to answer the question
How does the color of light affect the rate of photosynthesis?	We will put different colored film (red, blue, and green) over the light source and use the same leaf disk procedure. We will only use baking soda solution.
How does the intensity of light affect the rate of photosynthesis? ★	We will use the same leaf disk procedure with baking soda solution. We will put the light source at the following distances from the top of the cup: 20cm, 30 cm, 40 cm.

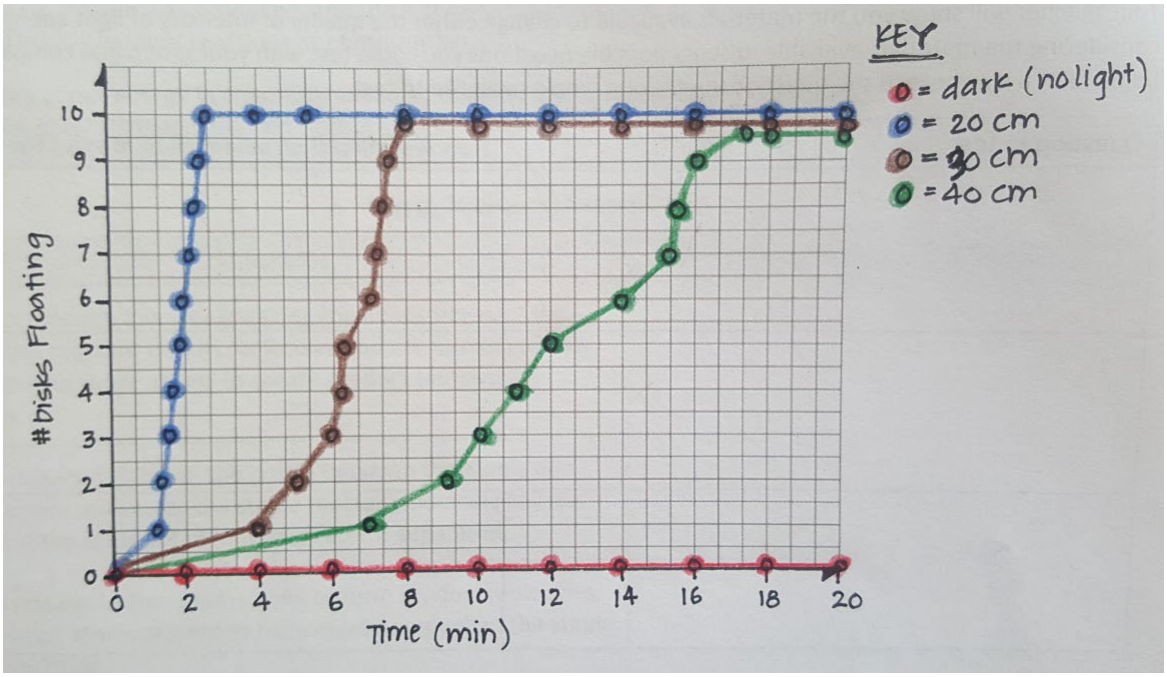
5. After your teacher approves your question and procedure, set up your investigation and record your data in the table below. Include the data your teacher provides from leaf disks placed in the dark with no light. Sample data is shown below.

Time / Variable	2 min	4 min	6 min	8 min	10 min	12 min	14 min	16 min	18 min	20 min
No light	0	0	0	0	0	0	0	0	0	0
20 cm	5	10	10	10	10	10	10	10	10	10
30 cm	0	1	2	10	10	10	10	10	10	10
40 cm	0	0	0	1	2	4	5	8	10	10

Implementation	Notes

Activity
• **STEP 4:** Mark that both investigations in Lesson 2 required an input of light energy for photosynthesis. In this investigation, they will consider the effects of quality and intensity of light energy on the rate of photosynthesis.
• Make sure students have the handout with the leaf disk protocol. Note that they will use the same protocol to prepare the leaf disks, but they will only use the bicarbonate solution. Show students the materials they can use to change either the light quality or light intensity:
  ○ To vary light quality, students can place colored cellophane over the light source. The distance from the light source to the cups should remain constant throughout the investigation.
  ○ To vary light intensity, students will vary the distance between the light source and cups. They can do this with materials, such as books, found in the room.
• Have teams consider possible questions they would like to test. They should record their questions and how they will collect evidence to answer the question in the chart in their notebooks. After they have starred the question they would most like to investigate, they should get approval from the teacher before proceeding to set up their investigation.
• As teams are generating questions, circulate among teams asking elicit, probe, and challenge questions that make their thinking visible.
• **STEP 5:** Ask students the purpose for placing a cup in the dark as indicated in row 1 of the data collection table. Students should identify this as the negative control for the investigation.
• As teams conduct their investigation, circulate among groups asking questions that will make student thinking visible and link what they are doing to a science idea. If students struggle to link their procedure to a science idea, invite them to cite ideas from the chart in Step 2 as well as the ideas in the leaf disk protocol handout.	

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



Focus on Student Thinking

Focus on using STeLLA Strategies 1, 2 and 3 to elicit, probe and challenge student thinking while groups are generating questions to test.

Example teacher and student dialogue is shown below:

- T: How do you think light intensity might affect the rate of photosynthesis? (ELICIT) S1: The more light, the faster photosynthesis will happen.
- S2: And the faster the disks will float
- T: What is the connection between the rate of photosynthesis and disks floating? (CHALLENGE)
- S3: Photosynthesis produces oxygen which causes the disks to float. The faster photosynthesis happens, the more oxygen is produced, so the disks will float faster.
- T: How will you change the light intensity? (ELICIT)
- S2: We're going to start with the light close to the cup and then move it 10 centimeters farther away each time.

7. Recall what you learned about how to write a scientific explanation in the Study of Changes in Populations unit. Working as a group, use the Explanation Tool on the next page to write a scientific explanation that answers the question you investigated.
   1) Begin by writing the question.
   2) Then add evidence from the data and observations you collected.
   3) Then add science ideas. These science ideas will help you justify why your evidence supports your claim.
   4) Write your claim in complete sentences.
   5) Write your explanation.

   Make sure that each member of the group has a complete explanation to share.

Implementation	Notes
• **STEP 6:** Teams should graph their data in their notebook, making sure to correctly label axes and to include a key to identify each variable tested. • Teams should discuss how the data provides evidence that will help them make a claim that answers the question. Use the information in "Focus on Student Thinking" in the SE key to see examples of ways to elicit and probe student ideas and link science ideas to the activity. • Important Note: Save several cups with leaf disks all floating. Share with students that you will place the cups in the dark until the next lesson. Ask students to predict what will happen to the disks. Do not, at this point, provide or confirm correct answers. • 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. *Activity Follow-up* • **STEP 7:** Ask students to discuss with an elbow partner what they remember about how to write a scientific explanation, using the steps listed. As several pairs to report out important ideas they discussed. • Share that while they will develop their explanation as a team, each member of the team will need to complete the Explanation Tool in their notebook. • Provide time for teams to develop their explanation, circulating through the room and supporting students as needed. • Once students have completed their explanations, share that, like scientists, they will consult with each other to get feedback. Mark that they will use the Consider-Contribute-Consult-Revise (CCCR) process. • Note that the first step in CCCR is Consider. In this step they will consider a question or problem and record their best ideas in their science notebook. Mark that they have already completed this step by writing their scientific explanation to answer the question, "How does the intensity of light affect the rate of photosynthesis?" or "How does the quality of light affect the rate of photosynthesis?" • Students should join in pairs for the Contribute step of the method. Depending on your class, you may assign partners or allow students to select a partner from another group. Have students stand facing each other to complete this step. Each pair should designate one student as Student A and the other as Student B.	

Explanation Tool

Question	
How does the intensity of light affect the rate of photosynthesis?	
Evidence from data and observations (e.g., patterns or trends specific to your investigation)	**Science ideas and concepts (e.g., patterns or trends that are generalizable across many situations; may include science vocabulary).**
Leaf disks in the dark did not float after 20 minutes	Light energy is required for the reactions of photosynthesis to occur. Without light, photosynthesis did not occur, and no oxygen was produced.
All leaf disks were floating in 4 minutes when the light source was 20 cm away from the base of the cup. All leaf disks were floating in 8 minutes when the light source was 30 cm away from the base of the cup. All leaf disks were floating in 18 minutes when the light source was 40 cm away from the base of the cup.	Light energy is required for the reactions of photosynthesis to occur. Photosynthesis uses light energy to break apart the molecules of carbon dioxide and water to produce glucose and oxygen. Oxygen, a gas, is less dense than water. As oxygen accumulates in the leaf disks, they become less dense than the solution, and they float.
The closer the light source, the less time it took for all the leaf disks to float.	Light intensity increases as the light source gets closer to the object. Increasing light intensity increases the rate of photosynthesis because more light energy is available for the chemical reactions of photosynthesis.
Claim (Your claim should answer the question.)	
Increasing light intensity increases the rate of photosynthesis.	
Scientific Explanation (Be sure to Include the claim, evidence, and reasoning in your explanation. Reasoning includes science concepts and linking words used to connect your ideas in the paragraph.)	
Increasing light intensity increases the rate of photosynthesis. Light energy is required for the reactions of photosynthesis. Without light, the chemical reactions of photosynthesis do not occur, and no oxygen will be produced. Oxygen accumulates in the leaf disks, making them less dense than the solution so they float. Light intensity decreases the farther away the light source is from the cup. The greater the light intensity, the more energy is available for the chemical reactions of photosynthesis. When the light source was 20 cm away from the base of the cup, all the leaf disks were floating after 4 minutes. When the light source was 30 cm from the base of the cup, all the leaf disks were floating by 8 minutes. Finally, when the light source was 40 cm away from the base of the cup, all the leaf disks were floating after 18 minutes. As the light source was moved farther from the base of the cup, it took longer for the leaf disks to float. As the rate of photosynthesis decreased with decreasing light intensity, the rate at which oxygen was produced was slower. This would result in a longer time for enough oxygen to accumulate in the leaf and a longer time for the disk to float.	

Implementation	Notes
• Have students read aloud to each other what they wrote. They should simply read what they have in their science notebooks without embellishing or explaining their ideas further. If students were working to make a sketch, they should explain the parts of the sketch and any labels. Students should not exchange science notebooks during this step. Reading aloud helps students process what they have written. Many students will begin the process of revision in their heads as they hear themselves read their answer aloud. o Here is an example Contribute prompt: "Read your answer aloud exactly as you wrote it. Do not add any explanation or say, 'What I meant was ….'" • Once Student A has read their explanation to Student B, the pair should switch roles and repeat the Contribute process. • In the Consult step, Student A will ask Student B for advice on his or her answers. Provide examples and prompts as well as nonexamples to help them. Nonexamples, or feedback that is not helpful, include, "I like the color of pen you used" and "Nice job." Examples of questions that students can use as prompts to help them provide better feedback: o "Was the claim a complete sentence that answers the question and is supported by evidence and reasoning?" o "Was enough evidence included?" o "Did the reasoning justify why the evidence supports the claim?" o "Did the reasoning show how the evidence follows logically from science ideas?" Students should ask themselves these prompts to help them think about what valuable feedback they can give. Although it is OK to disagree, the focus should be on improving answers and understanding. o Here is an example Consult prompt: "Consult with your partner to get feedback on how to improve your answer." • Once Student A has received feedback from Student B, the pair should switch roles and repeat the Consult process. • For the Revise step, students should return to their group to revise their group's explanation. Each member of the group should share the feedback they received, then the group should work together to revise their explanation. Tell them that the goal is to have the most complete, correct information they can in their answers. • Have them use a different-colored pen or pencil for revisions as this will help them, and you, keep track of their learning. Emphasize that they do not have to take all the advice that their partners gave them if they do not feel it was helpful advice. They should either make a change based on the feedback or write why they chose not to take the advice. Here is an example Revise prompt: "Work together to revise your explanation. Use a different- colored pen or pencil for your revisions. Think about what you noticed about your answer and consider all the feedback you got. If you choose not to take a piece of advice from your partner, explain why you chose not to."	Refer to the SE key to see an example of a completed Explanation Tool.

Lesson 3: A Closer Look at Photosynthesis

Phase of Lesson: *Synthesize and Summarize*

Main Learning Goal: The process of photosynthesis is a series of chemical reactions that both require and release energy. However, a net input of light energy is required. The amount of light energy can affect the rate of photosynthesis.

Focus Question: What is the role of energy in the chemical reactions 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 6: Engage students in developing and using content representations and models
- 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 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 areunrelated to each other.
- Energy is released whenever chemical bonds are broken.
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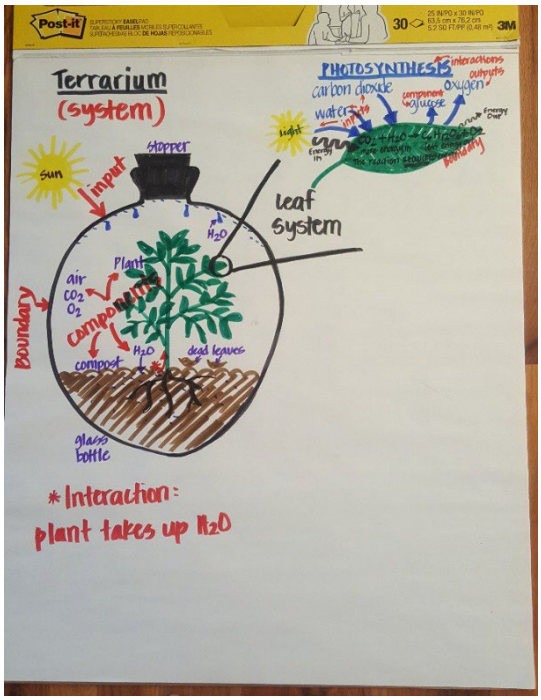
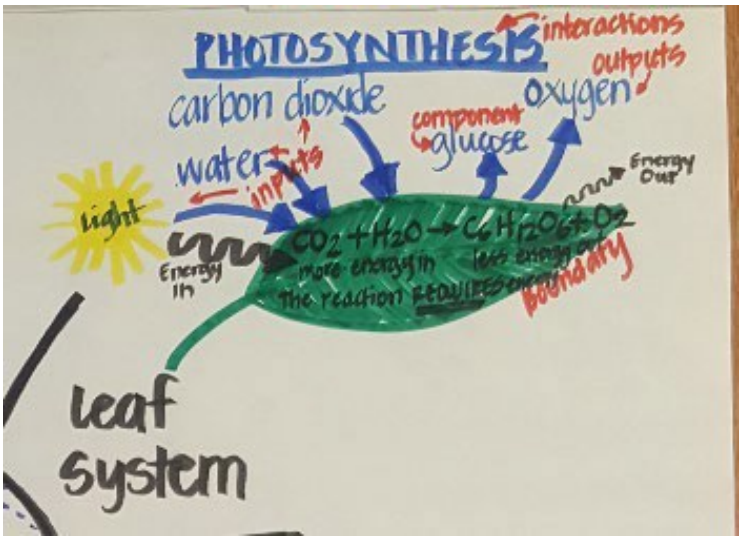
Synthesize and Summarize Ideas

8. Add your ideas about energy transfer to your model of the terrarium plant system. Add labels to help others understand your model.





9. 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.

Implementation	Notes
Synthesize and Summarize Science Ideas • **STEP 8:** Provide directions for adding labels and other information about the role of energy in photosynthesis 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 9:** 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 3: A Closer Look at Photosynthesis

Phase of Lesson: *Summarize and Link*

Main Learning Goal: The process of photosynthesis is a series of chemical reactions that both require and release energy. However, a net input of light energy is required. The amount of light energy can affect the rate of photosynthesis.

Focus Question: What is the role of energy in the chemical reactions 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

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 • Share that in this lesson, we learned that energy is needed to break the bonds between atoms in a molecule and energy is released as atoms bond together to make new molecules. An input of light energy is needed for the chemical reactions of photosynthesis because it takes more energy to break the bonds of the input molecules than the energy that is released when the product molecules are formed. • Revisit the unit question board. Ask students which questions they have answered thus far in the unit. Ask students what new questions should be added to the question board. Highlight any questions that will be explored in the next lesson such as: o What does the plant do with the glucose it produces? o Does photosynthesis provide the energy a plant needs to stay alive? o What is food for a plant? *Link to the Next Lesson* • Link to the next lesson by sharing that, in the next lesson, we will explore how plants use the glucose they produce as food to stay alive.	