Lesson 4: Explaining How Plants Make Food, Move, and Function

Overview

Students use molecular models to learn how matter and energy are transformed in plants during photosynthesis and cellular respiration. The focus of this lesson is on developing explanations for how plants make food, move, and function in the light and in the dark.

Download PDF of Lesson 4 Teacher's Guide

Guiding Question

What happens to atoms, carbon, and energy during photosynthesis and cellular respiration?

Activities in this Lesson

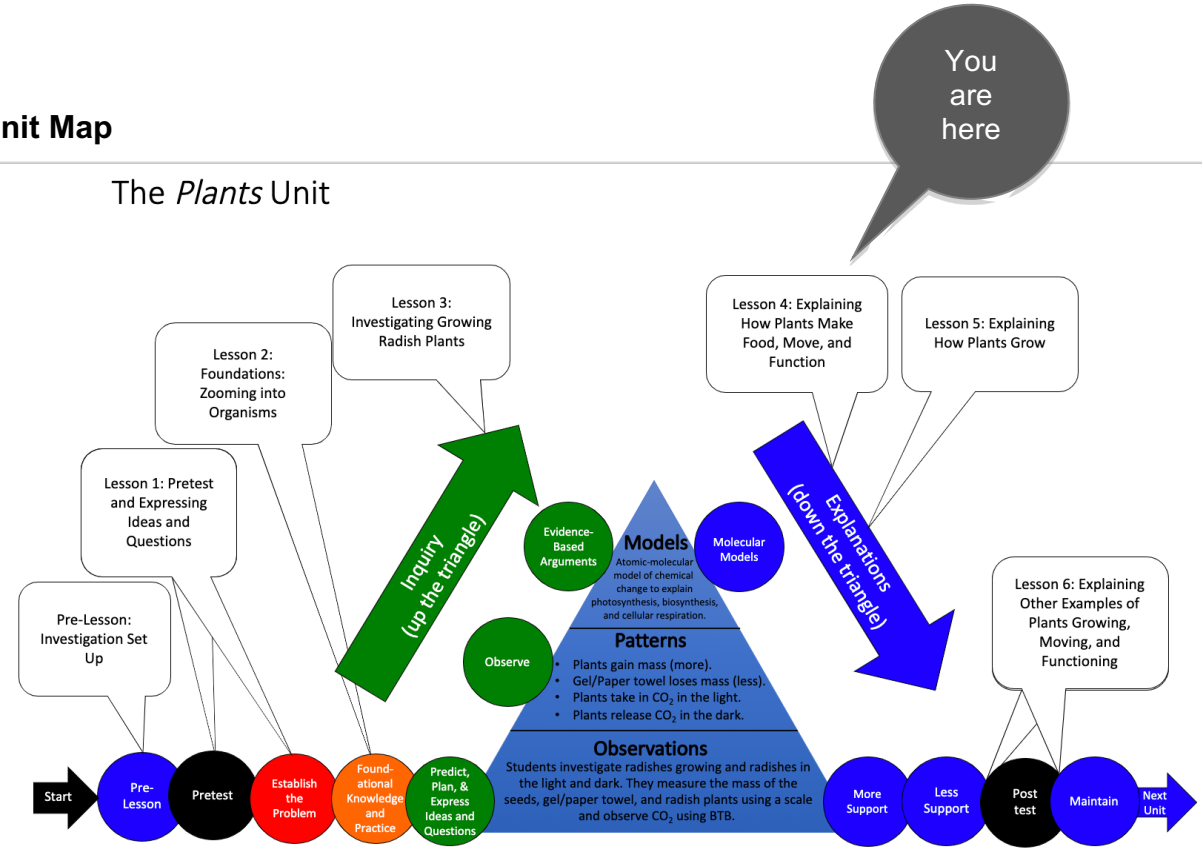
Note: There are multiple pathways to choose from in Lessons 4-5. Please see the Plants Unit Front Matter, the Student Challenges and Teacher Choices in the Plants Unit document, and/or the Background Information section below for clarification in making this instructional decision.

Activity 4.1: Molecular Models for Potatoes Moving and Functioning: Cellular Respiration (40 min)

- *Note: The steps that have students construct molecular models in this activity are optional if students did molecular modeling for cellular respiration in another unit and performed well on the pretest for items related to cellular respiration.*

- Activity 4.2: Explaining How Plants Move and Function: Cellular Respiration (40 min)
- Activity 4.3: Molecular Models for Potatoes Making Food: Photosynthesis (60 min)
- Activity 4.4: Explaining How Plants Make Food: Photosynthesis (40 min)

Unit Map



Learning Goals

Target Performances

Activity	***Target Performance***
Lesson 4: Explaining How Plants Make Food, Move, and Function (students as explainers)	
Activity 4.1: Molecular Models for Potatoes Moving and Functioning: Cellular Respiration	Students use molecular models to explain how carbon, oxygen, and hydrogen atoms in glucose and oxygen molecules are rearranged into carbon dioxide and water in a potato plant's cells.
Activity 4.2: Explaining How Plants Move and Function: Cellular Respiration	Students explain how matter moves and changes and how energy changes during cellular respiration in a potato plant's cells.
Activity 4.3: Molecular Models for Potatoes Making Food: Photosynthesis	Students use molecular models to explain how carbon, oxygen, and hydrogen atoms in carbon dioxide and water molecules are rearranged into glucose and oxygen in a potato plant's leaf cells.
Activity 4.4: Explaining How Plants Make Food: Photosynthesis	Students explain how matter moves and changes and how energy changes during photosynthesis in a potato plant's leaf cells.

NGSS Performance Expectations

Middle school

- MS. Structure and Properties of Matter. MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
- MS. Chemical Reactions. MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
- MS. Chemical Reactions. MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.
- MS. Matter and Energy in Organisms and Ecosystems. MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy among living and non-living parts of an ecosystem.
- MS. Matter and Energy in Organisms and Ecosystems. MS-LS1-7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.
- MS. Matter and Energy in Organisms and Ecosystems. MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and non-living parts of an ecosystem.

High school

- HS. Chemical Reactions. HS-PS1-4. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in the total bond energy.
- HS. Chemical Reactions. HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- HS. Structure and Function. HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
- HS. Matter and Energy in Organisms and Ecosystems. HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
- HS. Matter and Energy in Organisms and Ecosystems. HS-LS1-7. Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
- HS. Matter and Energy in Organisms and Ecosystems. HS-LS2-5. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

Background Information

Three-dimensional Learning Progression

This lesson helps middle school and high school students understand why plants “breathe” (i.e., exchange gases with the air) differently in the light and in the dark and how the mass of plants can come mostly from the air. As they model photosynthesis, they learn how to explain plant gas exchange and growth in a way that follows the key rules about matter and energy—atoms last forever and energy lasts forever (in chemical changes). As they model cellular respiration, they learn how to explain this carbon-transforming process that makes food energy available to plant cells.

We will consistently focus on the idea that understanding carbon-transforming processes involves answering the Three Questions:

- **The Matter Movement Question: Where are molecules moving?** (How do molecules move to the location of the chemical change? How do molecules move away from the location of the chemical change)
- **The Matter Change Question: How are atoms in molecules being rearranged into different molecules?** (What molecules are carbon atoms in before and after the chemical change? What other molecules are involved?)
- **The Energy Change Question: What is happening to energy? (**What forms of energy are involved? What energy transformations take place during the chemical change?)

Matter (Matter Movement and Matter Change). We find that even students who have learned how to balance chemical equations do not appreciate the meaning of the procedure:

- Conservation of atoms (the Matter Change Question): The numbers of atoms on the left and right side of a chemical equation have to be the same because they are THE SAME ATOMS! A chemical equation just shows how they are being rearranged into new molecules.
- Conservation of mass (the Matter Movement Question): ALL the mass of any material is in its atoms (and none of the mass is in the bonds, which are just attractive forces between atoms). So the mass of the products is always the same as the mass of the reactants.

Energy (the Energy Change Question). Chemists, physicists, and biologists have many different conventions for describing and measuring chemical energy. We have a deeper explanation of the conventions used in *Carbon TIME* units and how they relate to conventions used in different scientific fields on the BSCS website in a document called *Carbon TIME* Content Simplifications. Here are some key points:

- All bond energies are *negative* relative to individual atoms. So during a chemical reaction it always takes energy (the activation energy) to break bonds, then energy is released when new bonds are formed.
- Whether a chemical reaction releases energy depends on the total energy of the reactants, compared with the total energy of the products. So, energy is released when the total bond energy of the products is lower (i.e., more negative relative to individual atoms) than the energy of the reactants.
- In systems like our atmosphere, where excess oxygen is always present, the most abundant sources of chemical energy are substances that release energy when they are oxidized (e.g., substances with C-C and C-H bonds).

The four activities in this lesson represent the **Explanations Phase** of the *Plants* Unit. This involves modeling and coaching with the goal of helping students develop atomic-molecular scale accounts of photosynthesis and cellular respiration that were the drivers of the macroscopic changes in CO_2 concentration that they observed in their Plants in the Light and Dark Investigation in the previous lesson.

Key Ideas and Practices for Each Activity

Activity 4.1 is the first part of the **Explanations Phase** of the instructional model (going down the triangle) for cellular respiration. Students construct molecular models of the chemical change that took place during the investigation to help them develop an atomic-molecular explanation for how plants get energy to move. Plants use the energy released from cellular respiration to grow and function (for biosynthetic processes and other cellular functions) as well as to move. Plants engage in cellular respiration in both the light and the dark. If your students

did cellular respiration molecular modeling as part of the *Animals* or *Decomposers Units*, and did well on questions about cellular respiration on the pretest, you may want to skip the cellular respiration modeling steps in this Activity.

Activity 4.2 is the second part of the **Explanations Phase** of the instructional model (going down the triangle) for cellular respiration. Students use the **Explanations Tool** to construct final explanations of what happens when plants use energy to grow, move, and function through cellular respiration. Ideally, at this phase their explanations will combine evidence from macroscopic-scale observations during the investigation with their new knowledge of chemical change at the atomic-molecular scale.

Activity 4.3, is the first part of the **Explanations Phase** of the instructional model (going down the triangle) for photosynthesis. Students construct molecular models of the chemical change that explains how the plants give off oxygen in the light.

Activity 4.4, is the second part of the **Explanations Phase** of the instructional model (going down the triangle) for photosynthesis. Students use the **Explanations Tool** to construct final explanations of how plants make their own food. Ideally, at this phase their explanations will combine evidence from the macroscopic-scale observations during the investigation with their new knowledge of chemical change at the atomic-molecular scale. The questions in this Activity should also help students notice two important relationships:

- The relationship between photosynthesis and cellular respiration. The chemical reactions are reverses of one another, but the energy transformations are not—from light to chemical energy for photosynthesis and from chemical energy to motion and heat for cellular respiration.
- The relationship between plants and animals. Animals depend on plants for food and oxygen, while in most cases plants don't need animals to get food or oxygen.

There are multiple pathways from which to choose when teaching the carbon-transforming processes in Lessons 4 and 5. You may choose to go in the order presented here. You may choose to follow an order that makes more sense instructionally to you. Or you may choose to go in an order based on the types of questions your students are asking. Please see the Plants Unit Front Matter or the Student Challenges and Teacher Choices in the Plants Unit document for clarification in making this instructional decision. Remember that if you choose a different order than what is presented here, you will need to be aware of what you have and have not yet taught your students, and you may want to make small adjustments to the activities accordingly.

A note on the chemical change formulas for photosynthesis and cellular respiration. Activities 4.1 and 4.3 simplify the full story of what happens to matter during the multi-step processes of cellular respiration and photosynthesis. For a more detailed account, see http://dqc.crcstl.msu.edu/node/2027.

In Activity 4.1, we use a standard but simplified formula for the overall chemical change occurring in cellular respiration:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

This incorrectly suggests that some of the oxygen atoms in O_2 end up in CO_2, which does not happen directly during the multi-step process of cellular respiration. A more accurate formula to represent the multi-step process would be as follows:

$$C_6H_{12}O_6 + 6\ \mathbf{O}_2 + 6H_2O \rightarrow 6\ CO_2 + 12\ H_2\mathbf{O}$$

Thus all of the oxygen atoms in O_2 (**bolded** in the equation above) end up in H_2O, while the oxygen atoms in CO_2 all come from glucose or water.

In Activity 4.3, we use a standard but simplified formula for the overall chemical change occurring in photosynthesis:

$$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$$

This incorrectly suggests that some of the oxygen atoms in CO_2 end up in O_2, which does not happen directly during the multi-step process of photosynthesis. A more accurate formula to represent the multi-step process would be as follows:

$$6\ CO_2 + 12\ H_2\mathbf{O} \rightarrow C_6H_{12}O_6 + 6\ \mathbf{O}_2 + 6\ H_2O$$

Thus all of the oxygen atoms in O_2 (**bolded** in the equation above) come from H_2O, while the oxygen atoms in CO_2 all go to glucose or water. Although we ask students to identify C-C and C-H bonds as high in energy, it is important to recognize that releasing most of that energy requires a reaction with oxygen. It is more accurate to say that the chemical system of glucose and oxygen has more potential energy than the chemical system of carbon dioxide and water.

In practice, biochemists often do not try to trace individual H and O atoms through biochemical processes, since the processes always take place in environments where water provides H and O atoms.

Our research has consistently shown that these ideas are extremely difficult for students who have not formally studied chemistry. We therefore use the convention of twist ties to identify bonds that release energy when they are oxidized (C-C and C-H bonds). The products of cellular respiration have only lower-energy C=O and H-O bonds, so the energy released by the oxidation reaction is available for cell movement and function. Every living organism, from the smallest bacteria to the largest tree in the forest, needs to acquire a source of chemical energy, which is found in the C-C and C-H bonds in organic matter. Once organic matter is oxidized, the chemical energy found in the high-energy bonds is made available for cell functions such as movement, chemical work, and transport of materials. Ultimately all of this energy leaves the plant as heat.

A note on cellular respiration. Students usually do not think about plants doing cellular respiration. They learn that plants do photosynthesis, and often cellular respiration is overlooked. Students may not even wonder how seeds actually sprout when they have no leaves, no chlorophyll, and no way to photosynthesize. Fully grown plants also undergo cellular respiration on a continuous basis. It is easier to detect this process in plants during the night, as well as in winter months, when plants are not also photosynthesizing. During cellular respiration, plants take organic materials and oxidize them, which releases energy and gives off inorganic carbon dioxide and water as wastes. Many students also incorrectly see cellular respiration as the way plants convert food or stored biomass (fat, starch) into *energy* for movement, cell functions, and growth. Students need to develop an explanation of cellular respiration that conserves both matter and energy, and makes the connection between atomic-molecular transformations and macroscopic observations.

In *Carbon TIME* Units we explain that the chemical energy released during cellular respiration is used for cell functions and ultimately converted to heat. In more advanced classes, you may choose to include another intermediate step in this story: the energy released by oxidation of glucose is used to convert ADP (adenosine diphosphate) and phosphate into ATP (adenosine triphosphate), which is the immediate source of energy for cell functioning. Some of your students may believe that ATP is a form of energy and not a form of matter or that the matter in glucose is converted to ATP, so pay particular attention to how students describe ATP when learning about cellular respiration. ATP is matter with chemical energy stored in its bonds.

Key Carbon-Transforming Processes: Photosynthesis & Cellular Respiration

Content Boundaries and Extensions

Talk and Writing

At this stage in the unit, the students will be **developing Explanations**. The table below shows specific talk and writing goals for this phase of the unit.

Talk and Writing Goals for the Explanations Phase	Teacher Talk Strategies That Support This Goal	Curriculum Components That Support This Goal
Examine student ideas and correct them when there are problems. It's ok to give the answers away during this phase! Help students practice using **precise language** to describe **matter and energy**.	*Let's think about what you just said: air molecules. What are air molecules?* *Are you talking about matter or energy?* *Remember: atoms can't be created. So that matter must have come from somewhere. Where did it come from?* *Let's look at the molecule poster again… is carbon an atom or a molecule?*	Molecule Poster Three Questions Poster
Focus on making sure that explanations include multiple **scales**.	*The investigation gave us evidence for what was happening to matter and energy at a macroscopic sale. But what is happening at an atomic-molecular scale?* *What is happening to molecules and atoms?* *How does energy interact with atoms and molecules during chemical change?* *Why doesn't the macroscopic investigation tell us the whole story?* *Let's revisit our scale poster… what is happening to matter at the molecular scale?*	Molecular Models Molecular Modeling Worksheets **Explanations Tools** PPT animations of chemical change Powers of Ten Poster
Encourage students to recall the investigation.	*When did this chemical change happen during our investigation?* *How do we know that? What is our evidence?* *What were the macroscopic indicators that this chemical change took place?*	**Evidence-Based Arguments Tool** Investigation Video
Elicit a range of student explanations. Press for details. Encourage students to examine, compare, and contrast their explanations with others'.	*Who can add to that explanation?* *What do you mean by _____? Say more.* *So I think you said _____. Is that right?* *Who has a different explanation?*	**Explanations Tools**

	How are those explanations similar/different? *Who can rephrase _____'s explanation?*	

Activity 4.1: Molecular Models for Potatoes Moving and Functioning: Cellular Respiration (40 min)

Overview and Preparation

Target Student Performance

Students use molecular models to explain how carbon, oxygen, and hydrogen atoms in glucose and oxygen molecules are rearranged into carbon dioxide and water in a potato plant's cells.

Resources You Provide

- (From previous lesson) Students' unanswered questions they shared in Activity 3.5 Evidence-Based Arguments about Plants
- (From previous lesson) 3.5 Evidence-Based Arguments Tool for Plants
- molecular model kit (1 per pair of students)
- scissors (1 per pair of students)
- twist ties (at least 12 per pair of students)
- video of a plant moving, such as here https://www.youtube.com/watch?v=LICDb8nM5rs

Resources Provided

- 4.1 Molecular Models for Potato Cellular Respiration PPT
- 4.1 Molecular Models for Cellular Respiration Worksheet (1 per student)
- 4.1 Grading the Molecular Models for Cellular Respiration Worksheet

Recurring Resources

- Molecular Models 11 x 17 Placemat (1 per pair of students)
- Forms of Energy Cards (1 set per pair of students)
- Three Ways to Represent Glucose 11 x 17 Poster (1 per class)

Setup

Prepare one model kit, one Molecular Models 11 x 17 Placemat, one pair of scissors, and one set of the Forms of Energy Cards for each pair of students. Print one copy of the 4.1 Molecular Models for Cellular Respiration Worksheet for each pair of students. Prepare a computer and a projector to display the PPT. Retrieve the materials from Activity 3.5. This may include PPT slides from the lesson in which you typed students' unanswered questions or a photograph of their unanswered questions.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.1 Molecular Models for Potato Cellular Respiration PPT.

2. Remind students of their unanswered questions from Activity 3.5.

Tell students that in today's activity we will use molecular modeling to begin to answer some of their unanswered questions about what happens when a plant grows.

- Return students' completed 3.5 Evidence-Based Arguments Tool for Plants and ask them to review their unanswered questions from the last lesson.

- You may have typed and saved students' unanswered questions on the 3.5 Evidence-Based Arguments Tool for Plants PPT. Or you may have taken a picture of students' unanswered questions. Display the visual and review what students shared.

3. Make connections among processes at different scales.

Display slide 3 in the PPT.

- Show students the short clip of a plant moving. Follow the link in the PPT, in the materials list, or here (https://www.youtube.com/watch?v=LICDb8nM5rs).
- Help students connect to their unanswered questions about processes at different scales.
- At the macroscopic scale, we wonder, *How do potato plants move and function*?
- At the microscopic scale, we think about this question in terms of plant cells: *How do potato plant cells get energy to help the plant move and function?*
- At the atomic-molecular scale, we think about this question in terms of atoms and molecules in chemical changes: *What chemical change provides energy to the cells?*
- Assure students that we will be able to answer several of their unanswered questions by the end of today's activity.

4. How do a potato plant's cells get energy to move?

Use slide 4 to show students that plants use food in two ways.

- Today we'll be focusing on energy as one of those uses (cellular respiration).

5. Use the plant animation to connect the atomic-molecular scale to the macroscopic scale

Show slide 5 of the PPT.

- Use the animation to support students in connecting the atomic-molecular scale to the macroscopic scale.
- Tell students they will be modeling the change that occurs during cellular respiration at the atomic-molecular scale.

6. Introduce students to the three different ways we represent molecules in the *Carbon TIME* units.

Display slide 6 of the PPT. Post a copy of the Three Ways to Represent Glucose 11 x 17 Poster in your classroom and display slide 6 in the PPT. Have students discuss the differences in the three different images we use in the *Carbon TIME* Units to represent molecules.

- The first form uses letters and numbers. Each letter represents a type of atom and each number indicates how many of that atom are in the molecule.
- The second form uses letters and sticks. Each letter represents an atom, and each stick represents a bond.
- The third form uses balls and sticks. Each ball represents an atom, and each stick represents a bond.

7. Prepare for building molecular models.

Divide the class into pairs and give each pair a molecular model kit, a set of Forms of Energy Cards, and Molecular Models 11 x 17 Placemat. Pass out one copy of 4.1 Molecular Models for Cellular Respiration Worksheet to each student.

- Tell students that they'll be using molecular models to model the process of cellular respiration which will help them answer several of their unanswered questions.

- Show students slide 7 to explain the bonding of atoms in molecules. Tell students that the rules on this slide are important because they apply to all molecules that they will make in all *Carbon TIME* units.

8. Have students use the molecular model kits to construct the reactants.

Use slide 8 to show instructions to construct the reactants: glucose and oxygen. Students can also follow instructions in Part B of their worksheet.

9. Check students' work for the reactants.

Show slide 9 in the PPT.

- Have students compare their own molecules with the picture on the slide.
- Slide 10 shows an **important message**: after students create their reactant molecules, make sure they put away all unused pieces of their molecule kits. This helps reinforce that the matter and energy in the reactants are conserved through the chemical change, and that only the materials from the reactants are used to build the products.

10. Have students record their descriptions of atoms and energy in reactant molecules.

Show slide 11 in the PPT.

When they have completed their reactants, tell students to complete the table about matter and energy in Part C of their worksheet for the *reactants*.

11. Have students construct a model of the product molecules.

Show slide 12 of the PPT and have students re-arrange the atoms to make molecules of CO_2 and H_2O. Tell students to follow the instructions in steps 3 and 4 in Part B of the worksheet to construct their products.

- To do this, they will need to move their molecules from the reactants side to the products side of the placemat. Explain to students that atoms last forever, so they should not add or subtract atoms when they change the reactant molecule into product molecules.

12. Check students' work for the products.

Show slide 13 in the PPT.

- Have students compare their own molecule with the picture on the slide.
- Use slide 14 to compare the reactants and products.

13. Have students record their descriptions of atoms and energy in product molecules.

Show slide 15 in the PPT.

- When students have completed their reactants, tell students to complete the table in Part C in their worksheet that explains what they *ended* with.
- Have students verify that the number of atoms before and after remained constant: Atoms last forever! Tell students that this means that the number of atoms before and after the reaction does not change.

14. Have students watch an animation of the chemical change.

Show slides 16-22 in the PPT to help students make connections between what is happening in the animation and the molecular models they made.

- For each slide, focus on different atoms and forms of energy and how they change. The animation draws attention to where they atoms begin and end in the reaction.

15. Discuss results with the class.

Show slide 23 in the PPT.

- Complete the "check yourself" questions with the class in Part C.

16. Help students write a balanced chemical equation.

Tell students that now that they have represented a chemical change using molecular models and in animations, they will represent chemical change by writing the chemical equation.

- Show Slide 24 to guide students through the process of writing a balanced chemical equation for cellular respiration. Tell students that these rules apply to all chemical reactions.
- Tell students to write their equations in Part D of their worksheet.
- Have students write their own chemical equations before comparing them with the one on Slide 25.

17. Have students complete an exit ticket.

Show slide 26 of the 4.1 Molecular Models for Potato Cellular Respiration PPT.

- Conclusions: What happens to the glucose and oxygen during cellular respiration?
- Predictions: Where do you think cellular respiration occurs?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the predictions question can be used as a lead in to the next activity.

Assessment

Listen to students' ideas about how plants get energy to move. Are they able to make connections to the results from the Plants in the Light and Dark Investigation? Are they able to make connections to their experiences with the molecular modeling of cellular respiration?

If you had students complete the molecular modeling part of this activity, use 4.1 Grading the Molecular Models for Cellular Respiration Worksheet to get a sense of students' initial ideas and explanations about cellular respiration in plants. Students should be able to follow instructions and complete the worksheet correctly, so it is reasonable to grade this worksheet.

Tips

- You may want to display the results from the investigations from Lesson 3.
- Have students record their ideas about how plants get energy to move on individual posters.
- You may want to laminate the Molecular Models 11 x 17 Placemats. These will be used multiple times in each unit.
- If you choose to do the optional molecular models piece, stress that although we are using twist ties to represent energy, energy is actually not made of matter/molecules!

Differentiation & Extending the Learning

Differentiation

- Strategic grouping with strong speakers
- Build models for students to copy

Modifications

Extending the Learning

- Plants do not give off CO_2 at night only! Plants perform cellular respiration 24 hours a day. Encourage students to think about why we observed plants giving off CO_2 at night only, but we were unable to detect their CO_2 during the day.
- Have students compare the chemical reaction for combustion and the chemical reaction for cellular respiration. Ask: *What do you notice about these two reactions? What do they have in common?*

Activity 4.2: Explaining How Plants Move and Function: Cellular Respiration (40 min)

Overview and Preparation

Target Student Performance

Students explain how matter moves and changes and how energy changes during cellular respiration in a potato plant's cells.

Resources You Provide

- (From previous lesson) 3.5 Evidence-Based Arguments Tool for Plants

Resources Provided

- 4.2 Explanations Tool for Potato Cellular Respiration (1 per student)
- 4.2 Explaining How Potato Plants Move and Function: Cellular Respiration PPT
- 4.2 Grading the Explanations Tools for Potato Cellular Respiration
- 4.2 How do Plants Get the Energy They Need to Move and Function? Reading (1 per student)

Recurring Resources

- Three Questions 11 x 17 Poster (1 per class)
- Three Questions Handout (1 per student)
- Engaging Students with Readings and the Questions, Connections, Questions Reading Strategy Educator Resource
- Questions, Connections, Questions Student Reading Strategy
- Plants Matter Tracing Tool (1 per student)
- Assessing the Plants Matter Tracing Tool
- (Optional) Example Plant Explanations Handout (1 per student or per group)

Setup

Print one copy of the 4.2 Explanations Tool for Potato Cellular Respiration for each student. Return students' completed versions of the 3.5 Evidence-Based Arguments Tool for Plants for review. In this activity, your students will need to use the Three Questions Explanation Checklist on the back of the Three Questions Handout. Be sure to have this available to students and see the notes in the Modifications at the end of the Activity for ideas about how to use it.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.2 Explaining How Potato Plants Move and Function: Cellular Respiration PPT.

2. Revisit students' arguments about what happens when plants grow.

Show slide 3 of the 4.2 Explaining How Potato Plants Move and Function: Cellular Respiration PPT.

- Tell students that this activity's purpose is to develop explanations for how plant's use food to move and function.

- Return each student's copy of 3.5 Evidence-Based Arguments Tool for Plants and have them review their arguments before they completed the molecular modeling activity. Their arguments and unanswered questions should also apply to potato plants.
- Ask them to think about what they know now that they didn't know then.

3. Have students complete the Explanations Process Tool.

Show slide 4 of the 4.2 Explaining How Potato Plants Move and Function: Cellular Respiration PPT. Give each student one copy of 4.2 Explanations Tool for Potato Cellular Respiration.

- Tell students that in this part of the unit, they will combine everything they learned about how plants use food to move and function into an explanation.
- Remind them to consider both their evidence from the investigation as well as what they learned in the molecular modeling activity to construct their explanations.
- Give students about 10 minutes to complete the Explanations process tool.

4. Have students share explanations with each other.

Show slide 5 of the 4.2 Explaining How Potato Plants Move and Function: Cellular Respiration PPT. Divide students into pairs and have them compare explanations for the Three Questions and the final explanation on the process tool.

Have students use the Three Questions 11 x 17 Poster (or Handout) as a reference. Have students check their explanations with the middle and right-hand columns of the poster to make sure they are following the "rules."

5. Have students think about how cellular respiration answers the Matter Movement question.

Use slides 6-10 in the PPT to have the students discuss what is happening to matter during cellular respiration and to have them check their answers to the Matter Movement Question on their 4.2 Explanations Tool for Potato Cellular Respiration.

- Show students slide 6-8 to have them think about where atoms are moving from and moving to during cellular respiration.
- Display slides 9-10 to have students compare their answers to the Matter Movement Question with the answers on the slide. Students only need to have arrows showing the movement of molecules into and out of the cell. Have students use a different colored writing utensil to make any needed changes to their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.
- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

6. Have students think about how cellular respiration also answers the Matter Change Question.

Show slide 11 to have student consider the Matter Change Question.

- Display slides 12-13 to have students compare their answers to the Matter Change Question on the 4.2 Explanations Tool for Potato Cellular Respiration with the answers on the slide. Have students use a different colored writing utensil to make any needed changes to their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.

- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

7. Discuss how cellular respiration helps to answer the Energy Change Question.

Show slide 14 to have student consider the Energy Change Question.

- Display slide 15 to have students compare their answers to the Energy Change Question on the 4.2 Explanations Tool for Potato Cellular Respiration with the answers on the slide. Have students use a different colored writing utensil to make any needed changes to their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.
- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.
- Have students consider how these answers address Energy Change at macroscopic, atomic-molecular, and cellular scales.

8. Using the Plants Matter Tracing Tool, have students answer the question: How does cellular respiration fit into the story of how plants grow and function?

Show slide 17 and have students pull out their Plants Matter Tracing Tool. Allow students to complete their tools, keeping in mind the discussion that just took place.

- Display slide 18 to have students check their arrows on the Plants Matter Tracing Tool. Allow for corrections if necessary.

9. (Optional) Have students critique example explanations

Have students look at two handouts: (a) the Three Questions Handout, and (b) the Plants Example Explanations Handout.

- Ask students to evaluate the two example explanations of cellular respiration on the Plants Example Explanations Handout: Which explanation is better? Why?
- Have students use the Three Questions Explanation Checklist on the back of the Three Questions Handout to justify their critiques of the explanations.

10. Have students read about cellular respiration.

Pass out 4.2 How do Plants Get the Energy They Need to Move and Function? Reading. The reading provides a summary explanation of cellular respiration and additional information about how plants absorb and reflect light. Students can complete the reading using the Questions, Connections, Questions Student Reading Strategy. See the Engaging Students with Readings and the Questions, Connections, Questions Reading Strategy Educator Resource document for information about how to engage students with this strategy.

- After pairs are finished reading, have students share with the class what they found interesting and any questions they have.

11. Have students critique and improve their full explanations.

Display slide 19 of the PPT for the full explanation. Have students use the Three Questions Explanation Checklist on the back of the Three Questions Handout to check that their story includes each of the parts (matter movement, matter change, energy change, and matter movement) and answers the prompt in a cohesive way.

- If students don't have all four parts in their explanation, instruct them to add to their explanation using a different colored writing utensil.
- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

12. Lead a discussion about how student ideas have changed over time.

Show slide 20 of the 4.2 Explaining How Potato Plants Move and Function: Cellular Respiration PPT. Have students look back over their process tools for this unit.

- Have students consider how their ideas changed with regard to scale, movement, and carbon.
- What do they know now about how plants use food to move and function that they didn't know before the investigation?

13. Revisit unanswered questions.

Show slide 21. Have students look at their 3.5 Evidence-Based Arguments Tool for Plants. Display the class list of unanswered questions from Activity 3.5.

- Ask students which of their unanswered questions they can now answer with their understanding of cellular respiration. Which ones are left unanswered? Do they have any new questions to add to the list?

14. Have students complete an exit ticket.

Show slide 22 of the 4.2 Explaining How Potato Plants Move and Function: Cellular Respiration PPT.

- Conclusions: How do matter and energy change during cellular respiration?
- Predictions: Where do you think the glucose for cellular respiration comes from?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used

on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the predictions question can be used as a lead in to the next activity.

Assessment

During the class, circulate while students are comparing their explanations. Listen to see if they are able to explain cellular respiration at both the macroscopic and atomic-molecular scales. Use 4.2 Grading the Explanations Tools for Potato Cellular Respiration to grade your students' work on the 4.2 Explanations Tool for Potato Cellular Respiration. At this point in the lesson, students should be held accountable for correct answers. Use Grading the Plants Matter Tracking Tool to grade the tool.

Tips

- Make sure students understand that the chemical energy in glucose (not the glucose itself) is converted to heat and light energy.
- Make sure that students discuss and understand all three columns of the Three Questions 11 x 17 Poster or Handout. They play a central role in all *Carbon TIME* units.

Differentiation & Extending the Learning

Differentiation

- Provide sentence stems for discussion and filling in the Explanations Tool
- Work through the tool as a class and provide sentence stems for final explanation
- Hand out and refer to Example Plants Explanation Handout when working on the Explanations Tool
- Refer to the word wall for questions on cellular respiration related vocabulary
- Refer to the Plants Matter Tracing Tool to support students further

Modifications

The Three Questions Explanation Checklist on the back of the Three Questions Handout can be used to scaffold students' explanations in many ways.

- Students refer to the checklist as they are constructing their explanations.
- Students use the checklist as they are sharing and revising their explanations with a partner.
- Students use the checklist to critique and revise their final explanations.
- Students use the checklist to critique the example explanations for each unit.
- Students use the checklist to create and/or evaluate a whole-class consensus explanation.

We recommend using this checklist with a gradual release. As students improve in their ability to write their own explanations, they may rely on the checklist less.

Activity 4.3: Molecular Models for Photosynthesis Worksheet (60 min)

Overview and Preparation

Target Student Performance

Students use molecular models to explain how carbon, oxygen, and hydrogen atoms in carbon dioxide and water molecules are rearranged into glucose and oxygen in a potato plant's leaf cells.

Resources You Provide

- Molecular modeling kit (1 per pair of students; includes 6 carbon atoms, 12 hydrogen atoms, 18 oxygen atoms, 36 or more bond links)
- Twist ties (12 per pair of students)
- Scissors (1 per pair of students)

Resources Provided

- 4.3 Molecular Models for Potato Photosynthesis PPT
- 4.3 Molecular Models for Photosynthesis Worksheet (1 per student)
- 4.3 Grading Molecular Models for Photosynthesis Worksheet
- https://www.youtube.com/watch?v=9nHHTnnvxFQ&list=PL4te0BRLizI4XHj4SiEmGg148vgPNOYe0&index=8

Recurring Resources

- Forms of Energy Cards (1 set per pair of students)
- Molecular Models 11 x 17 Placemat (1 per pair of students)

Setup

Print one copy of 4.3 Molecular Models for Potato Photosynthesis Worksheet for each student. For each pair of students, print one copy of Molecular Models 11 x 17 Placemat, Forms of Energy Cards, and prepare a pair of scissors. Prepare enough molecular modeling kits for each group. Prepare a computer and a projector to show the PPT while the students are creating models.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.3 Molecular Models for Potato Photosynthesis PPT.

2. Make connections among processes at different scales.

Display slide 3 in the PPT.

- Introduce students to the driving question: *How does a potato plant make the food it needs to grow and function?*
- Connect this question at the macroscopic scale to an unanswered question about the Energy Change Question at the microscopic scale: *How do a potato's' leaf cells produce the food the potato needs to grow and function?*

- Connect this question at the microscopic scale to an unanswered question about the Energy Change Question at the atomic-molecular scale: *What chemical change produces food in the potato's leaf cells?*
- Assure students that we will be able to answer several of their unanswered questions by the end of today's activity.

3. Use the Plants in the Light and Dark investigation results to ask about how plants make their own food.

Display slide 4 of the PPT. Remind students of the results of the Plants in the Light and Dark Investigation: The plants in the light changed the BTB solution to blue, which indicated a decrease in CO_2. The plants in the dark changed the BTB solution to yellow, which indicated an increase in CO_2. The carbon must be going to and coming from somewhere around the plants.

- Discuss the diagram on slide 4, which shows that food made in the leaves is needed for both growth and movement. Explain that modeling photosynthesis will help them understand the results of the investigation.
- Display slide 5 of the PPT. Use the animation to support students in connecting the atomic-molecular scale to the macroscopic scale.
- Tell students they will be modeling the change that occurs during photosynthesis at the atomic-molecular scale.

4. Prepare for building molecular models.

Divide the class into pairs and give each pair a molecular model kit, a set of Forms of Energy Cards, and Molecular Models 11 x 17 Placemat. Pass out one copy of 4.3 Molecular Models for Photosynthesis Worksheet to each student.

- Show students slide 6 to review the bonding of atoms in molecules. Tell students that the rules on this slide are important because they apply to all molecules that they will make in all *Carbon TIME* units.
- Watch the video about molecular models. https://www.youtube.com/watch?v=9nHHTnnvxFQ&list=PL4te0BRLizI4XHj4SiEmGg148vgPNOYe0&index=8

5. Have students use the molecular model kits to construct the reactants.

Use slide 7 to show instructions to construct the reactants: carbon dioxide and water. Students can also follow instructions in Part B of their worksheet.

6. Check students' work for the reactants.

Show slide 8 in the PPT.

- After students get a chance to create the reactant molecules, show students the photo on Slide 8 and explain that the twist ties represent energy, and will represent the transformation of light energy to chemical energy. Have students put 12 twist ties on the reactants side of their poster. Have students put the light energy card under the twist ties. Have students note how many energy units (twist ties) they begin with.
- Have students compare their own molecule with the picture on the slide.
- Slide 9 shows an **important message**: after students create their reactant molecules, make sure they put away all unused pieces of their molecule kits. This helps reinforce that the matter and energy in the reactants are conserved through the chemical change, and that only the materials from the reactants are used to build the products.

7. Have students record their results.

Show slide 10 in the PPT.

- When they have completed their reactants, tell students to complete the table about matter and energy in Part C of their worksheet for the *reactants*.

8. Have students use molecular models and twist ties to show changes in matter and energy.

Have students continue working in pairs to observe how light, carbon dioxide, and water can be rearranged into the molecules of the products: glucose and oxygen. Tell students that the light energy from the Sun is transformed into chemical energy in the C-C and C-H bonds of the glucose, which is represented with twist ties. Oxygen does not contain any high-energy bonds, so these molecules do not take twist ties.

- Use Slides 11 and the instructions on the worksheet to have students use the same materials they used to form their reactant molecules to form the product molecules. Tell them to place their products in the appropriate box on the product side of the placemat.

9. Check students' work for the products.

Show Slide 12 to let students compare their products to the products in the picture.

- Have students use the chemical energy card to indicate what form the energy is in after the chemical change by putting the card under the glucose molecule.
- Show slide 13 to give students an overview of the entire reaction.

10. Have students record their results.

Show slide 14 in the PPT.

- When students have completed their reactants, tell students to complete the table in Part C in their worksheet that explains what they *ended* with.
- Have students verify that the number of atoms before and after remained constant: Atoms last forever! Tell students that this means that the number of atoms before and after the reaction does not change.

11. Have students watch an animation of the chemical change.

Show slides 15-19 in the PPT to help students make connections between what is happening in the animation and the molecular models they made.

- For each slide, focus on different atoms and forms of energy and how they change. The animation draws attention to where they atoms begin and end in the reaction.

12. Discuss results with the class.

Show slide 20 in the PPT.

- Complete the "check yourself" questions with the class in Part C.

13. Help students write a balanced chemical equation.

Tell students that now that they have represented a chemical change using molecular models and in animations, they will represent chemical change by writing the chemical equation.

- Show Slide 21 to guide students through the process of writing a balanced chemical equation for photosynthesis. Tell students that these rules apply to all chemical reactions.
- Tell students to write their equations in Part D of their worksheet.

- Have students write their own chemical equations before comparing them with the one on Slide 22.

18. Have students complete an exit ticket.

Show slide 23 of the 4.3 Molecular Models for Potato Photosynthesis PPT.

- Conclusions: Where do the reactants for photosynthesis come from?
- Predictions: Where do you think photosynthesis occurs?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the predictions question can be used as a lead in to the next activity.

Assessment

Monitor your students' work as they put together their molecular models. Are they correctly identifying forms of energy on either side of the reaction? Do they understand that all materials used in the reactants must be present in the products? Notice students' ability to identify molecules that have C-C and C-H bonds as materials that have chemical energy. Use 4.3 Grading Molecular Models for Photosynthesis Worksheet to assess their work. Students should be able to follow instructions and complete the worksheet correctly, so it is reasonable to grade this worksheet.

Tips

- During the demonstration, stress that although we are using twist ties to represent energy, energy actually is not made of matter/molecules!
- You may want to laminate the Molecular Models 11 x 17 Placemats. These will be used multiple times in each unit.
- Although we ask students to identify C-C and C-H bonds as high in energy, it is important to recognize that releasing most of that energy requires a reaction with oxygen. It is more accurate to say that the chemical system of glucose and oxygen has more potential energy than the chemical system of carbon dioxide and water.

Differentiation & Extending the Learning

Differentiation

- Strategic grouping with strong speakers
- Build models for students to copy
- Refer to models building Activity 4.1: Molecular Models for Potatoes Moving and Functioning: Cellular Respiration

Modifications

Students may work in groups of three or four if you are short on molecule kits.

Extending the Learning

- At the end of the Activity, have students explain the process of photosynthesis to a partner.
- Have the students “act out” photosynthesis by assigning them molecules using signs. Have them move around the room to represent the process by linking and unlinking hands.
- Have students compare the chemical reactions for combustion, cellular respiration, and photosynthesis. What do they notice about these reactions?

Activity 4.4: Explaining How Plants Make Food: Photosynthesis (40 min)

Overview and Preparation

Target Student Performance

Students explain how matter moves and changes and how energy changes during photosynthesis in a potato plant's leaf cells.

Resources You Provide

- (From previous lesson) 3.5 Evidence-Based Arguments Tool for Plants

Resources Provided

- 4.4 Explaining How Plants Make Food: Photosynthesis PPT
- 4.4 Explanations Tool for Potato Photosynthesis (1 per student)
- 4.4 Grading the Explanations Tools for Potato Photosynthesis
- 4.4 How do Plants Produce Food? Reading (1 per student)

Recurring Resources

- Three Questions 11 x 17 Poster (1 per class)
- Three Questions Handout (1 per student)
- Engaging Students with Readings and the Questions, Connections, Questions Reading Strategy Educator Resource
- Questions, Connections, Questions Student Reading Strategy
- Learning Tracking Tool for Plants (1 per student)
- Assessing the Learning Tracking Tool for Plants
- Plants Matter Tracing Tool
- Assessing the Plants Matter Tracing Tool
- (Optional) Example Plant Explanations Handout (1 per student or per group)

Setup

Print one copy of the 4.4 Explanations Tool for Potato Photosynthesis for each student. In this activity, your students will need to use the Three Questions Explanation Checklist on the back of the Three Questions Handout. Be sure to have this available to students, and see the notes in the Modifications at the end of the Activity for ideas about how to use it. Prepare a computer and a projector to display the PPT.

Directions

1. Use the instructional model to show students where they are in the course of the unit.

Show slide 2 of the 4.4 Explaining How Plants Make Food: Photosynthesis PPT.

2. Revisit students' arguments about what happens when plants are in Light & Dark.

Show slide 3 of the 4.4 Explaining How Plants Make Food: Photosynthesis PPT.

- Tell students that this activity's purpose is to develop explanations for how plants make food.

- Return each student's copy of 3.5 Evidence-Based Arguments Tool for Plants and have them review their arguments before they completed the molecular modeling activity. Their arguments and unanswered questions should also apply to potato plants.

3. Have students know that plants make their own food.

Show slide 4 of the 4.4 Explaining How Plants Make Food: Photosynthesis PPT.

- Tell students that plants make glucose from photosynthesis in leaves. Glucose can be transported to cells through phloem and used for biosynthesis and cellular respiration.

4. Have students complete the Explanations process tool.

Show slide 5 of the 4.4 Explaining How Plants Make Food: Photosynthesis PPT. Give each student one copy of 4.4 Explanations Tool for Potato Photosynthesis.

- Tell students that in this part of the unit, they will combine everything they learned about how plants make food into an explanation.
- Remind them to consider both their evidence from the investigation as well as what they learned in the molecular modeling activity to construct their explanations.
- Give students about 10 minutes to complete the Explanations Process Tool.

5. Have students share explanations with each other.

Show slide 6 of the 4.4 Explaining How Plants Make Food: Photosynthesis PPT. Divide students into pairs and have them compare explanations for the Three Questions and the final explanation on the process tool.

- Have students use the Three Questions 11 x 17 Poster (or Handout) as a reference. Have students check their explanations with the middle and right-hand columns of the poster to make sure they are following the "rules."

6. Have students think about how photosynthesis answers the Matter Movement question.

Use slides 7-13 in the PPT to have the students discuss what is happening to matter during photosynthesis and to have them check their answers to the Matter Movement Question on their 4.4 Explanations Tool for Potato Photosynthesis.

- Show students slides 7-9 to have them think about where atoms are moving from and moving to during photosynthesis.
- Display slides 10-13 to have students compare their answers to the Matter Movement Question with the answers on the slide. Students only need to have arrows showing the movement of molecules into and out of the cell. Have students use a different colored writing utensil to make any needed changes to their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.
- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

7. Have students think about how photosynthesis also answers the Matter Change Question.

Show slides 14-16 to have student consider the Matter Change Question.

- Display slides 17-18 to have students compare their answers to the Matter Change Question on the 4.4 Explanations Tool for Potato Photosynthesis with the answers on the slide. Have students use a different colored writing utensil to make any needed changes to

their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.

- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

8. Discuss how photosynthesis helps to answer Energy Change question.

Display slide 19 to have students compare their answers to the Energy Change Question on the 4.4 Explanations Tool for Potato Photosynthesis with the answers on the slide. Have students use a different colored writing utensil to make any needed changes to their answers. Allow students to ask questions if they do not understand why their ideas are incorrect.

- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

9. Have students think about how photosynthesis answers the Matter Movement question following the chemical change.

Display slide 20 to have students think about what happens to glucose made by photosynthesis.

10. Using the Plants Matter Tracing Tool, have students answer the question: How does photosynthesis fit into the story of how plants grow and function?

Show slide 21 and have students pull out their Plants Matter Tracing Tool. Allow students to complete their tools, keeping in mind the discussion that just took place.

- Display slide 22 to have students check their arrows on the Plants Matter Tracing Tool. Allow for corrections if necessary.

11. (Optional) Have students critique example explanations.

Have students look at two handouts: (a) the Three Questions Handout, and (b) the Plants Example Explanations Handout.

- Ask students to evaluate the two example explanations of photosynthesis on the Plants Example Explanations Handout: Which explanation is better? Why?
- Have students use the Three Questions Explanation Checklist on the back of the Three Questions Handout to justify their critiques of the explanations.

12. Have students read about photosynthesis.

Pass out 4.4 How do Plants Produce Food? Reading. The reading provides a summary explanation of photosynthesis and additional information about how plants use and store carbon dioxide. Students can complete the reading using the Questions, Connections, Questions Student Reading Strategy. See the Engaging Students with Readings and the Questions, Connections, Questions Reading Strategy Educator Resource document for information about how to engage students with this strategy.

- After pairs are finished reading, have students share with the class what they found interesting and any questions they have.

13. Have students critique and improve their full explanations.

Display slide 23 of the PPT for the full explanation. Have students use the Three Questions Explanation Checklist on the back of the Three Questions Handout to check that their story includes each of the parts (matter movement, matter change, energy change, and matter movement) and answers the prompt in a cohesive way.

- If students don't have all four parts in their explanation, instruct them to add to their explanation using a different colored writing utensil.
- If students have model explanations to share, display student work and discuss. If students have common areas of weakness in their explanations, ask for a volunteer to share, display student work, and discuss ways of strengthening the response.

14. Have students consider how their ideas have changed.

Show slide 24 of the 4.4 Explaining How Plants Make Food: Photosynthesis PPT. Have students look back over their process tools for this unit.

- Have students consider how their ideas changed with regard to scale, movement, and carbon.
- What do they know now about how plants make food that they didn't know before the investigation?

15. Revisit unanswered questions.

Show slide 25 of the 4.4 Explaining How Plants Make Food: Photosynthesis PPT. Have students look at their 3.5 Evidence-Based Arguments Tool for Plants. Display the class list of unanswered questions from Activity 3.5.

- Ask students which of their unanswered questions they can now answer with their understanding of photosynthesis. Which ones are left unanswered? Do they have any new questions to add to the list?

19. Have students complete an exit ticket.

Show slide 26 of the 4.4 Explaining How Plants Make Food: Photosynthesis PPT.

- Conclusions: How do matter and energy change during photosynthesis?
- Predictions: What do you think happens to the glucose made during photosynthesis?
- On a sheet of paper or a sticky note, have students individually answer the exit ticket questions. Depending on time, you may have students answer both questions, assign students to answer a particular question, or let students choose one question to answer. Collect and review the answers.
- The conclusions question will provide you with information about what your students are taking away from the activity. Student answers to the conclusions question can be used on the Driving Question Board (if you are using one). The predictions question allows students to begin thinking about the next activity and allows you to assess their current ideas as you prepare for the next activity. Student answers to the predictions question can be used as a lead in to the next activity.

16. Have a discussion to complete the Learning Tracking Tool for this activity.

Show slide 27 of the 4.4 Explaining How Plants Make Food: Photosynthesis PPT.

- Pass out a Learning Tracking Tool for Plants to each student.
- Have students write the activity chunk name, "Explaining How Plants Make Food, Move, and Function" and their role, "Explainer" in the first column.
- Have a class discussion about what students did during the activity chunk. When you come to consensus as a class, have students record the answer in the second column of the tool.
- Have a class discussion about what students figured out during the activity chunk that will help them in answering the unit driving question. When you come to consensus as a class, have students record the answer in the third column of the tool.
- Have a class discussion about what students are wondering now that will help them move towards answering the unit driving question. Have students record the questions in the fourth column of the tool.
- Have students keep their Learning Tracking Tool for future activities.
- Example Learning Tracking Tool

Activity Chunk	What Did We Do?	What Did We Figure Out?	What Are We Asking Now?
Explaining How Plants Make Food, Move, and Function Explainer	Model cellular respiration and photosynthesis using molecular model kits and use the Explanations Tools to explain what happens when plants make food, move, and function.	Plants make glucose and O_2 from CO_2 and H_2O, the process of photosynthesis. Then they use some of that glucose for cellular respiration, combining glucose with O_2 to make CO_2 and H_2O and providing energy for plant functions.	What happens to the food plants make during photosynthesis?

Assessment

Use 4.4 Grading the Explanations Tools for Potato Photosynthesis to grade student responses. At this point, students can be held accountable for correct answers. If students are still struggling with these concepts, you may want to revisit parts of the lesson they are finding difficult. Use Assessing the Plants Matter Tracing Tool to grade the tool.

Differentiation & Extending the Learning

Differentiation

- Provide sentence stems for discussion and filling in the Explanations Tool
- Work through the tool as a class and provide sentence stems for final explanation
- Hand out and refer to Example Plants Explanation Handout when working on the Explanations Tool
- Refer to the word wall for questions on photosynthesis related vocabulary
- Refer to the Plants Matter Tracing Tool to support students further

Modifications

The Three Questions Explanation Checklist on the back of the Three Questions Handout can be used to scaffold students' explanations in many ways.

- Students refer to the checklist as they are constructing their explanations.
- Students use the checklist as they are sharing and revising their explanations with a partner.
- Students use the checklist to critique and revise their final explanations.
- Students use the checklist to critique the example explanations for each unit.
- Students use the checklist to create and/or evaluate a whole-class consensus explanation.

We recommend using this checklist with a gradual release. As students improve in their ability to write their own explanations, they may rely on the checklist.