Lesson 5: Explaining How Plants Grow

Overview

Students develop a story about how the high-energy glucose molecules created during photosynthesis are transformed into larger organic polymers during biosynthesis in plants.

Download PDF of Lesson 5 Teacher's Guide

Guiding Question

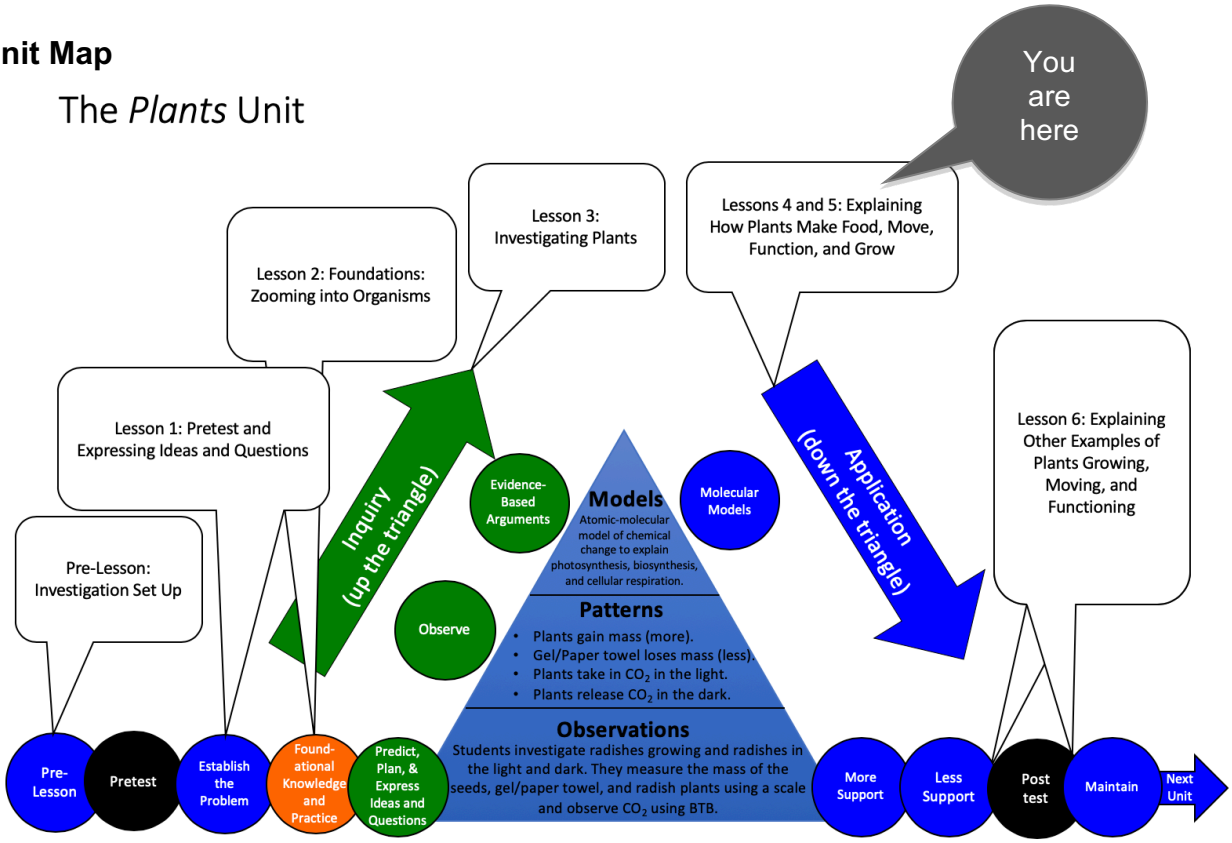
How can a potato plant make a potato?

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 5.1: Tracing the Process of Potatoes Growing: Biosynthesis (40 min)
- Activity 5.2: Molecular Models for Potatoes Growing: Biosynthesis (40 min)
- Activity 5.3: Explaining How Potato Plants Grow: Biosynthesis (40 min)

Unit Map



Learning Goals

Target Performances

Activity	*Target Performance*
Lesson 5 – Explaining How Plants Grow (students as explainers)	
Activity 5.1: Tracing the Process of Potatoes Growing: Biosynthesis	Students "zoom in" to the structure and function of a potato plant's systems and cells, tracing atoms and energy.
Optional Activity 5.2: Molecular Models for Potatoes Growing: Biosynthesis	Students use molecular models to explain how plants make monomers from glucose and minerals and monomers are linked into polymers during biosynthesis.
Activity 5.3: Explaining How Potato Plants Grow: Biosynthesis	Students explain how matter moves and changes and how energy changes during biosynthesis in a potato plant's 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. Structure, Function, and Information Processing. MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.
- 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. Matter and its Interactions. 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 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. From Molecules to Organisms: Structures and Processes. 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-LS1-6. Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

Background Information

Three-dimensional Learning Progression

The three 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 biosynthesis that answer the question: where do the *atoms* come from that make up a plant? Plants are different from animals because animals take in organic materials for food. Most of the atoms in a plant come from CO_2 in the air, and a few atoms come from water and minerals in the soil, like the nitrogen from ammonia.

This lesson is about *molecules* and how all the molecules of a plant are made during biosynthesis. During biosynthesis, plants use the glucose produced by photosynthesis and soil minerals to produce other small organic molecules or monomers (including amino acids, fatty acids, other simple sugars) to construct large organic polymers: primarily proteins, fats, and carbohydrates. Most of the chemical energy stored in the bonds is transferred from monomers to polymers. These polymers are used to construct the plant's cells and organelles. Thus most of the dry mass of plants originates in CO_2 taken in from the air. Coming into this unit, students may incorrectly think that plants either create mass themselves (e.g., through cell division) or build most of their mass using molecules from soil and water. The activities in this lesson help students revise these ideas.

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?)
- **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 (the Matter Movement and Matter Change Questions). 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 or not 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).

Our research has consistently showed 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.

The investigations in all units will make use of two essential tools:

- Digital balances. Students can detect movement of atoms (the Matter Movement Question) by measuring differences in mass. In this activity, students observe a difference in the plants systems.
- Bromothymol blue (BTB) is an indicator that changes from blue to yellow in response to high levels of CO2. Thus, changes in BTB can partially answer the Matter Change Question by detecting whether there is a chemical change that has CO_2 as a reactant or product.

Key Ideas and Practices for Each Activity

Activity 5.1 is the first part of the **Explanations Phase** of the instructional model (going down the triangle) for Lesson 5. Students trace the process, on a poster of a plant, of the chemical

change that took place during the investigation to help them develop an atomic-molecular explanation for how plants gain mass.

Activity 5.2 is a 2-turtle activity appropriate for advanced middle school or high school students and classes. If you decide not to teach Activity 5.2, you can move directly from Activity 5.1 to Activity 5.3. In Activity 5.2, students model the chemical changes of biosynthesis using paper molecules. This activity introduces and uses the vocabulary of polymer and monomer, as well as the names of specific monomers.

The modeling focuses on the building of polymers inside the cells. Plants rearrange the atoms of glucose, and soil minerals (especially nitrogen in ammonia) to first build small organic molecules (monomers): amino acids, glucose, fatty acids, and glycerol (this step is not included in the tracing in Activity 5.1). The energy that is stored in the C-C and C-H bonds of the glucose molecules is conserved and passed along from the glucose molecules to the small organic molecules. These small organic molecules are then used to build large organic molecules (proteins, carbohydrates, and fats), which are called polymers.

Activity 5.3 is the second part of the **Explanations Phase** of the instructional model (going down the triangle) for Lesson 5. Students use the **Explanations Tool** to construct final explanations for biosynthesis. 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. By this point in the unit, the students will have completed at least one of each of the process tools: Expressing Ideas and Questions, Predictions and Planning, Evidence-Based Arguments, and the three Explanations Tools for photosynthesis, cellular respiration, and biosynthesis.

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 mass and weight: Grams and kilograms in the SI (metric) system are units of mass—the amount of matter in a system. On the other hand, pounds and ounces in the English system are units of weight—the force of gravity on a particular mass. As long as gravity doesn't change, these units are interconvertible: The force of gravity on a 1 kg mass is about 2.205 pounds. Since most American students are more familiar with the English units of weight, we sometimes use "weight" and "weight," especially when encouraging students to express their own ideas. When referring to measurements in grams, we use "mass" as both a verb and a noun.

Key Carbon-Transforming Processes: Biosynthesis

Content Boundaries and Extensions

Talk and Writing

At this stage in the unit, the students will complete the inquiry and application sequences for Plant Investigations—they will go up and down the triangle. This means they will go through the **Observations Phase**, the **Evidence-Based Arguments Phase**, and the **Explanations Phase**. The tables below show specific talk and writing goals for these phases of the unit.

Talk and Writing Goals for the Observations Phase	Teacher Talk Strategies That Support This Goal	Curriculum Components That Support This Goal
Help students discuss data and identify patterns.	*What patterns do we see in our data?* *How do you know that is a pattern?* *What about _____ data. What does this mean?*	Class Results Poster Class Results Spreadsheet
Encourage students to compare their own conclusions about the data and evidence with other groups and other classes.	*What about this number? What does this tell us?* *How is group A's evidence different from Group B's data?* *How do our class's data differ from another classes' data?*	Class Results Spreadsheet Class Results Poster Investigation Video (selected segments)
Make connections between the observations and the data/evidence.	*It says here that our BTB turned colors. What does that mean?* *You recorded that your plant gained mass. What does that mean?*	
Have students consider how their predictions and results compare.	*Let's revisit our predictions. Who can explain the difference between our class predictions and our results?* *Who had predictions that were similar to our results? Has your explanation changed? How?*	

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?*	Molecular Models Molecular Modeling Worksheets **Explanations Tool**

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

Activity 5.1: Tracing the Process of Potatoes Growing: Biosynthesis (40 min)

Overview and Preparation

Target Student Performance

Students "zoom in" to the structure and function of a potato plant's systems and cells, tracing atoms and energy.

Resources You Provide

- pennies (5 per pair of students)
- nickels (1 per pair of students)
- video of a plant growing, such as here: https://www.youtube.com/watch?v=YbTFCh_XdYI

Resources Provided

- 5.1 Tracing the Process of Plants Growing: Biosynthesis PPT
- 5.1 Tracing the Process of Potatoes Growing: Biosynthesis Directions (1 per student or pair of students)
- 5.1 Tracing Atoms and Energy in Plants Worksheet (1 per student)
- 5.1 Grading Tracing Atoms and Energy in Plants Worksheet
- 5.1 Soil Minerals for Tracing the Process of Potatoes Growing (1 per class)

Recurring Resources

- Digestion and Biosynthesis of Carbohydrates 11 x 17 Poster (1 per class)
- Digestion and Biosynthesis of Fat 11 x 17 Poster (1 per class)
- Digestion and Biosynthesis of Protein 11 x 17 Poster (1 per class)
- Metabolic Pathways Poster (http://www.sigmaaldrich.com/content/dam/sigma-aldrich/docs/Sigma/General_Information/metabolic_pathways_poster.pdf) (1 per class)
- Potato 11 x 17 Poster (1 per pair of students)

Setup

Print one copy of the Potato 11 x 17 Poster and gather 5 pennies and 1 nickel for every pair of students. Print and cut apart 5.1 Soil Minerals for Tracing the Process of Potatoes Growing. Print one copy of the 5.1 Tracing Atoms and Energy in Plants Worksheet for each student. Print one copy of 5.1 Tracing the Processes of Potatoes Growing: Biosynthesis Directions for each student or pair of students. Prepare a computer and a projector to display the PPT and video. Print and hang the Digestion and Biosynthesis 11 x 17 Posters, and the Metabolic Pathways Poster.

Directions

1. Have students start to think about how plants grow.

Tell students that in today's activity we will use molecular modeling to think about how plants grow through biosynthesis.

- Open 5.1 Tracing the Process of Plants Growing: Biosynthesis PPT.

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

Show slide 2 of the 5.1 Tracing the Process of Plants Growing: Biosynthesis PPT.

3. Discuss Connecting Questions about Processes at Different Scales for Biosynthesis

Display slide 3 in the PPT.

- Show students the short clip of a potato plant growing. Follow the link in the PPT, in the materials list, or here (https://www.youtube.com/watch?v=YbTFCh_XdYI).
- Introduce students to the new driving question: *How do potatoes grow*?
- Connect this question at the macroscopic scale to an unanswered question at the microscopic scale: *How do potatoes' cells use food to grow*?
- Connect this question at the microscopic scale to an unanswered question at the atomic-molecular scale: *How are molecules from food used for growth? Where do the glucose molecules used in cellular respiration come from*?
- Assure students that we will be able to answer several of their unanswered questions by the end of today's activity.

4. Have students discuss how atoms enter the plant get to plant cells in order for cells to get bigger and grow.

Use slides 4-6 to lead a discussion about how atoms enter the plant and get to plant cells.

- Use slides 4-5 to ask students where glucose made from carbon dioxide and water in photosynthesis goes.
- Use slide 6 to remind students that glucose moves from the leaves to all the cells of the plant to be used for growth or energy. They have already learned how plants use glucose for energy. In this activity, they will trace the chemical processes involved in **growth**.

5. Have students trace the process of biosynthesis on the potato poster.

Display slide 7. Give each pair of students a Potato 11 x 17 Poster, a copy of the 5.1 Tracing the Process of Potatoes Growing: Biosynthesis Directions, 5 pennies, a nickel and several soil minerals (cut out from 5.1 Soil Minerals for Tracing the Process of Plants Growing). Explain that they will follow the directions to use their nickels and pennies to trace the path of how matter moves and changes in plants for growth.

6. Show students an animation of biosynthesis and discuss the process.

Use slide 8-9 to show students what happens to carbon atoms and chemical energy when plants make large organic molecules.

- Ask students what is happening to energy during biosynthesis. Listen to see if they notice that chemical potential energy is conserved in the C-C and C-H bonds through the chemical change.
- Refer to the Digestion and Biosynthesis 11 x 17 Posters in your classroom to help students visualize the biosynthesis of small organic molecules to large organic molecules. You do not need to focus on what small organic molecules are combined to produce the large organic molecules (carbohydrates, fat, and proteins).
- Make sure students understand that cells increase in size as they perform biosynthesis, because atoms enter the cells and do not leave. Eventually, the cells grow large enough to divide. The growth and division of cells results in plant growth.

7. Discuss how plants use glucose molecules in other ways.

Use slides 10 to discuss the other ways plant cells use glucose molecules, which include cellular respiration and making cellulose and starch.

8. Transition to have students consider the atoms that make up plants.

Show slide 11 of the PPT. Pass out 5.1 Tracing the Atoms and Energy in Plants Worksheet to each student.

- Tell students that now they have considered how molecules move through and are used by a plant they will now consider the atoms that make up plants.
- Read the top portions of the worksheet with students.
- Have students work with a partner to complete the first chart on the worksheet about atoms.

9. Have students identify where the atoms that make up plants come from.

Show slides 12-13 of the PPT.

- Remind students that in Lesson 2 they learned about the molecules that make up cells and the atoms that make up the molecules.
- Discuss the answers to the first chart on the worksheet. The atoms in the large organic molecules of plants all primarily come from the air. Some of the oxygen atoms do come from the soil and water, as well as air. The hydrogen atoms do come from soil and water. The other elements come from minerals in the soil.
- Although some atoms come from soil, students should recognize at this point in the unit that the majority of the atoms in plants come from the air. You can remind students of the results of the plant investigation as further evidence.

10. Have students identify where the energy in plants come from.

Show slide 14 of the PPT.

- Have students complete the second chart on 5.1 Tracing the Atoms and Energy in Plants Worksheet on energy with a partner.
- Show slide 15. Discuss students' answers together. Energy, in the form of light, is only found in the sunlight that plants take in. There is no energy in the water, air, or soil plants take in.

11. Show students that there are many additional metabolic pathways.

Use slide 16 and the Metabolic Pathways Poster to show students that there are many more metabolic pathways besides what they learned about in this lesson.

- This poster only shows pathways in which small organic molecules are changed into other small organic molecules. There are other pathways that change small organic molecules into large organic molecules.
- Organisms are complex; this poster also offers students a glimpse of their complexity.

Assessment

- Matter tracing: note if students are able to recognize that the same atoms that were in the reactants are also in the products.
- Energy tracing: note the ways that students explain how chemical energy is conserved through both digestion and biosynthesis.

Tips

- During the tracing activity and animation, focus on how matter and energy are conserved through the chemical change. This is the main goal of the activity!

Differentiation & Extending the Learning

Differentiation

- Remind students of the terms Large Organic Molecules and Small Organic Molecules with examples from past units.
- Strategic grouping with strong speakers
- Hand out individual Potato 11 x 17 Posters for students to trace molecules that can be written on
- Work on 5.1 Tracing Atoms and Energy in Plants Worksheet together and create a pie chart to show what makes up plants from the information students gather

Modifications

- Have the students “act out” biosynthesis by assigning them molecules using signs. Have them move around the room to represent the processes by linking hands.

Extending the Learning

- Have students research the role of nitrogen in plants for homework and share what they learn. Ask: How do plants and animals obtain and use nitrogen differently?

Activity 5.2: Molecular Models for Potatoes Growing: Biosynthesis (40 min)

Overview and Preparation

Target Student Performance

Students use molecular models to explain how plants make monomers from glucose and minerals and monomers are linked into polymers during biosynthesis.

Resources You Provide

- scissors (1 per pair of students)
- removable or re-stick tape (1 dispenser per pair of students)

Resources Provided

- 5.2 Molecular Models for Plants Growing: Biosynthesis PPT
- 5.2 Monomers for Cutting Handout (1 copy for every four students)

Recurring Resources

- Molecular Models 11 x 17 Placemat (1 per pair of students)
- Forms of Energy Cards (1 per pair of students)
- Digestion and Biosynthesis of Carbohydrates 11 x 17 Poster (1 per class)
- Digestion and Biosynthesis of Fat 11 x 17 Poster (1 per class)
- Digestion and Biosynthesis of Protein 11 x 17 Poster (1 per class)

Setup

Prepare one Molecular Models 11 x 17 Placemat, one pair of scissors, one set of Forms of Energy Cards, and one dispenser of removable tape dispenser for each pair of students. Print one copy of 5.2 Monomers for Cutting Handout for every four students. Cut each handout in half so you can give each pair one of set of monomers (e.g., 4 amino acids, 3 glucoses, 1 glycerol and 3 fatty acids). Prepare a computer and a projector to display the PPT. Print and hang the Digestion and Biosynthesis 11 x 17 Posters.

Directions

1. Have students start to think about how plants grow.

Tell students that in today's activity we will use molecular modeling to think about how plants grow through biosynthesis.

- Open 5.2 Molecular Models for Plants Growing: Biosynthesis PPT.

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

Show slide 2 of the 5.2 Molecular Models for Plants Growing: Biosynthesis PPT.

3. Discuss the process at different scales for biosynthesis.

Display slide 3 in the PPT.

- Revisit the driving questions first seen in Activity 5.1. Tell students that today's activity is focused at the atomic-molecular scale.

4. Have student think about what happens to the glucose plants make during photosynthesis.

Display slide 4 of the PPT.

- Remind students that plants use glucose in two ways for growth and energy. They have already learned how plants use food for energy. In this activity they will model the chemical processes involved in growth, biosynthesis.

5. Tell students that glucose is used with soil minerals to make other small organic molecules (or monomers).

Use slide 5 to explain how plants use the monomer they make in photosynthesis (glucose) to make all the other monomers they use to build polymers.

- Point out that ammonia is also needed to supply the nitrogen atoms to make amino acids. Note: while we use nitrogen as a mineral example, plants use many other minerals in biosynthesis (e.g., Sulfur in some amino acids, Magnesium in chlorophyll).
- Note: This step was not introduced in the tracing in Activity 5.1.

6. Explain that after monomers are made, they are combined into polymers.

Use slide 6 to explain how plants use small organic molecules (monomers) to make large organic molecules (polymers). This is how cells can grow bigger and divide.

- Explain than large organic molecules are called polymers and small organic molecules are called monomers. It may help students to remember these words by explaining the meaning of the words' prefixes (poly means many and mono means one).

7. Review the "rules" of molecular bonding in digestion.

Use slide 7 to remind students how atoms bond to make molecules.

- Oxygen atoms bond to carbon or hydrogen (not other oxygen atoms) whenever possible. This will help students decide which monomer will bond to an –OH and which will bond to an –H.
- Nitrogen forms three bonds.
- Point out that digestion will not make or break "high energy" C-C or C-H bonds. Students can use this information to determine where to attach the –H vs. –OH in the activity.

8. Remind students what is in plants.

Show slide 8 to remind students of the information they learned from plant (leaves and seeds) nutritional labels: leaves are made primarily of carbohydrate (11g) and protein (2g), and seeds are made primarily of fat (50g), carbohydrate (22g), and protein (24g). This means that the cells in a plant are going to make fat, protein, and carbohydrate (starch) molecules so the cells can grow bigger and divide.

- Tell students that they will use the placemat and molecules to model the process of biosynthesis, which is what happens when plants build polymers from monomers
- Point out that when they are modeling, they should remember that during biosynthesis, no "high energy" C-C or C-H bonds will be made or broken. The chemical energy is conserved!
- Refer to the Digestion and Biosynthesis 11 x 17 Posters in your classroom to help students visualize the biosynthesis of monomers to polymers.

9. Have students set up their reactants and model biosynthesis.

Have students cut up their monomers so each piece of paper only has one monomer molecule. Have students place a "chemical energy card" on the reactants side of their placemat, along with their amino acids, fatty acids, glycerol, and glucose molecules.

- Coach students to simulate the actual process of dehydration synthesis by making a water molecule *each time* they tape two monomers together. This helps show that each time a bond is broken a chemical reaction takes place and new bonds form.
    - **Carbohydrate**: Show slide 9. Have students cut off an –H and –OH of each monomer, then tape together three glucose monomers to form one starch polymer and two water molecules. Then, watch the animation on slides 10-11.
    - **Protein**: Show slide 12. Have students cut off an –H and –OH of each monomer, tape together four amino acid monomers to form one protein polymer and three water molecules. Then, watch the animation on slides 13-14.
    - **Fat**: Show slide 15. Have students cut off an –H and –OH of each monomer, tape together one glycerol and three fatty acid monomers to form one fat polymer and three water molecules. Then, watch the animation on slides 16-17.
- Have students move the new molecules with the energy card to the products side of their placemat. Ask students what is happening to energy during biosynthesis. Listen to see if they notice that chemical potential energy is conserved through the chemical change.

Assessment

- Matter tracing: note if students are able to recognize that the same atoms that were in the reactants are also in the products.
- Energy tracing: note the ways that students explain how chemical energy is conserved through both digestion and biosynthesis.

Tips

- This activity may not be appropriate for middle school students due to its emphasis on molecular details of biosynthesis.
- Laminate the Molecular Models 11 x 17 Placemats. These will be used multiple times in each unit.
- During the molecular modeling activity and animation, focus on how matter and energy are conserved through the chemical change. This is the main goal of the activity!
- If students have already completed the modeling of biosynthesis activity from the *Animals* or *Decomposers* Unit, you may want to skip those portions of the activity.

Differentiation & Extending the Learning

Differentiation

- Strategic grouping with strong speakers
- Remind students of the terms Large Organic Molecules and Small Organic Molecules with examples used in past units.

Modifications

Activity 5.3: Explaining How Potato Plants Grow: Biosynthesis (40 min)

Overview and Preparation

Target Student Performance

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

Note: This lesson should be taught, regardless of if you taught only Activity 5.1 or both Activities 5.1 and 5.2. However, the language you use and the responses you should expect from your students will be different. Students who did 5.2, molecular modeling, should use the terms "polymers" and "monomers" in their explanations of digestion and biosynthesis, including the names of specific polymers (e.g., proteins, fats and carbohydrates) and monomers (e.g., amino acids, fatty acids, glycerol). Students who only did 5.1 should use the terms "large organic molecules" and "small organic molecules" rather than polymers and monomers and use the names of specific large organic molecules (e.g., proteins, fats and carbohydrates) only. Throughout the PPT, you will find both sets of vocabulary.

Resources You Provide

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

Resources Provided

- 5.3 Explaining How Plants Grow: Biosynthesis PPT
- 5.3 Explanations Tool for Potato Biosynthesis (1 per student)
- 5.3 Grading the Explanations Tools for Potato Biosynthesis
- 5.3 How do Plants Use Food to Grow? Reading (1 per student)

Recurring Resources

- (Optional) Big Idea Probe: Houseplant for a Busy Family (1 per student)
- (Optional) Assessing the Big Idea Probe: Houseplant for a Busy Family (1 per student)
- Plants Matter Tracing Tool (1 per student)
- Assessing the Plants Matter Tracing Tool
- Learning Tracking Tool for Plants (1 per student)
- Assessing the Learning Tracking Tool for Plants
- Example Plant Explanations Handout (1 per student or per group)
- Three Questions 11 x 17 Poster (1 per class)
- Three Questions Handout (1 per student)
- Digestion and Biosynthesis of Carbohydrates 11 x 17 Poster (1 per class)
- Digestion and Biosynthesis of Fat 11 x 17 Poster (1 per class)
- Digestion and Biosynthesis of Protein 11 x 17 Poster (1 per class)
- (Optional) Metabolic Pathways Poster (http://www.sigmaaldrich.com/content/dam/sigma-aldrich/docs/Sigma/General_Information/metabolic_pathways_poster.pdf)
- Questions, Connections, Questions Student Reading Strategy

Setup

Print one copy of the 5.3 Explanations Tool for Potato Biosynthesis for each student. If you are using it, print one copy of the Big Idea Probe: Houseplant for a Busy Family for each student. Prepare a computer and a projector to display the PPT. Print and hang the Digestion and

Biosynthesis 11 x 17 Posters. 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 5.3 Explaining How Plants Grow: Biosynthesis PPT.

2. Remind students of their unanswered questions.

Using slide 3 of the PPT have students revisit their arguments and unanswered questions from the Plant Investigation by looking at 3.5 Evidence-Based Arguments Tool for Plants.

- Remind students that after explaining cellular respiration and photosynthesis in Activities 4.2 and 4.4 there were still unanswered questions about how plants grow.
- In today's lesson, students will use what they learned in Activities 5.1 (and 5.2) to explain how plants get glucose to their cells and how plants use glucose for growth.

3. Have students review the process of biosynthesis.

Use slides 4-5 of the 5.3 Explaining How Plants Grow: Biosynthesis PPT to guide students through a review of biosynthesis.

- Ask students for their ideas about what they remember from the previous activity.

4. Have students complete their Explanations Process Tool for Biosynthesis.

Show slide 6 of the PPT. Give each student one copy of 5.3 Explanations Tool for Potato Biosynthesis.

- Tell students that in this part of the unit, they will combine everything they learned about how plants use food to grow into an explanation.
- Remind them to consider both their evidence from the investigation as well as what they learned in the molecular modeling (or tracing) 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 7 of the 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 or handout to make sure they are following the "rules."

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

Use slides 8-9 in the PPT to have the students discuss what is happening to matter during biosynthesis and to have them check their answers to the Matter Movement Question on their 5.3 Explanations Tool for Potato Biosynthesis.

15. Show students slide 8-9 to have them think about where atoms are moving from and moving to during biosynthesis.

- Display slides 10-12 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 biosynthesis answers the Matter Change Question.

Show slide 13 to begin discussing the Matter Change Question.

- Display slides 14-15 to have students compare their answers to the Matter Change Question on the 5.3 Explanations Tool for Potato Biosynthesis 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.
- Refer to the Digestion and Biosynthesis 11 x 17 Posters in your classroom to help students visualize the biosynthesis of monomers to polymers.
  - Note: If you taught only 5.1, you can use the posters to help students visualize the process, but do not need to focus on the names of the small organic molecules.
  - (Optional): You can also show students the Metabolic Pathways Poster to give them an impression of how complicated actual biochemical processes are inside cells.

8. Discuss how biosynthesis helps answer the Energy Change questions.

Display slide 16 to have students compare their answers to the Energy Change Question on the 5.3 Explanations Tool for Potato Biosynthesis 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. Using the Plants Matter Tracing Tool, have students answer the question: How does biosynthesis fit into the story of how plants grow?

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.

10. (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 biosynthesis 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.

11. Have students read about biosynthesis and complete part of the matter tracing tool.

Pass out 5.3 How do Plants Use Food to Grow? Reading. The reading provides a summary explanation of biosynthesis and additional information about other metabolic pathways. Students can complete the reading using the Questions, Connections, Questions Student Reading Strategy. See 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.

12. 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.

13. (Optional) Have students complete the Big Idea Probe: Houseplant for a Busy Family for the second time.

If you decided to use the Big Idea Probe: Houseplant for a Busy Family, have students complete it and share their ideas for a second time. See Assessing the Big Idea Probe: Houseplant for a Busy Family and Using Big Idea Probes for suggestions about how to use the Big Idea Probe.

14. Have students complete an exit ticket.

Show slide 20 of the 5.3 Explaining How Plants Grow: Biosynthesis PPT.

- Conclusions: What do plants use soil minerals for?
- Predictions: How do you think what we have learned about potatoes applies to other types of plants?
- 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.

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

Show slide 21 of the 5.3 Explaining How Plants Grow: Biosynthesis PPT.

- Pass out a Learning Tracking Tool for Plants to each student.
- Have students write the activity chunk name, "Explaining How Plants Grow" 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

15.

Activity Chunk	What Did We Do?	What Did We Figure Out?	What Are We Asking Now?
Explaining How Plants Grow Explainer	Trace the process involved in a potato growing on a poster of a potato, construct a model of the building of molecules through biosynthesis, and use the Explanations Tool to explain biosynthesis.	Some glucose that plants make is combined with soil minerals to make large organic molecules for growth (biosynthesis).	How do other plants grow, move, and function?

Assessment

Use 5.3 Grading the Explanations Tools for Potato Biosynthesis 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

- You may want students to first complete the front side of the Explanations Tool with the Plants Matter Tracing Tool and check it together as a class to confirm that the arrows and responses to the prompts are correct. Then, students can use the corrected matter tracing tool as a tool to construct their written explanation.
- Encourage students to explain verbally as well as writing on the Plants Matter Tracing Tool

- As the Plants Matter Tracing Tool is completed, post in the classroom so students can refer to it.
- Have students highlight challenging vocabulary in the 5.3 How do Plants Use Food to Grow? Reading to support the word wall
- Refer to the word wall for questions on biosynthesis related vocabulary.

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.