Plants Unit Front Matter

Unit Home

Download PDF of Unit Front Matter

Plants is one of the six *Carbon TIME* units. If you are new to teaching *Carbon TIME*, read the *Carbon TIME* FAQ: Which Units Should I Teach.

The *Plants Unit* supports students in using core disciplinary ideas, science practices, and cross-cutting concepts to develop scientific explanations of how different plants *transform matter and energy* as they grow, move, and function.

Follow these steps to get ready to teach the *Plants Unit.*

Step 1	Step 2	Step 3	Step 4	Step 5
Read The Unit Overview	Choose Your Unit Sequence	Learn About The Instructional Model & Storyline	Prepare Unit Materials	Dig Into The Lessons

Lead Editor for 2019 Version

Kirsten D. Edwards, Department of Teacher Education, Michigan State University

Principal Authors

Kirsten D. Edwards, Department of Teacher Education, Michigan State University
Christie Morrison Thomas, Department of Teacher Education, Michigan State University
Elizabeth Tompkins, Michigan State University
Hannah K. Miller, Northern Vermont University
Christa Haverly, Department of Teacher Education, Michigan State University
Charles W. “Andy” Anderson, Department of Teacher Education, Michigan State University

Contributing Authors

Beth Covitt, Jenny Dauer, Jennifer H. Doherty, Allison Freed, Wendy Johnson, Deborah Jordan, Craig Kohn, Lindsey Mohan, Joyce Parker, Emily Scott, Carly Seeterlin, Alex Walus, Nicholas Verbanic, Pingping Zhao

Illustrations

Craig Douglas, Kendra Mojica

This research is supported in part by grants from the National Science Foundation: A Learning Progression-based System for Promoting Understanding of Carbon-transforming Processes (DRL 1020187) and Sustaining Responsive and Rigorous Teaching Based on *Carbon TIME* (NSF 1440988). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation or the United States Department of Energy.

This unit is also available online at http://carbontime.bscs.org/. Contact the MSU Environmental Literacy Program for more information: EnvLit@msu.edu.

Overview

The Driving Question and Research Base

Download PDF of Unit Overview

The *Plants Unit* starts by asking students to express their ideas about the driving question about an anchoring phenomenon: *How does a radish plant grow, move, and function?*

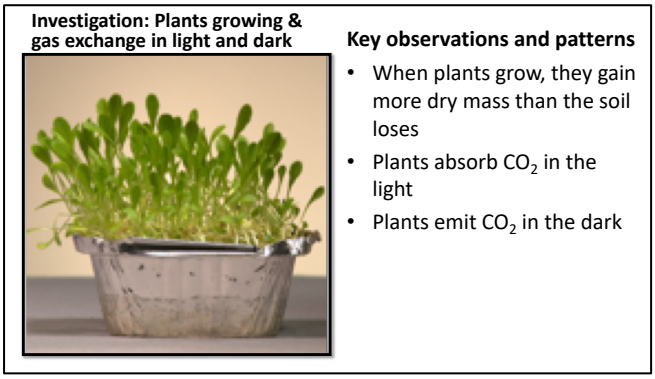
Carbon is the key! In the unit, students learn to tell the story of how matter and energy are transformed as they move through plant systems. A particularly powerful strategy for explaining how plant systems transform matter and energy involves *tracing carbon atoms*. For more information about the *Next Generation Science Standards* **disciplinary core ideas** included in this unit see the sections on the Matter Movement, Matter Change, and Energy Change Questions below and the Unit Goals.

Research base. This unit is based on learning progression research that describes the resources that students bring to learning about plants and the barriers to understanding that they must overcome. It is organized around an instructional model that engages students in three-dimensional practices.

Students' Roles and Science Practices

As students learn to answer the driving question by explaining how animal systems transform matter and energy, they play three different roles that encompass all of the *Next Generation Science Standards* **science and engineering practices**. (For more details on science and engineering practices, see the Unit Goals.)

- Questioners: Students explore the driving question, clarify, and generate more detailed questions
- Investigators: Students conduct matter-tracing investigations of radish plants growing; and develop evidence-based arguments about key observations and patterns
- Explainers: Students construct model-based explanations of how a potato plant grows and functions.



The roles that students play are embedded in the *Carbon TIME* Instructional Model and Discourse Routine. The Discourse Routine guides how classroom discourse aimed first at divergent thinking and then at convergent thinking should be sequenced through the unit.

Good Explanations Answer the Three Questions

Students figure out how to answer the driving question by tracing carbon-containing molecules through a series of movements and chemical changes inside plants. At each stage in these processes they answer Three Questions about what is happening: the *Matter Movement Question, the Matter Change Question,* and the *Energy Change Question.* Below, we use the anchoring phenomenon of plant growth as an example of how students learn to answer the Three Questions for different plants

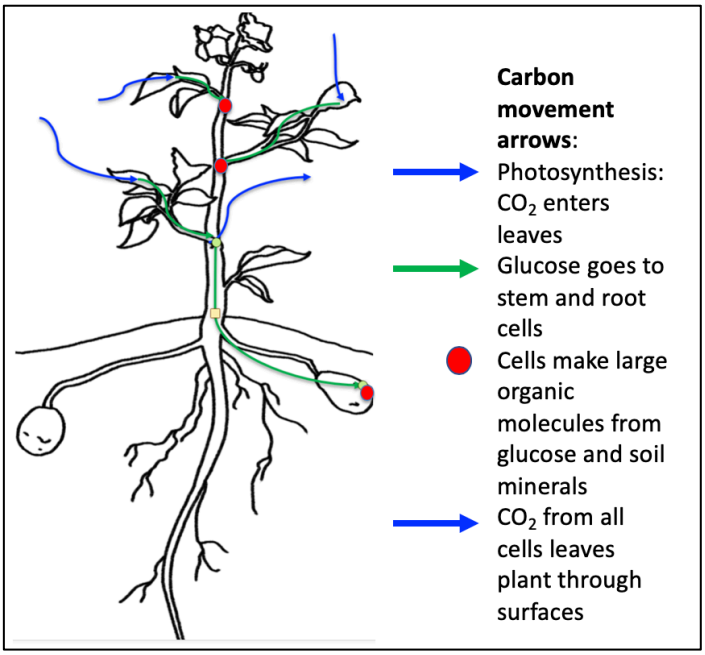
Note that, in *Carbon TIME*, *NGSS* **crosscutting concepts** serve as the "rules of grammar" for producing a scientific performance. With respect to plants growing, high quality explanations should attend to the following rules that are implied by crosscutting concepts. Explanations should attend to…

- *Scale* by explaining events and phenomena at the appropriate scale (see more in the structure and function bullets below).
- *Systems and system models and energy and matter* by following rules for tracing matter and energy through systems and system models. For example, neither energy nor matter should be created or destroyed as it moves into, through, or out of a system.
- *Structure and function* by linking structures and functions in explanations at each scale.
    - Macroscopic scale (tracing matter and energy through processes occurring in plants and plants systems)
    - Cellular scale (tracing matter and energy into and out of cells as cellular functions are carried out)
    - Atomic-molecular scale (tracing matter and energy through chemical processes—cellular respiration and biosynthesis—involving molecules with different structures and properties)

The Matter Movement Question: Tracing Molecules Through Plants

Students learn to tell the following story of how carbon-containing molecules move through plants.

- Carbon atoms enter plants in CO_2 molecules that are absorbed through the leaves, where they become part of glucose (sugar) molecules.
- The sugar molecules travel through the stems and roots to all of the plant's cells.[1]
- Some of the carbon atoms stay in the cells, as they are



[1] Sugar molecules travel through the phloem as the disaccharide sucrose ($C_{12}H_{22}O_{11}$) rather than the monosaccharide glucose ($C_6H_{12}O_6$). We do not feel that this distinction is important for basic life science courses.

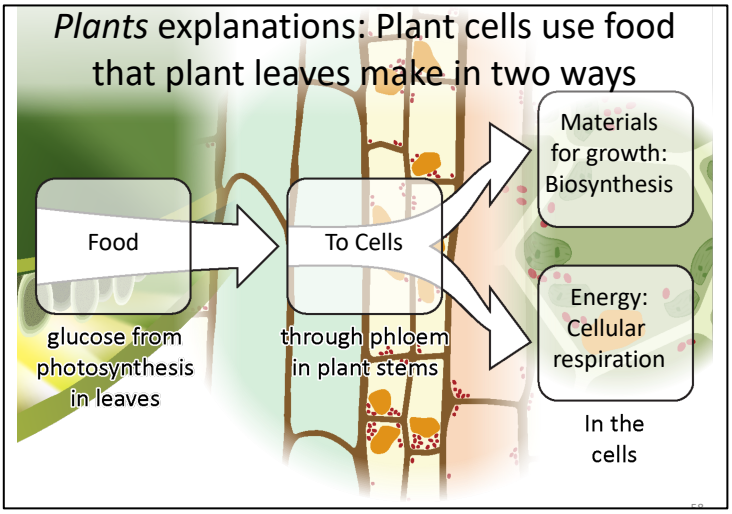
incorporated into the large organic molecules that make up cell structures through biosynthesis.

- Some of the sugar molecules are oxidized in the process of cellular respiration. They leave the plant in CO_2 that diffuses through plant surfaces.

The Matter Change and Energy Change Questions: Explaining How Plants Use Organic Molecules to Grow, Move, and Function

Matter movement is an essential part of the story, but not the whole story. To answer the driving question, students learn to explain chemical changes that occur inside plants:

- *Photosynthesis.* Plants' leaf cells absorb CO_2 and water. They use energy from sunlight to rearrange the atoms into new molecules: glucose and oxygen. Glucose has chemical energy stored in their C-C and C-H bonds.
- *Biosynthesis and growth.* Plants grow when their cells grow and divide through the process of biosynthesis. Plant cells combine glucose with soil minerals to make other small organic molecules. Then they combine small organic molecules to make the large organic molecules needed for cells' structure and function.
- *Cellular respiration—energy to move and function.* Plant cells get the energy they need to move and function by combining sugars and other small organic molecules with oxygen, releasing energy when high-energy C-C and C-H bonds are replaced by lower-energy bonds in carbon dioxide and water.



How Much Detail?

There are more complicated and more scientifically accurate ways of talking about chemical bonds and about changes in energy; we discuss some of those in detail in our educator resource: *Carbon TIME* Content Simplifications. But our learning progression research has shown that there is an important tradeoff here—many students get lost in the details and never learn a basic coherent story that answers the driving question. The *Next Generation Science Standards* take a clear position on this tradeoff; a coherent story based on principles such as matter and energy conservation is more important than the details. Consult the Unit Sequence tab and the sections on Extending the Learning at the end of each Activity page to decide how much detail is appropriate for your students.

Unit Sequence

Before beginning the *Plants Unit*, you need to decide what to teach and importantly, what not to teach! Use this page to choose the unit sequence that's most appropriate for your students. Also see Student Challenges and Teacher Choices in the Plants Unit for additional information to support your planning for the Plants Unit.

- Some activities are REPEATING ACTIVITIES ( ). Omit these activities if students have already completed them in another unit (unless you'd like students to repeat them as review).

- Other activities are TWO-TURTLE ACTIVITIES (), which place a higher demand on students. Decide whether the higher demand required by these activities will be useful or distracting for y*our students*. The *Carbon TIME* Turtle Trails document provides further info about choices for making units more or less demanding, depending on your students' needs.

Unless otherwise noted in the table below, all activities in the unit should be taught.

Plants Unit Sequence and Decisions Table

Lesson	Activity Sequence	Feature	Make a Decision
Pre-Lesson (1-2 hr)	**Gel Protocol** 0.1GL: Keeping Track of Water in Solids and Liquids (60 min + overnight or several days) **AND** 0.2GL: Plant Growth Investigation Setup (45-60 min over one or two days) **OR** **Paper Towel Protocol** 0.2PT: Plant Growth Investigation Setup	 	*When to plant radish seeds:* Students should plant their radish seeds before beginning the *Plants* Unit so that plants will grow big enough for the Lesson 3 investigations. Allow at least 2-4 weeks from the Pre-Lesson to Lesson 3, depending on which Turtle Trail you choose. *How to plant radish seeds:* Decide whether to follow a paper towel (PT or 1-Turtle Trail) a plant-growing gel protocol (GL or 2-Turtle Trail). Both versions give students the invaluable experience of watching plants grow, then analyzing plant gas exchange and mass change data. The Gel Protocol is more complex and rigorous, and there are more things that can go wrong. Two other differences include **growing materials** (paper towel vs. gel) and **time** (the gel protocol has two additional activities; some 2-Turtle activities may take longer, and the plants will need longer to grow).
1 (50 min)	1.1: Plants Unit Pretest (20 min) 1.2: Expressing Ideas and Questions About How Plants Grow (30 min)		For the 1-Turtle Trail, wait at least one week after planting radishes before beginning Lesson 1. For the 2-Turtle Trail, wait at least three weeks after planting radishes before beginning Lesson 1.
2 (2 hr 5 min)	2.1: Zooming Into Plants, Animals, And Decomposers (40 min) 2.2: Molecules Cells Are Made Of (45 min) 2.3: Molecules In Cells Quiz (20 min)		These activities are exactly the same as the equivalent activities in *Animals* and *Decomposers Units*. **Do not repeat these activities in multiple units unless students need a review.** Also, in Activity 2.1, the "Cells: The Building Blocks" reading is optional.
	2.4: Questions About Plants (20 min)		Activity 2.4 is plant-specific, so we recommend teaching it.
3 (2 hr 40 min)	3.1 Predictions and Planning about Radish Plants Growing (50 min)		To be ready, your plants should have at least two sets of leaves open and well developed (two cotyledons and two true leaves). • If plants are ready, you can begin with the Mass Change investigation. While plants are drying, use extra radish plants (or another leafy plant such as a houseplant) for the light and dark investigation. • If plants are not ready, we recommend using another leafy plant such as a houseplant for the Light/Dark investigation, giving your plants a little more time to grow. This will mean teaching the two Mass Change Activities (3.2 & 3.4) consecutively, but you will need **time** in between them for plants to dry! In this case, we
	Gel Protocol 3.2GL: Observing Plants' Mass Changes, Part 1 (30 min) **OR** **Paper Towel Protocol** 3.2PT: Observing Plants' Mass Changes, Part 1 (30 min)	 	
	3.3: Observing Plants in the Light and Dark (60 min)		
	Gel Protocol 3.4GL: Observing Plants' Mass Changes, Part 2 (45 min) **OR**		

	Paper Towel Protocol 3.4PT: Observing Plants' Mass Changes, Part 2 (45 min)		recommend that you (a) partially complete the Evidence-Based Arguments tool after the Light/Dark investigation in Activity 3.3, (b) harvest the radish plants in Activity 3.2, (c) move on to Lesson 4 to teach Cellular Respiration and Photosynthesis, and (d) return to complete Activities 3.4 and 3.5 after plants have dried.
	3.5: Evidence-Based Arguments about How Plants Grow (50 min)		
Consider your students' questions on the EBA Tool: *What are they wondering?* Use their unanswered questions to guide instructional sequencing of the three carbon-transforming processes. You and your students can choose whether to start with cellular respiration (Activities 4.1 and 4.2) or photosynthesis (Activities 4.3 and 4.4). You may choose the order presented in the curriculum, an order more familiar to you, or according to the types of questions students are asking. • If your students are asking *"Why do plants give off CO_2 in the dark?"* or *"How do plants move and function?"* then teach cellular respiration (Activities 4.1 and 4.2) first. • If your students are asking *"Why do plants absorb CO_2 in the light?"* or *"Where does the mass of the growing plants come from?"* then teach photosynthesis (Activities 4.3 and 4.4) first.			
4 (1 hr 20 min)	4.1: Molecular Models For Potatoes Moving and Functioning: Cellular Respiration (40 min)		The molecular modeling part of Activity 4.1 is the same as the molecular modeling for cellular respiration in the *Plants* and *Decomposers Units*. **Do not repeat unless for review.**
	4.2: Explaining How Plants Move and Function: Cellular Respiration (40 min)		There are multiple scaffolds you can choose from to use with Activity 4.2 including the cellular respiration PPT, the Three Questions Checklist, example explanations, and a reading. Choose options that fit for your class at this time.
	4.3: Molecular Models for Potatoes Making Food: Photosynthesis (60 min)		
	4.4: Explaining How Plants Make Food: Photosynthesis (40 min)		In Activity 4.4, you can choose from among similar scaffolding tools as those listed for Activity 4.2
5 (2 hr)	5.1: Tracing the Process of Plants Growing: Biosynthesis (40 min)		
	5.2: Molecular Models For Plants Growing: Biosynthesis (40 min)		Activity 5.2 is exactly the same as molecular modeling for biosynthesis in the *Plants* and *Decomposers Units*. It's also a 2-turtle activity. **Consider skipping 5.2 if you've already taught it in another unit or if it's too advanced for your class.**
	5.3: Explaining How Plants Grow: Biosynthesis (40 min)		In Activity 5.3, you can choose from among similar scaffolding tools as those listed for Activity 4.2
6 (2 hr 50 min)	6.1: Explaining Other Examples of Plants Growing, Moving, and Functioning (50 min)		Activity 6.1 has explanations about 3 different plants. **Consider a jigsaw format with different students becoming experts on different plants and then sharing/comparing.**
	6.2: Function of All Plants (50 min)		
	6.3: Comparing Plants and Animals (50 min)		
	6.4: Plants Unit Posttest (40 min)		

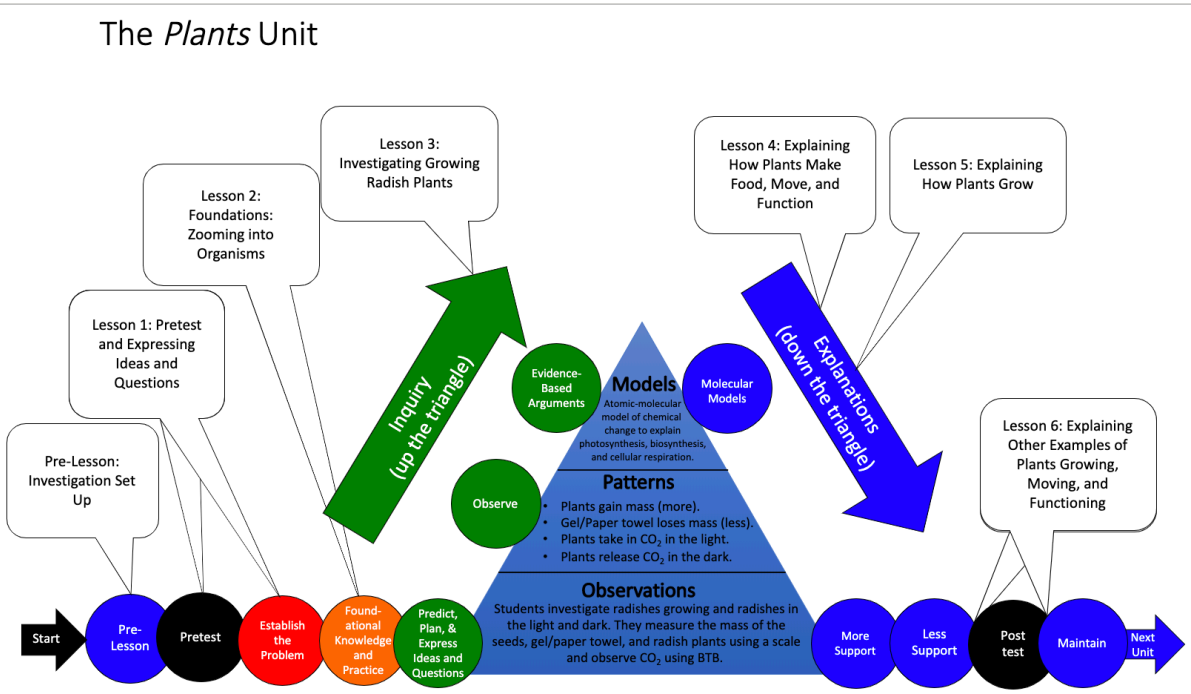
IM & Storyline

Here, we present two ways to think about how lessons are sequenced in the *Plants Unit*. The Instructional Model, immediately below, emphasizes how students take on roles of questioner, investigator, and explainer to learn and apply scientific models they can use to

answer the driving question. Further below, the Unit Storyline Chart highlights the central question, activity, and answer that students engage with in each lesson of the *Plants Unit*.

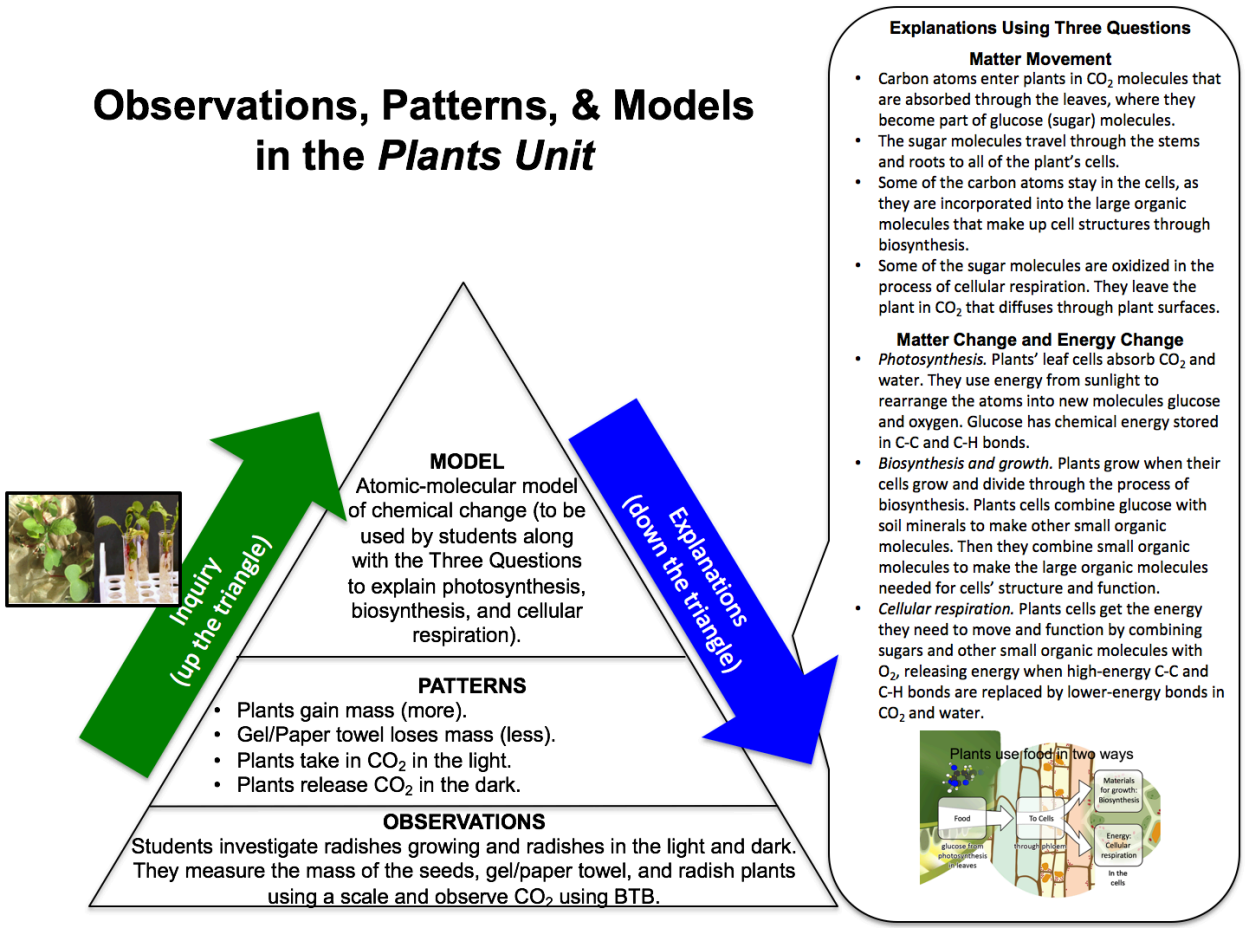
Instructional Model

Like all *Carbon TIME* units, this unit follows an instructional model (IM) designed to support teaching that helps students achieve mastery at answering the driving question through use of disciplinary content, science practices, and crosscutting concepts. To learn more about this design, see the *Carbon TIME* Instructional Model.



The core of the *Carbon TIME* IM is the Observation, Patterns, Models (OPM) triangle, which summarizes key aspects to be attended to as the class engages in unit inquiry and explanation. The OPM triangle for the *Plants Unit*, shown below, articulates the key observations students make during the unit investigation, the key patterns they identify through analyzing their investigation data, and the central scientific model that can be used to answer the unit's driving question. During the inquiry portion of the unit (Lesson 3), the class moves from making observations to identifying patterns, eventually using these patterns to make evidence-based arguments. During the explanation portion of the unit (Lessons 4, 5, and 6), the class learns the atomic-molecular model, makes connections across scales, and uses the atomic-molecular model to explain how animals grow, move, and function. Across the unit, classroom discourse is a necessary part of 3-dimensional *Carbon TIME* learning. The Carbon TIME Discourse Routine document provides guidance for scaffolding this discourse in lessons.

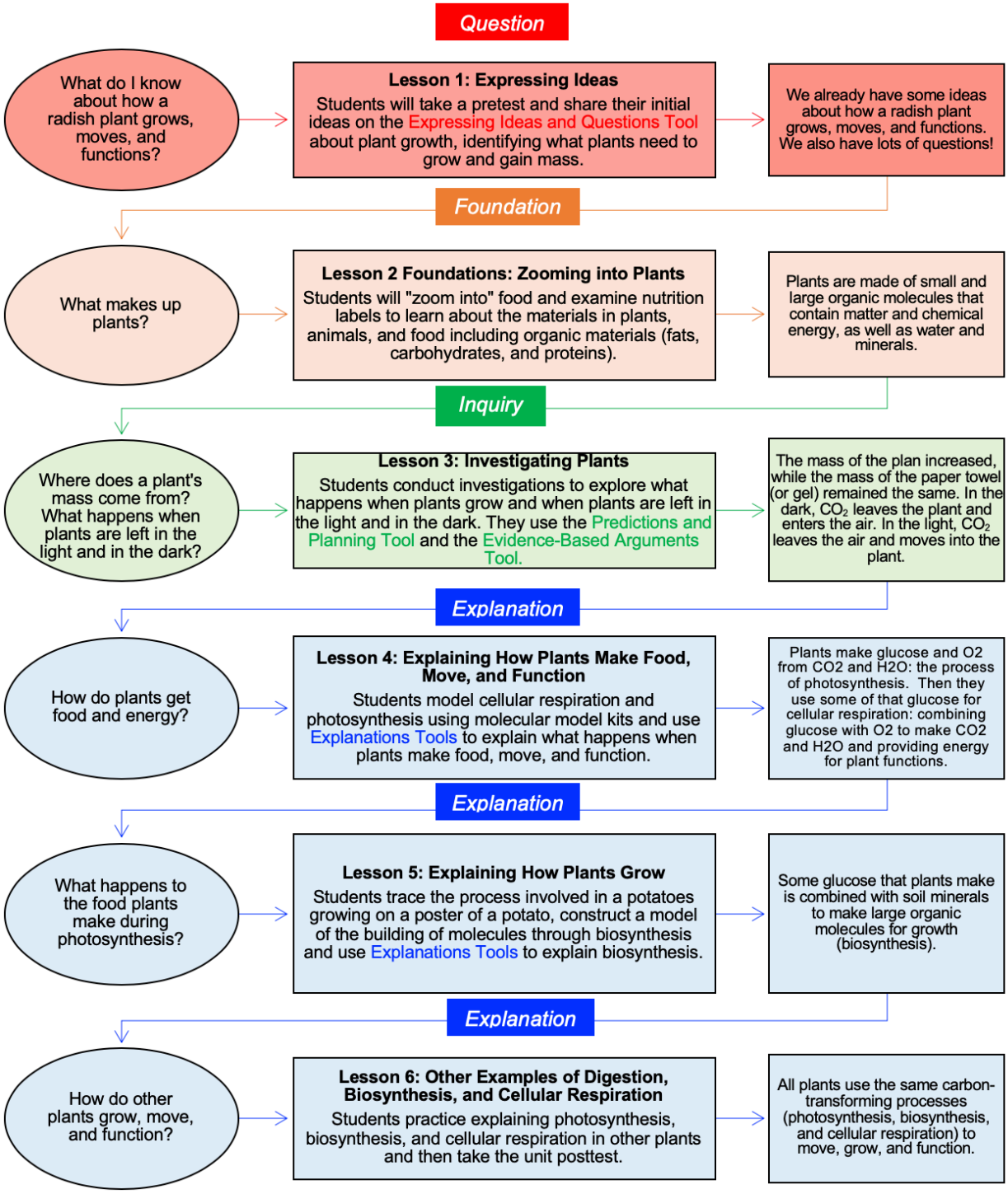
Observations, Patterns, Models, and Explanations in the Plants Unit



Unit Storyline Chart

Another way to familiarize yourself with the sequence of lessons in the *Plants Unit* is with the Unit Storyline Chart depicted below. The Unit Storyline Chart summarizes a unit phenomenon-based driving question associated with each lesson, what classes will do in each lesson to address the question, what conclusions they will come to, and how they will transition to a subsequent lesson.

Download PDF of Unit IM and Storyline Chart



Unit Goals

The tables below show goals for this unit in two forms. A table showing specific target performances for each activity is followed by a list of the *Next Generation Science Standards (NGSS)* addressed by this unit.

Target Performances for Each Activity

Download PDF of Unit Target Performances

All *Carbon TIME units* are organized around a common purpose: *assessing and scaffolding students' three-dimensional engagement with phenomena.* Every *Carbon TIME* activity has its specific expectation for students' three-dimensional engagement with phenomena, what we call its **target performance**. Each activity also includes tools and strategies that teachers can use to asses and scaffold the target performance in rigorous and responsive ways.

The target performances for each activity in the *Plants* unit are listed in the table below.

Activity	***Target Performance***
Pre-Lesson 1: Investigation Setup	
Pre-Activity 0.2GL: Keeping Track of Solids in Mixtures	Students will distinguish between solid mass (or dry mass) and total mass of materials consisting of water mixed with solid materials and use measurement techniques to determine the mass of solids in the mixtures.
Pre-Activity 0.2GL: Plant Growth Investigation Setup	Students will make initial measurements of the dry mass of radish seeds and growth media and start plants growing.
Pre-Activity 0.2PT: Plant Growth Investigation Setup	Students will make initial measurements of the dry mass of radish seeds and growth media and start plants growing.
Lesson 1 – Pretest and Expressing Ideas (students as questioners)	
Activity 1.1: *Plants* Unit Pretest	Students show their initial proficiencies for the overall unit goal: Questioning, investigating, and explaining how matter and energy move and change as plants live, move, and grow.
Activity 1.2: Expressing Ideas and Questions about How Plants Grow	Students ask and record specific questions about changes in matter and energy in response to the unit driving question: How do you think that a plant grows, moves, and functions?
Lesson 2 – Foundations: Zooming into Organisms (students developing foundational knowledge and practice)	
Activity 2.1: Zooming into Plants, Animals, and Decomposers	Students "zoom in" to animals, plants, and decomposers, describing how all of these organisms are made of cells with special structures and functions.
Activity 2.2: Molecules Cells Are Made of	Students use food labels to describe molecules in animal, plant, and decomposer cells: large organic molecules (carbohydrates, proteins, and fats), as well as water, vitamins, and minerals.

Activity	***Target Performance***
Activity 2.3: Molecules in Cells Quiz	Students complete a quiz to assess their understanding of the molecules in cells and how to identify which molecules store chemical energy.
Activity 2.4: Questions about Plants	Students observe their growing radish plants and pose questions about plants to prepare for their upcoming investigation.
Lesson 3 – Investigating Growing Radish Plants (students as investigators and questioners)	
Activity 3.1: Predictions and Planning about Radish Plants Growing	Students develop hypotheses about how matter moves and changes and how energy changes when radishes move, and grow and make predictions about how they can use their investigation tools—digital balances and BTB—to detect movements and changes in matter.
Activity 3.2 (PT or GL): Observing Plants' Mass Changes, Part 1	Students harvest their radish plants and dry down the plants and the paper towel or gel in preparation for Activity 3.4.
Activity 3.3: Observing Plants in the Light and Dark	Students observe how plants affect BTB in the light and dark, identify patterns in data, and reach consensus with other groups about their results.
Activity 3.4 (PT or GL): Observing Plants' Mass Changes, Part 2	Students measure the dry weight of harvested plants and of paper towels or gel, identify patterns in data, and reach consensus with other groups about their results.
Activity 3.5: Evidence-Based Arguments about Plants	Students (a) use data from their investigations to develop evidence-based arguments about how matter moves and changes and how energy changes when plants grow, move, and function; and (b) identify unanswered questions about matter movement and matter change that the data are insufficient to address.
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	***Target Performance***
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.
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.
Lesson 6 – Explaining Other Examples of Plants Growing, Moving, and Functioning (students as explainers)	
Activity 6.1: Explaining Other Examples of Plants Growing, Moving, and Functioning	Students develop integrated accounts of how other plants (Lodgepole pine, *Spartina* marsh grass, prickly pear cactus) grow, move and function through the processes of photosynthesis, cellular respiration, and biosynthesis.
Activity 6.2: Functions of All Plants	Students develop integrated accounts of how all plants grow, move and function through the processes of photosynthesis, cellular respiration, and biosynthesis.
Activity 6.3: Comparing Plants and Animals	Students compare how matter moves and changes and how energy changes in a growing tree vs. a growing child, connecting macroscopic observations with atomic-molecular models and using the principles of conservation of matter and energy.
Activity 6.4: Plants Unit Posttest	Students show their end-of unit proficiencies for the overall unit goal: Questioning, investigating, and explaining how plants move and change matter and energy as they live, move, and grow.

Next Generation Science Standards

The *Next Generation Science Standards* (*NGSS*) performance expectations that middle and high school students can achieve through completing the Animals Unit are listed below. To read a discussion of how the *Carbon TIME* project is designed to help students achieve the performances represented in the NGSS, please see Three-dimensional Learning in *Carbon TIME*.

High School

- 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 total bond energy.
  http://www.nextgenscience.org/hsps-cr-chemical-reactions
- Chemical Reactions. HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
  http://www.nextgenscience.org/hsps-cr-chemical-reactions
- 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.
  http://www.nextgenscience.org/hsls-sfip-structure-function-information-processing
- Matter and Energy in Organisms and Ecosystems. HS-LS1-5. Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.
  http://www.nextgenscience.org/hsls-meoe-matter-energy-organisms-ecosystems
- 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.
  http://www.nextgenscience.org/hsls-meoe-matter-energy-organisms-ecosystems
- 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.
  http://www.nextgenscience.org/hsls-meoe-matter-energy-organisms-ecosystems
- 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.
  http://www.nextgenscience.org/hsls-meoe-matter-energy-organisms-ecosystems

Middle School

- Structure and Properties of Matter. MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.
  http://www.nextgenscience.org/msps-spm-structure-properties-matter
- 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.
  http://www.nextgenscience.org/msps-cr-chemical-reactions
- 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.
  http://www.nextgenscience.org/msps-cr-chemical-reactions
- 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 into and out of organisms.

http://www.nextgenscience.org/msls-meoe-matter-energy-organisms-ecosystems

- 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.
  http://www.nextgenscience.org/msls-sfip-structure-function-information-processing
- Matter and Energy in Organism 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.
  http://www.nextgenscience.org/msls-meoe-matter-energy-organisms-ecosystems
- Matter and Energy in Organism 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.
  http://www.nextgenscience.org/msls-meoe-matter-energy-organisms-ecosystems

Materials

Recurring Resources

- Three Questions 11 x 17 Poster (1 per class)
- Three Questions Handout (1 per student)
- BTB Color Handout (1 per group)
- Forms of Energy Cards
- (Optional for more demanding classes) Posters about large organic molecules:
  - 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)
- Molecule 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)
- Molecular Models 11 x 17 Placemat (1 per pair of students)
- Potato 11 x 17 Poster (1 per pair of students)
- Three Ways to Represent Glucose 11 x 17 Poster (1 per class)
- Forms of Energy Cards (1 set per pair of students)
- Investigation Planning Tool
- Questions, Connections, Questions Student Reading Strategy
- Learning Tracking Tool for Plants
- Assessing the Learning Tracking Tool for Plants
- Plants Matter Tracing Tool
- Assessing the Plants Matter Tracing Tool
- Using Big Idea Probes
- Big Idea Probe: Houseplant for a Busy Family
- Assessing the Big Idea Probe: Houseplant for a Busy Family
- Example Plants Explanations Handout (1 per student or per group)

Materials You Provide:

Pre-Lesson Activity 0.1: Keeping Track of Solids in Mixtures (60 min + overnight or several days)

For whole-class demonstrations:

- Calculators (1 per pair of students)

- Dry sponge
- Salt (about 100 g)
- Dry plant gel crystals (1 packet per class)
- Baby carrot
- Salt water mixture (about 10 g of salt in 50 ml of water)
- Ionic Grow (4 teaspoons, about 17 g; plus, an additional 4 teaspoons to make a mixture, see Setup below)
- Distilled Water (1 gallon per class)
- Glass Petri dishes (3)
- Digital Scale
- Scissors or knife
- Strainer/colander large enough for hydrated gel (1 per class)
- Bucket or bowl (>1 gallon) to hydrate gel overnight (1 per class)

For students working in pairs:

- Dry sponge (1 per pair of students)
- Salt (1t per pair of students)
- Dry plant gel crystals (1 packet per class)
- Baby carrot (1 per pair of students)
- Saltwater mixture (about 1 cup of salt in 4 cups of water)
- Ionic Grow (1t per pair of students; plus an additional 4 teaspoons to make a mixture, see Setup below)
- Distilled Water (1 gallon per class)
- Small bowls, preferably transparent (3 per pair of students)
- Petri dish (3 per pair of students)
- Digital Scale (1 per pair of students)
- Calculator (1 per pair of students)
- Scissors or knife (1 per pair of students)
- Tape and marking pens (enough for container labels)
- Strainer/colander large enough for hydrated gel (1 per class)
- Bucket or bowl (>1 gallon) to hydrate gel overnight (1 per class)

Pre-Activity 0.2GL: Plant Growth Investigation Setup (45 min)

- Large (37mL) test tubes or another clear receptacle (1 per student)
- Hydrated (nutrient solution) packet of gel crystals (completed in Pre-lesson 0.1) (1 per class)
- 4 teaspoons of Ionic Grow (1 per class – not necessary if completed pre 0.1)
- Gallon of distilled water (1 per class – not necessary if completed pre 0 .1)
- Bucket or bowl (>1 gallon) to hydrate gel overnight (1 per class – not necessary if completed pre 0.1)
- Strainer/colander large enough for hydrated gel (1 per class- not necessary if completed pre 0.1)
- Digital scale (to 0.1g) (1 per group)
- Grow/Fluorescent Light
- Test tube rack
- Permanent markers and labels for test tubes
- Fresh packets of radish seeds (at least one seed per student or group plus a few more)
- Squeeze bottle to water plants

Pre-Activity 0.2PT: Plant Growth Investigation Setup (45-60 min)

- Small (e.g. 7X10 cm or ramekin) aluminum container (1 per student group)
- 20 radish seeds (1 set per student group)
- 15 cm of cotton yarn (1 per student group)
- **Brown** paper towel (1 roll or 2-3 sheets each student group) Note: brown, unbleached paper towel is required
- Markers/masking tape to label containers (1 per student group)
- A balance to measure masses (1 per student group)
- Large trays with at least 5 cm sides to put the containers in and hold water.(enough for all containers per class)
- Grow lights (highly recommended)
- 1 L of water (for starting seeds)
- 4 L of water with dilute nutrients. (E.g. Ionic Grow, Miracle Grow, etc.) for use once seeds have sprouted.

Activity 1.1: Plants Unit Pretest (20 min)

- pencils (1 per student)

Activity 1.2: Expressing Ideas and Questions about How Plants Grow (30 min)

- Sticky notes (1 per student)
- Time-lapse video of plants growing, such as http://www.youtube.com/watch?v=d26AhcKeEbE

Activity 2.3: Molecules in Cells Quiz (20 min)

- pencils (1 per student)

Activity 2.4: Questions about Plants (20 min)

- (From previous lesson) 1.2 Expressing Ideas and Questions for Plants Growing

Activity 3.1: Predictions and Planning about Radish Plants Growing (50 min)

- (From previous lesson) Pre-Lesson 0.2 Plant Growth Investigation Worksheet
- (From previous lesson) 1.2 Expressing Ideas and Questions Tool for Plants Growing
- Time lapse video of plants growing (http://www.youtube.com/watch?v=d26AhcKeEbE)

Activity 3.2GL: Observing Plants' Mass Changes, Part 1 (30 min)

- Tubes of radish plants from the Pre-Lesson (1 per student)
- Digital scale (1 per group)
- Small containers to collect gel from individual tubes to mass.
- Small paper bags or envelopes for drying plants (1 per plant)
- Sunny windowsill or drying oven (domestic ovens work at low settings)
- Markers to label plants by student or group (1 per group)

Activity 3.2PT: Observing Plants' Mass Changes, Part 1 (30 min)

- Containers of radish plants from the Pre-Lesson (1 per group)
- Digital scale (1 per group)
- Small paper bags or envelopes for drying plants (1 per container)
- Sunny windowsill or drying oven (domestic ovens work at low settings)
- Markers to label plants by student or group (1 per group)

Activity 3.3: Observing Plants in the Light and Dark (60 min over 2 days)

- Radish plants (either in tubes (GL) or containers (PT) from the Pre-Lesson. Note: 3-4 tubes or 1-2 containers will be plenty for each experiment replicate.
- Dark box, thick black trash bag, or very dark closet (1 per class)
- Fluorescent grow light or sunny windowsill (1 per class)
- Label (1 per group student group)
- Petri dish with blue BTB (1 per container/student group)
- Petri dish with yellow BTB (1 per container/student group)
- Sealable 6.8-liter (or 29 cup) container (1 per group)
- (From previous lesson) 3.1 Predictions and Planning Tool for Plants Investigations with student answers

Activity 3.4GL: Observing Plants' Mass Changes, Part 2 (45 min)

- Students' dry radish plants (1 per student)
- Digital balance (1 per group of four students)
- Empty container (for measuring the mass of dried plant and optional dried gel) (1 per group of four students)
- (From previous lesson) Pre-Lesson 0.2GL Plant Growth Investigation Setup Worksheet
- (From previous lesson) 3.1 Predictions and Planning Tool for Plant Investigations
- (From previous lesson) 3.2GL Observing Plants' Mass Changes, Part 2 Worksheet

Activity 3.4PT: Observing Plants' Mass Changes, Part 2 (45 min)

- Students' dry radish plants (1 envelope or bag per group)
- Digital balance (1 per group)
- (From previous lesson) Pre-Lesson 0.2PT Plant Growth Investigation Setup Worksheet
- (From previous lesson) 3.1 Predictions and Planning Tool for Plant Investigations
- (From previous lesson) 3.2PT Observing Plants' Mass Changes, Part 1 Worksheet

Activity 3.5: Evidence-Based Arguments about Plants (50 min)

- (From previous lesson) 3.4 Plants' Mass Changes Class Results 11 x 17 Poster
- (From previous lesson) 3.4 Observing Plants Mass Changes, Part 2 Worksheet (GL or PT)
- (From previous lesson) 3.3 Plants in the Light and Dark Class Results 11 x 17 Poster
- (From previous lesson) 3.3 Observing Plants in the Light and Dark Worksheet

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

- (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

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

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

Activity 4.3: Molecular Models for Potatoes Making Food: Photosynthesis (60 min)

- 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)

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

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

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

- 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

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

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

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

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

Activity 6.1: Explaining Other Examples of Plants Growing, Moving, and Functioning (50 min)

- (From previous activity) 3.3 Plants in the Light and Dark Class Results 11 x 17 Poster
- (From previous activity) 3.5 Evidence-Based Arguments Tool for Plants

Activity 6.2: Functions of All Plants (50 min)

- computers (1 per pair of students, for option 2 in step 2)
- blank posters (1 per pair of students or small group, for option 3 in step 2)

Activity 6.4: Plants Unit Posttest (40 min)

- pencils (1 per student)

Materials Available on the Website:

Pre-Lesson Activity 0.1GL: Keeping Track of Solids in Mixtures (60 min + overnight or several days)

- Pre-Lesson 0.1GL Measuring the Mass of Solids in Mixtures Worksheet (1 per student)
- Pre-Lesson 0.1GL Measuring the Mass of Solids in Mixtures PPT
- Pre-Lesson 0.1GL Estimating the Mass of Solids Mixed with Water Handout (1 per student)
- (Optional) Measuring Plant Growth Video (https://www.youtube.com/watch?v=hVTZMLnhrJQ)

Pre-Activity 0.2GL: Plant Growth Investigation Setup (45 min)

- Pre-Lesson 0.2GL Plant Growth Investigation Setup Worksheet (1 per student)
- Pre-Lesson 0.2GL Plant Growth Investigation Setup PPT

Pre-Activity 0.2PT: Plant Growth Investigation Setup (45-60 min)

- Pre-Lesson 0.2PT Plant Growth Investigation Setup Worksheet (1 per student)
- Pre-Lesson 0.2PT Plant Growth Investigation Setup PPT
- (Optional) Measuring Plant Growth Video (https://www.youtube.com/watch?v=hVTZMLnhrJQ)

Activity 1.1: Plants Unit Pretest (20 min)

- 1.1 Plants Unit Pretest (1 per student)
- 1.1 Assessing Plants Unit Pretest

Activity 1.2: Expressing Ideas and Questions about How Plants Grow (30 min)

- 1.2 Expressing Ideas and Questions About How Plants Grow PPT
- 1.2 Expressing Ideas and Questions Tool for Plants Growing (1 per student)
- 1.2 Assessing the Expressing Ideas and Questions Tool for Plants Growing
- 1.2 Plants Storyline Reading: Learning from the Work of Asima Chatterjee

Activity 2.1: Zooming into Plants, Animals, and Decomposers (40 min)

- 2.1 Zooming Into Plants, Animals, and Decomposers PPT
- 2.1 Comparing Plants, Animals, and Decomposers Worksheet (1 per student)
- 2.1 Assessing the Comparing Plants, Animals, and Decomposers Worksheet
- 2.1 Cells: The Building Blocks of Organisms Reading (1 per student)

Activity 2.2: Molecules Cells Are Made Of (45 min)

- 2.2 Food Labels Worksheet (1 per student)
- 2.2 Grading the Food Labels Worksheet
- 2.2 Molecules Cells Are Made of PPT
- 2.2 Reading Nutrition Labels Handout (1 per pair of students)
- 2.2 Food Label Cards (1 per pair of students)

Activity 2.3: Molecules in Cells Quiz (20 min)

- 2.3 Molecules in Cells Quiz (1 per student)
- 2.3 Grading the Molecules in Cells Quiz

Activity 2.4: Questions about Plants (20 min)

- 2.4 Questions about Plants PPT

Activity 3.1: Predictions and Planning about Radish Plants Growing (50 min)

- *Carbon TIME* Growing Plants Video (https://youtu.be/SWrdn73-jrM)
- 3.1 Predictions and Planning Tool about Radish Plants Growing PPT
- 3.1 Predictions and Planning Tool for Plant Investigations (1 per student)
- 3.1 Assessing the Predictions and Planning Tool for Plant Investigations

Activity 3.2GL: Observing Plants' Mass Changes, Part 1 (30 min)

- 3.2GL Observing Plants' Mass Changes, Part 1 Worksheet (1 per student)
- 3.2GL Grading Observing Plants' Mass Changes, Part 1 Worksheet
- 3.2GL Observing Plants' Mass Changes, Part 1 PPT

Activity 3.2PT: Observing Plants' Mass Changes, Part 1 (30 min)

- 3.2PT Observing Plants' Mass Changes, Part 1 Worksheet (1 per student)
- 3.2PT Grading Observing Plants' Mass Changes, Part 1 Worksheet
- 3.2PT Observing Plants' Mass Changes, Part 1 PPT

Activity 3.3: Observing Plants in the Light and Dark (60 min over 2 days)

- 3.3 Observing Plants in the Light and Dark Worksheet (1 per student)
- 3.3 Grading the Observing Plants in the Light and Dark Worksheet

- 3.3 Observing Plants in the Light and Dark PPT
- 3.3 Plants in the Light and Dark Class Results 11 x 17 Poster (1 per class)
- *Carbon TIME* Growing Plants Video (https://youtu.be/SWrdn73-jrM)
- (Optional) 3.5 Evidence-Based Arguments Tool for Plants

Activity 3.4GL: Observing Plants' Mass Changes, Part 2 (45 min)

- 3.4GL Observing Plants' Mass Changes, Part 2 PPT
- 3.4GL Observing Plants' Mass Changes Class Results 11 x 17 Poster (1 per class)
- 3.4GL Observing Plants' Mass Changes, Part 2 Worksheet (1 per student)
- 3.4GL Grading the Observing Plants' Mass Changes, Part 2 Worksheet
- *Carbon TIME* Growing Plants Video (https://youtu.be/SWrdn73-jrM)

Activity 3.4PT: Observing Plants' Mass Changes, Part 2 (45 min)

- 3.4PT Observing Plants' Mass Changes, Part 2 PPT
- 3.4PT Observing Plants' Mass Changes Class Results 11 x 17 Poster (1 per class)
- 3.4PT Observing Plants' Mass Changes, Part 2 Worksheet (1 per student)
- 3.4PT Grading the Observing Plants' Mass Changes, Part 2 Worksheet
- *Carbon TIME* Growing Plants Video (https://youtu.be/SWrdn73-jrM)

Activity 3.5: Evidence-Based Arguments about Plants (50 min)

- 3.5 Evidence-Based Arguments Tool for Plants (1 per student)
- 3.5 Assessing the Evidence-Based Arguments Tool for Plants
- 3.5 Evidence-Based Arguments Tool for Plants PPT
- *Carbon TIME* Growing Plants Video (https://youtu.be/SWrdn73-jrM)

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

- 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

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

- 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)

Activity 4.3: Molecular Models for Potatoes Making Food: Photosynthesis (60 min)

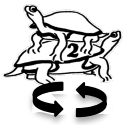
- 4.3 Molecular Models for Potato Photosynthesis PPT
- 4.3 Molecular Models for Potato Photosynthesis Worksheet (1 per student)
- 4.3 Grading Molecular Models for Potato Photosynthesis Worksheet

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

- 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)

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

- 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)



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

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

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

- 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)

Activity 6.1: Explaining Other Examples of Plants Growing, Moving, and Functioning (50 min)

- 6.1 Explaining Other Examples of Plants Growing and Moving PPT
- 6.1 Other Plants Readings Lodgepole Pine
- 6.1 Other Plants Readings Prickly Pear
- 6.1 Other Plants Readings Smooth Cordgrass
- 6.1 Lodgepole Pine Worksheet
- 6.1 Prickly Pear Worksheet
- 6.1 Smooth Cordgrass Worksheet
- 6.1 Grading Lodgepole Pine Worksheet
- 6.1 Grading Prickly Pear Worksheet
- 6.1 Grading Smooth Cordgrass Worksheet

Activity 6.2: Functions of All Plants (50 min)

- 6.3 Functions of All Plants PPT
- 6.3 Functions of All Plants Worksheet (1 per student for option 1 in step 3)
- 6.3 Grading Functions of All Plants Worksheet

Activity 6.3: Comparing Plants and Animals (50 min)

- 6.2 Comparing Plants and Animals PPT
- 6.2 Comparing a Growing Tree and a Growing Child Worksheet (1 per student)
- 6.2 Grading Comparing a Growing Tree and a Growing Child Worksheet

Activity 6.4: Plants Unit Posttest (40 min)

- 6.4 Grading the Plants Unit Posttest
- 6.4 Plants Unit Posttest