Plants and the

Carbon Cycle

*How seeds grow to trees*

*and plants transform Carbon*

**The Environmental Literacy Project**

**Carbon: Transformations in Matter and Energy**

**(Carbon TIME)**

**2011-2012**

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# Unit Overview

*Plants* is one unit in a series of six units developed by the *Carbon: Transformations in Matter, and Energy (Carbon TIME)* Project. In the *Carbon TIME* project we are developing a series of six teaching modules that can be used at the middle school or high school level. They are based on research focusing on learning progressions leading to environmental science literacy, described below. The purpose of these units is to enable students to *uncover the chemical basis of life and lifestyles.*

**Key scientific ideas about carbon-transforming processes.** The chemical basis of life and lifestyles lies in *carbon-transforming processes* in socio-ecological systems at multiple scales, including cellular and organismal metabolism, ecosystem energetics and carbon cycling, carbon sequestration, and combustion of fossil fuels. These processes: (a) create organic materials (*photosynthesis*), (b) transform organic materials (*biosynthesis, digestion*), and (c) oxidize organic materials (*cellular respiration, combustion*). We think that it is important for students to understand carbon-transforming processes for many reasons; among them: the primary cause of global climate change is the current worldwide imbalance among these processes.

The reason these processes are unbalanced lies in the nature of *organic materials:* foods, fuels, and biomass (the tissues of living and dead organisms). All organic materials contain carbon and hydrogen, and store chemical energy in their carbon-carbon and carbon-hydrogen bonds that can be released when those materials combine with oxygen.[[1]](#footnote-1)

Virtually all of the chemical energy on Earth is stored in organic materials, and we need that chemical energy to maintain our lifestyles, so we burn organic materials—especially fossil fuels. So understanding these process is essential for students to act as informed citizens—what we call *environmental science literacy.*

**Describing student learning in terms of learning progression levels.** We have found that in order to achieve our program goals, students must learn new *knowledge and practices—*the science content described above. Underlying those changes, however, is an even more fundamental kind of learning—what we refer to as mastering scientific *discourse.*

Our everyday accounts of carbon-transforming processes are based on *force-dynamic* *discourse* or reasoning. Force-dynamic reasoning construes the events of the world as caused by actors (including people, animals, plants, machines, and flames), each with its own purposes and abilities, or by natural tendencies of inanimate materials. In order to accomplish their purposes, the actors have needs or enablers that must be present. For example, force-dynamic reasoning explains the growth of a tree by identifying the actor (the tree), its purpose (to grow), and its needs (sunlight, water, air, and soil). Force-dynamic predictions involve identifying the most powerful actors and predicting that they will be able to overcome antagonists and achieve their purposes as long as their needs are met.

This approach to reasoning about socio-ecological processes contrasts sharply with *principled scientific discourse*, which construes the world as consisting of hierarchically organized systems at different scales. Rather than identifying the most powerful actors, scientific reasoning sees systems as constrained by fundamental laws or principles, which can be used to predict the course of events. Each of our learning progressions involves students learning to apply fundamental scientific principles to the phenomena of the world around them.

So it is useful to think of learning science as like learning a second language. Students at the beginning of the learning progression are monolingual: They have mastered force-dynamic discourse but know little of the nature and power of scientific discourse. So our goal is to help students become “bilingual,” able to use force-dynamic or scientific discourse as the occasion demands. This is a difficult goal in part because force-dynamic and scientific discourse often use the same words (e.g., energy, growth, food, nutrient, matter) with different meanings. The differences can remain hidden to both teachers and students, creating the appearance of common understanding while profound differences remain.

We define students’ progress toward mastering scientific knowledge, practices, and discourse in terms of four *levels of achievement,* ranging from Level 1 (completely dependent on force-dynamic discourse) to Level 4 (able to choose between force-dynamic and principled scientific accounts of carbon-transforming processes). Very briefly, the levels we have identified are as follows:

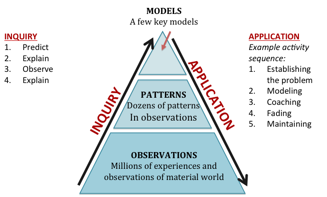
*Level 1: Pure force-dynamic accounts:*Students have no choice but to rely on force-dynamic discourse. Their accounts focus on actors, enablers, and natural tendencies of inanimate materials, using relatively short time frames and macroscopic scale phenomena.

*Level 2: Elaborated force-dynamic accounts:*Students’ accounts continue to focus on actors, enablers, and natural tendencies of inanimate materials, but they add detail and complexity, especially at larger and smaller scales. The include ideas about what is happening inside plants and animals when they grow and respond, for example, and they show awareness of larger scale connections among phenomena such as food chains and how decay enriches the soil.

*Level 3: Incomplete or confused scientific accounts:* Students show awareness of important scientific principles and of models at smaller and larger scales, such as cells, atoms and molecules, and cycling of gases and materials in ecosystems. They have difficulty, though, connecting accounts at different scales and applying principles consistently. In particular, they often confuse matter and energy and fail to account for the mass of gases in their accounts.

*Level 4: Coherent scientific accounts:* Students successfully apply fundamental principles such as conservation of matter and energy to phenomena at multiple scales in space and time. In general, our descriptions of Level 4 performances are consistent with current national science education standards and with the draft framework for new standards.

**Purpose and structure of *Carbon TIME* units.**  Each of our six units (*Systems and Scale, Animals, Plants, Decomposers, Ecosystems, Human Energy Systems*) focuses on familiar systems and events that involve carbon-transforming processes. Each unit is designed to help students at Level 2 in the learning progression (the most common starting point for middle school and high school students) advance to Level 3 or Level 4.

All of the units focus on *conservation of matter and energy as fundamental principles,* and all follow a general instructional model (see figure) that engages students in both inquiry and application (accounts) practices. The investigations follow a PEOE (predict-explain-observe-explain) sequence. Teaching of application practices is based on a *cognitive apprenticeship* model: (a) students are put in situations where they can observe other people engaging in the activity—*modeling*, (b) the students engage in the practice with scaffolding or support from others—*coaching,* and (c) the support is gradually withdrawn until the students are independently engaged in the practice—*fading.*

Instructional model for teaching units

**The central role of the Three Questions.** We believe that we can help students move to higher levels in the learning progression most effectively by focusing both the inquiry and application sequences on *Three Questions: the Movement Question, the Carbon Question, and the Energy Question.* These questions along with rules that we will expect students to follow and evidence we will expect them to look for in answering them, are presented in Table 1 below.

**Table 1: The Three Questions**

|  |  |  |
| --- | --- | --- |
| **Question** | **Rules to Follow** | **Evidence to Look For** |
| **The Movement Question: Where are atoms moving?**  Where are atoms moving from?  Where are atoms going to? | **Atoms last forever** in combustion and living systems  All materials (solids, liquids, and gases) are made of atoms | When materials change mass, atoms are moving  When materials move, atoms are moving |
| **The Carbon Question: What is happening to carbon atoms?**  What molecules are carbon atoms in before the process?  How are the atoms rearranged into new molecules? | Carbon atoms are bound to other atoms in molecules  **Atoms can be rearranged to make new molecules** | The air has carbon atoms in CO2  Organic materials are made of molecules with carbon atoms   * Foods * Fuels * Living and dead plants and animals |
| **The Energy Question: What is happening to chemical energy?**  What forms of energy are involved?  How is energy changing from one form to another? | **Energy lasts forever** in combustion and living systems  C-C and C-H bonds have more stored chemical energy than C-O and H-O bonds | We can observe indicators of different forms of energy   * Organic materials with chemical energy * Light * Heat energy * Motion |

**Comments on goals based on the Three Questions.** Our focus on the Three Questions arises from our reading of the data from the first pilot tests of our units during the 2011-12 school year, as well as our reading of data from other projects (e.g., Jin & Anderson, in press). We are convinced that our first priority for student learning should be to engender a ***sense of necessity*** about conservation of matter and energy, along with the ability to apply these principles to carbon-transforming processes.

The essential understandings that students should have from *Systems and Scale* are summarized in the three columns of the Three Questions Poster—Table 1 above, which is available as a wall poster and as a handout for Lesson 1 Activity 2 in this unit. Each of the three columns in this poster is important:

* The Movement Question, the Carbon Question, and the Energy Question. Students should understand that a good explanation of a process such as decomposition of a tree includes answers to each of these questions. Note that each question focuses on a different aspect of the process:
  + The Movement Question focuses on physical movements of materials.
  + The Carbon Question focuses on chemical change—atoms being rearranged into new molecules.
  + The Energy Question focuses on transformation of energy.
* Rules to Follow. Students should understand that the matter and energy conservation laws are never broken in chemical and physical changes: *Atoms last forever* and *energy lasts forever.*
* Evidence to Look For. Students should understand that evidence from investigations can inform them about answers to the three questions. In particular:
  + *Mass changes* can tell about answers to the Movement Question because the mass of a system can change ONLY if atoms move in or out of the system.
  + *Changes in the color of BTB* can help to answer the Carbon Question by showing what is happening to carbon dioxide
  + *Energy indicators* can help them identify the four forms of energy discussed in this unit: light, chemical energy in organic molecules, heat, and work/motion.

*Systems and Scale,* our first unit, introduces students to key ideas that form the basis for all the other units by developing a scientific account of organic and inorganic materials, how all systems exist at multiple scales, and how *combustion* transforms organic materials to inorganic materials and chemical energy to heat and light.

# Specifications for Plants Unit

*Plants* builds on key ideas established in the Systems and Scale Unit, but introduces a new carbon transforming process: photosynthesis. Together with cellular respiration and biosynthesis, these three carbon-transforming processes are the central processes around which we ask students to develop scientific accounts. Mainly, we want students to tell a story about plant growth that are constrained by scientific principles (conservation laws) and include the details of photosynthesis, biosynthesis, and cellular respiration at different scales.

## Plants Unit At a Glance

|  |  |
| --- | --- |
| Pre Lesson: Investigation Set Up | Time Estimate |
| Activity 1: Plant Growth Investigation: Predictions | 15 min |
| Activity 2: Investigation Set Up | 30 min |
| Lesson 1: Harvesting our Plants | Time Estimate |
| Activity 1: Unit Pre-Test | 20 min |
| Activity 2: Plant Growth Initial Explanations and Predictions | 30 min |
| Optional Activity: Water and Plant Biomass Demonstration | 20 min |
| Activity 3: Harvest | 45 min |
| Activity 4: Explaining Our Results | 20 min |
| Lesson 2: Movement, Carbon, and Energy In Photosynthesis | Time Estimate |
| Activity 1: Plants in the Light Investigation | 60 min |
| Activity 2: Modeling Photosynthesis | 45 min |
| Activity 3: Zooming into Plants | 60 min |
| Activity 4: Photosynthesis Quiz | 20 min |
| Optional Activity: Famous Studies of Plants | 30 min |
| Optional Lesson 3: Movement, Carbon, and Energy in Biosynthesis | Time Estimate |
| Activity 1: How can a potato plant make a potato? | 20 min |
| Activity 2: What do Soil, Water, and Air give to Plants? | 15 min |
| Activity 3: Modeling Biosynthesis | 30 min |
| Activity 4: Movement, Carbon, and Energy in Biosynthesis | 45 min |
| Activity 5: Biosynthesis Quiz | 20 min |
| Lesson 4: Movement, Carbon, and Energy in Cellular Respiration | Time Estimate |
| Activity 1: Plants in the Dark Investigation | 60 minutes |
| Activity 2: Modeling Cellular Respiration | 45 min |
| Lesson 5: Explaining Other Examples of Plant Growth and Function | Time Estimate |
| Activity 1: Explaining other Examples of Plant Growth and Functioning | 20 min |
| Activity 2: Unit Post-Test | 20 min |

## Learning Objectives for Middle and High School Students

The table below lists the key goals for student learning in terms of inquiry and application practices and the challenges that those goals pose for Level 2 students (including most middle school students and many high school students and Level 3 students (including some high school students).

| **Type of Objective** | **Learning Objective** | **Challenges for Level 2 Students** | **Challenges for Level 3 Students** |
| --- | --- | --- | --- |
| Inquiry: Measurement | Measure changes in dry mass of plants.  Detect changes in CO2 concentration in plants in the light and in the dark. | Level 2 students may have trouble reading digital balances and attaching meaning to measurements in small fractions of grams.  Level 2 students will not think of air as a mixture of different gases, so while they can understand that BTB detects CO2, they will not think of CO2 as one of the mix of gases in the air. | Level 3 students may have trouble accounting for tare weight and interpreting small fluctuations in readings on digital balances. They will have difficulty identifying threats to accuracy and precision in measurement. |
| Inquiry: Arguments from evidence | Construct arguments that use evidence about mass gain in plants, and CO2 concentration to defend claims about movements of atoms and chemical changes during plant growth and functioning. | Level 2 students will not interpret changes in mass as evidence of movements of atoms, believing instead that plants gain mass simply by “getting bigger.” They will also believe that a plant’s mass can be created from “food and energy” without accounting for the idea that the carbon that builds the glucose molecules must have come from somewhere (the air). | Level 3 students will see the relevance of evidence to claims, but they will not systematically consider alternate hypotheses or show how evidence supports or refutes specific claims. |
| Inquiry: Collective validation | Find patterns in data collected by multiple groups about changes in mass or gas exchange in plants. | Level 2 students may focus primarily on their own results rather than seeing the value of multiple measurements. | Level 3 students will understand that multiple measurements are valuable, but they will have few strategies for finding patterns across multiple trials. |
| Application: Movement question | Describe plant systems and processes in a hierarchy of scales, including atomic-molecular, macroscopic, and large scale.  Draw and explain movements of materials in a growing plant, including:   * CO2, O2, H2O, and minerals entering a plant * Glucose, H2O, and minerals moving within a plant, and * CO2, O2, and H2O exiting the plant. | Level 2 students will explain plant growth and functioning as actions of the plant (e.g., the plant makes itself bigger). They will not interpret weight gain in the plant as evidence that atoms are moving. | Level 3 students will describe a general movement of materials in the plant, but may not confuse the roles of matter and energy in plant growth. |
| Application: Carbon question | Describe molecules of key materials in plant processes, including atmospheric gases, soil minerals, water, and organic materials.  Explain how atoms are rearranged into new molecules in photosynthesis, biosynthesis, and cellular respiration in plants. | Level 2 students will explain what happens as an action of the plant (the plant grows and gets bigger) rather than as a chemical change in which atoms and mass are conserved. They will recognize that plants need food and energy to grow, but they will not try to trace those materials through the chemical change process. | Level 3 students will recognize that a chemical change is taking place, but they will not be able to successfully trace all the materials through the plant. They may not exhibit a sense of necessity in tracing carbon from the air to small organic molecules to large organic molecules to plant biomass and back to the air. |
| Application: Energy question | Identify forms of energy at different stages of plant growth and life processes.  Explain transformation and conservation of energy during photosynthesis, biosynthesis, and cellular respiration in plants. | Level 2 students will recognize that the sun is a form of energy, but they will not be committed to the idea that this energy is transformed into chemical energy that is stored in the bonds of the organic molecules in the plant. | Level 3 students are likely to identify glucose as an energy source for the plant, but they may not distinguish between matter and energy within the molecule, conflating the role that matter plays in plan growth with the role of energy. |

## Timeline and Overview

The table below summarizes the sequence of unit activities, showing how they address the inquiry and application goals and how they fit into the instructional model for the unit.

| **Structure and Sequence** | **Guiding Question** | **Activity Description** | **Learning Objectives** | **Background Information** |
| --- | --- | --- | --- | --- |
| **Pre-Lesson 1: Plant Growth Investigation Set Up.**  **Guiding Question:** How does a plant gain mass?  **Lesson Description:** Students record their initial ideas about how plants grow and set up an investigation in preparation to begin the Plants Unit when plants are ready to harvest (4 weeks later). *Note: We recommend doing this Pre-Lesson at least 4 weeks before you intend to begin the plants unit to allow the plants to grow for 4 weeks. It might be an appropriate sequence to do the Plants Pre-Lesson and continue with the Animals Unit.* | | | | |
| **Activity 1:** Plant Growth Investigation: Predictions  **15 min** | How does a plant gain mass? | Students complete a pretest assessing their understanding of materials and combustion. | Share predictions about how a plant gains mass with classmates before the investigation begins. | Students may begin this unit thinking that plants build the majority of their mass from minerals and nutrients in the soil. Although atoms from soil minerals and water contribute trace amounts of materials during biosynthesis (e.g., nitrogen, potassium, and phosphorous from the soil and hydrogen from the water), the majority of biomass is built from carbon from CO2 in the air. By growing plants from seed and taking measurements of plant dry mass and soil dry mass, this investigation gives students evidence that plants do not build their mass from soil or water. Lessons 2 (Photosynthesis), Lesson 3 (Biosynthesis), and Lesson 5 (Respiration) gives students further evidence that plants build their mass from materials they get from the air. |
| **Activity 2:** Investigation Set up  **30 min** | How does a plant gain mass? | Students plant seeds, record initial mass, and let seeds grow for 4 weeks. After 4 weeks, the plants will be ready to harvest so the plants unit can begin. | Set up an investigation that will allow for measurement of plant mass gain. |

| **Structure and Sequence** | **Guiding Question** | **Activity Description** | **Learning Objectives** | **Background Information** |
| --- | --- | --- | --- | --- |
| **Lesson 1: Harvesting Our Plants**  **Guiding Questions:** How des a plant gain mass? How do atoms move as a plant gains mass? How are carbon and energy transformed as a plant gains mass?  **Lesson Description:** Students harvest plants and collect evidence that help them construct arguments about how a plant builds mass. | | | | |
| **Activity 1:** Unit Pre-Test  **20** **min** | What do we think about plant growth at the beginning of the unit? | Students take a written pre-test (online or on paper). Your students’ responses will provide a starting point for discussions in the rest of the unit. | Document ideas about plant growth at the beginning of the lesson | The purpose of the pre-test is to elicit initial ideas from the students about their understanding of plant growth. No background information is needed to administer the pre-test. |
| **Activity 2:** Plant Growth Initial Explanations and Predictions  **30 min** | How do we describe movement, carbon, and energy before we know results of the investigation? | Students record their initial ideas about movement, carbon, and energy during plant growth. These ideas serve as a starting place for assessment and will be revisited when the investigation ends. | Express ideas about movement and transformation of atoms, carbon, and energy when a plant grows before results are known. | Students may begin this unit thinking that plants build the majority of their mass from minerals and nutrients in the soil. Although atoms from soil minerals and water contribute trace amounts of materials during biosynthesis (e.g., nitrogen, potassium, and phosphorous from the soil and hydrogen from the water), the majority of biomass is built from carbon from CO2 in the air.  By growing plants from seed and taking measurements of plant dry mass and soil dry mass, this investigation gives students evidence that plants do not build their mass from soil or water. Lessons 2 (Photosynthesis), Lesson 3 (Biosynthesis), and Lesson 5 (Respiration) gives students further evidence that plants build their mass from materials they get from the air. |
| **Optional Activity:** Water and plant biomass demonstration  **30 min** | What is “biomass?” | The teacher uses the mass of a dry and wet carrot and sponge to demonstrate the concept of biomass and dry weight in plants. | Develop a definition of biomass in preparation for the plant growth investigation. |
| **Activity 3:** Harvest  **45 min** | Does plant mass come from air, water, or soil? | Students harvest and dry their plants. They record the end mass of the vermiculite and plants in their data table and compare the results to the start mass. | Collect and interpret data to provide evidence that plants do not gain mass from soil. |
| **Activity 4:** Explaining our Results  **20 min** | What does evidence from our investigation tell us? | Students construct modified arguments about mass, movement, carbon, and energy using evidence from the plant investigation. They compare their ideas from the beginning of the investigation and note remaining questions. | Collect and interpret data from a scientific investigation; Construct arguments (using evidence) that explain that the majority of a plant’s mass comes from the air, not soil or water. |
|  |  |  |  |  |
| **Lesson 2: Movement, Carbon, and Energy in Photosynthesis**  **Guiding Questions:** How do atoms move during photosynthesis? How are carbon and energy transformed during photosynthesis?  **Lesson Description:** Students are introduced to movement, carbon, and energy in the context of photosynthesis. Then a molecular modeling activity helps them visualize how matter and energy are transformed during this process. | | | | |
| **Activity 1: Plants in the Light Investigation**  **60 min** | Why do plants change BTB blue in the light? | Students conduct an investigation of aquatic plants in the light and discuss how atoms move and how carbon and energy are transformed during photosynthesis. | Collect evidence for gas exchange during photosynthesis. | Many students may be familiar with photosynthesis. However, it is likely they do not understand how photosynthesis explains how atoms move and how carbon and energy are transformed during this process. At this point, students should understand that plants cannot get the majority of their mass from water or soil minerals/vitamins. They are ready to develop more scientific accounts of photosynthesis in light of the evidence they have recently collected as a way of filling in gaps: if plants don’t get their mass from the soil, where does their mass come from? |
| **Activity 2:** Modeling Photosynthesis  **45 min** | How are carbon and energy transformed during photosynthesis? | Students construct models of molecules using molecular model kits to answer questions about how carbon and energy change during photosynthesis. | Construct models that show how carbon and energy are transformed during photosynthesis. | Carbon enters the plant in the form of CO2 from the air. Inside the plant, it is transformed into C6H12O6. (glucose or sugar). Energy enters a plant during photosynthesis in the form of light energy from the sun. This energy is transformed during photosynthesis from light energy into chemical potential energy, and is stored in the bonds of organic molecules that are used to build the plant’s biomass. |
| **Activity 3:** Zooming into Plants  **60 min** | Where are carbon and energy stored in a plant’s body? At what scale can we see carbon atoms and chemical energy? | Students zoom into different parts of a plant and seed, using Powers of Ten, and examine where the carbon and energy is stored in a plant. | Identify where carbon and energy are stored in a plant’s body.  Observe plant material at a macro, micro, and atomic/molecular scale. | At macro and micro scales, students are unable to see the carbon and energy that plays such a prominent role in this lesson. Zooming into a plant gives students opportunities to refine their stories about matter and energy in a plant at different scales. |
| **Activity 4:** Photosynthesis Quiz  **20 minutes** | How have student ideas evolved since the beginning of the lesson in terms of movement, carbon, and energy? | Students take a quiz that covers movement, carbon, and energy in photosynthesis. | Assess where student thinking is concerning the 3 questions. |  |
| **Optional Activity:** Famous studies of plants  **30 minutes** | How have our ideas about plant growth evolved over centuries? | Students discuss how studies and evidence of plant growth have evolved over time, beginning with van Helmont’s studies in the 1640’s through Senebier’s work in the late 18th century. | Synthesize conclusions about plant growth from evidence; Interpret evidence that scientists collected over time that tell us what plants are made of. | It is not always possible to conduct firsthand investigations and experiments in class to demonstrate complex scientific principles. But students can examine evidence collected by scientists and see if this evidence supports or contradicts their ideas. While none of these scientists were completely correct in their ideas about plant growth, their findings advanced the field of plant physiology. Each study provides additional evidence for students to consider against their developing models for plant growth. |
| **Lesson 3: Movement, Carbon, and Energy in Biosynthesis**  **Guiding Question:** How does a plant build biomass out of glucose, water, and soil minerals?  **Lesson Description:** Students develop a story about how matter and energy taken into the plant during photosynthesis (in the form of high-energy glucose molecules) are transformed into larger organic polymers during biosynthesis. | | | | |
| **Activity 1:** How can a Potato Plant Make a Potato?  **15 min** | Where do water, glucose, and soil nutrients start in a plant? | Students share ideas about how glucose, water, and minerals begin in a plant using sticky notes and a potato poster. | Illustrate where water, soil nutrients, and glucose begin in a plant. | This activity follows up on the question of how plants use the food they make. Students should understand that plants cells need materials to multiply and they get it from food. In this activity students learn more about the details of how and why plants use glucose (a small organic monomer) to build proteins, fats, and carbohydrates. |
| **Activity 2.** What do soil, water, and air give to plants?  **15 min** | Which materials do soil, water, and air give to plants? | Students look at atoms and molecules that make up plants, soil, air, and water to determine which atoms the plant receives from air, water, and soil. | Measure mass changes and detect changes in CO2 concentration when ethanol burns.  Find patterns in data collected by multiple groups about changes in mass and CO2 concentration.  Construct arguments that use evidence about changes in mass of fuels and CO2 concentration to defend claims about movements of atoms when ethanol burns. | **Water**- can potentially contribute oxygen or hydrogen (in reality water mainly contributes hydrogen atoms).  **Soil** Minerals-can potentially contribute phosphorus, calcium, magnesium, etc. (note that students may also say oxygen although oxygen in soil is tied up in phosphates and other compounds).  **Air**—can potentially contribute carbon, oxygen, or hydrogen (in reality plants get their carbon and oxygen atoms from air, but their hydrogen from water). |
| **Activity 3:**  Modeling Biosynthesis  **30 minutes** | How is the matter and energy in monomers transformed into matter and energy in polymers? | Students examine the chemical structure of carbohydrates, fats and proteins and then model how these polymers are built from smaller organic monomers using paper clips. | Construct a model of monomers (glucose, amino acids, fatty acids) and polymers (proteins, fats, starches); Model how monomers are used to build polymers. | Students have learned that photosynthesis builds glucose molecules from carbon in the air. What happens to these glucose molecules once they are in the plant’s cells? Plants rearrange the atoms of glucose, water, and soil minerals to build larger organic molecules: fats, carbohydrates, and proteins. 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 larger organic molecules called polymers. |
| **Activity 4:** Movement, Carbon, and Energy in Biosynthesis  45 min | What have we learned about biosynthesis? | Students synthesize the ideas they have put together concerning biosynthesis in preparation for the Lesson 3 quiz. | Synthesize ideas from the Biosynthesis lesson**;** Document current accounts about biosynthesis. | The students at this point should have constructed a story about plant growth that includes photosynthesis and biosynthesis. Student ideas here are unlikely to include the final piece of the plant growth story: cellular respiration (coming in lesson 4). |
| **Activity 5:** Biosynthesis Quiz  **20 min** |  |  |  |  |
| **Lesson 4: Movement, Carbon, and Energy in Cellular Respiration**  **Guiding Question:** Why do plants in the dark release CO2?  **Lesson Description:** Students have gathered data that shows that plants in the dark give off CO2. This final lesson helps answer the reason for this: cellular respiration. | | | | |
| **Activity 1:** Plants in the Dark Investigation  **60 minutes** | Why do plants give off CO2 in the dark? | Students conduct an investigation with aquatic plants in the dark and discuss how atoms move and how carbon and energy are transformed during cellular respiration. | Explain why plants give off CO2 in the dark; Identify the reactants and products of cellular respiration. | Students usually do not think about plants doing cellular respiration. They learn that plants do photosynthesis, and often cellular respiration is overlooked. Students may not even wonder how seeds actually sprout when they have no leaves, no chlorophyll, and no way to photosynthesize. Fully grown plants also undergo cellular respiration on a continuous basis. This is the primary process happening in plants during the night, as well as in winter months, when many trees lose their leaves. During cellular respiration, plants take organic materials and oxidize them, giving off inorganic carbon dioxide and water as wastes. |
| **Optional Activity:** Modeling Cellular respiration  **45 min** | How do matter and energy change during cellular respiration? | Molecular model kits allow students to physically rearrange atoms from reactants to products to demonstrate how plants transform carbon and energy during cellular respiration. | Model matter and energy transformation during cellular respiration. |
| **Lesson 5: Explaining other examples of plant growth and functioning**  **Guiding Question:** How do other plants grow and function?  **Lesson Description:** Students apply what they have learned to other examples involving plant growth and other plant functions. | | | | |
| **Activity 1:** Explaining other examples of plant growth and function | How do plant growth and functioning influence our lives? | Students apply what they have learned to other examples of plant growth and functioning. | Synthesize ideas about movement, energy, and carbon during plant growth. |  |
| **Unit Post Test**  **20 min** |  |  |  |  |

## Teaching *Plants* to Middle and High School Students

*Plants* is designed for students who have completed the *Systems and Scale* unit. We also recommend that students complete the *Animals* before *Plants,* but the activities of this unit are designed to be meaningful to students who have not completed *Animals.* The majority of students in most middle school and high school classes start at Level 2.

The essential understandings that students should have from *Systems and Scale* are summarized in the three columns of the Three Questions Poster—available as a wall poster and as a handout for Lesson 1 Activity 2 in this unit. Each of the three columns in this poster is important:

* The Movement Question, the Carbon Question, and the Energy Question. Students should understand that a good explanation of a process such as plant growth includes answers to each of these questions.
* Rules to Follow. Students should understand that the matter and energy conservation laws are never broken in chemical and physical changes: *Atoms last forever* and *energy lasts forever.*
* Evidence to Look For. Students should understand that evidence from investigations can inform them about answers to the three questions. In particular:
  + *Mass changes* can tell about answers to the Movement Question because the mass of a system can change ONLY if atoms move in or out of the system.
  + *Changes in the color of BTB* can help to answer the Carbon Question by showing what is happening to carbon dioxide
  + *Energy indicators* can help them identify the four forms of energy discussed in this unit: light, chemical energy in organic molecules, heat, and work/motion.

If you have **middle school students** or if most of your students are starting at Level 2, then we recommend that several activities are not essential:

* The Plant Growth Investigation—*Pre Lesson and Lesson 1 Activity 3*—requires time, patience, grow lights, a drying oven, and reasonably good experimental technique in separating the plants from the soil. If your classroom lacks these assets, then you may want to use the data provided on the file PlantsClassResults.xlsx instead of having students collect data themselves.
* The *Optional Activity: Water and Plant Biomass Demonstration* at the end of Lesson 1 is also not essential, especially for students who did not to the Plant Growth Investigation themselves.
* The *Optional Activity: Famous Studies of Plants* at the end of Lesson 2 may be more detailed and complex than your students are ready to handle.
* *Optional Lesson 3: Movement, Carbon, and Energy in Biosynthesis* may have more detail about movement of materials inside plants and synthesis of large biomolecules than you wish to get into with your students. The essential ideas of this lesson are in *Lesson 2 Activity 3: Zooming into Plants.*

If you have **high school students**, particularly if the students in your class have studied the *Animals* unit, you may be able to do some lessons as review activities.

* The discussion of biomolecules and nutrition labels in *Lesson 2 Activity 3: Zooming into Plants.* Much of this content was also covered in the *Animals* unit: *Lesson 2: What Makes Up Our Food?*
* Optional Activity 2: Modeling Cellular Respiration In Plants probably is not necessary for students who modeled cellular respiration in the *Animals* unit.

## Vocabulary

* Amino Acid
* Biosynthesis
* Carbohydrate
* Carbon
* Carbon Dioxide
* Cellular Respiration
* Chemical Energy
* Energy
* Fat
* Fatty Acid
* Glucose
* Glycerol
* Inorganic Matter
* Mass
* Molecule
* Monomer
* Movement
* Organic Matter
* Photosynthesis
* Polymer
* Process
* Protein
* Scale
* Starch

## Materials

**Pre-Lesson Materials**

*For Activity 1*

* Plants\_Pre-Lesson.pptx Slide 1 (for poster)
* Plants\_Pre-Lesson.pptx Slide 2 (for projecting)
* Optional: 1 sticky note per student

*For Activity 2*

*General*

* Vermiculite for growing plants
* 4 large, shallow trays (such as baking sheets) for students to place cups on
* Fluorescent lamp that will provide 24 hours of light to plants
* Liquid nutrients to add to water (see instructions for dilution here: [http://hydrodynamicsintl.com/ionicgrow.htm](http://hydrodynamicsintl.com/ionicgrow.htm" \t "_blank))
* Plant Growth Investigation Set up Checklist
* Plant Growth Investigation: DataTable
* PlantsClassResults.xlsx
* PlantsPosters.pptx (optional)

*Per Group*

* 0.1 g Lettuce seeds
* 1 Aluminum utility cup (rectangular 5” x 6”)
* 2 Handi-wipes (cut into ~1/2 inch x 1.5 inch strips) for wicking
* 1 digital balance (200g; x0.01 sensitivity)
* 1 permanent marker and label

**Lesson 1 Materials**

*For Activity 1: Unit Pre-Test*

* Plants Unit Pre-test

*For Activity 2: Initial Predictions and Explanations*

* Computer and Projector
* Initial Explanations and Predictions Worksheet
* Plant growth and movement time lapse videos (on website)

*For Optional Activity:*

* 1 digital scale
* 1 cup water
* 1 sponge
* 1 fresh carrot

*For Activity 3: Harvest*

*General*

* Oven or dehydrator
* Scissors
* Lesson1Harvest.pptx
* PlantsClassResults.xlsx
* PlantsPosters.ppt (optional)

*Per Group*

* Plant Growth Investigation Data Table (started in Pre-Lesson)
* Harvest Checklist
* 1 paper bag
* 1 digital balance
* 1 flat tray, smooth place mat, or piece of paper

*For Activity 4: Explaining our Results*

* Observations and Conclusions Worksheet
* Completed worksheets from Activity 2: Initial Explanations and Predictions Worksheet

**Lesson 2 Materials**

*For Activity 1*

* Lesson2Photosynthesis.pptx, Slides 1-13
* PlantsClassResults.xlsx OR Results poster (in PlantsPosters.pptx)

*Per Group*

* What is Photosynthesis Checklist
* 2 test tubes with lids
* 1 cup blue BTB
* 1 drinking straw
* 2 sprigs elodea
* 1 marker or pencils
* 2 labels

*Per Student*

* Observations and Conclusions: Plants in the Light Worksheet

*For Activity 2*

* Lesson2Photosynthesis.pptx, Slides 14-34
* Modeling Photosynthesis Checklist
* Process Tool For Molecular Models (in PlantsPosters.pptx)
* Molecular Model Kits, including:
  + 6 carbon atoms
  + 12 hydrogen atoms
  + 18 oxygen atoms
  + 36+ bond links
* 12 Twisty Ties
* 4 energy cards

*For Activity 3*

*General*

* Lesson2Photosynthesis.pptx, Slides 35-52

*Per Student*

* Zooming Into Plants Worksheet

*For Activity 4*

*Per Student*

* Photosynthesis Quiz

*For Optional Activities*

*General*

* FamousStudiesofPlants.pptx

*Per Student*

* Famous Studies of Plants Worksheet

**Lesson 3 Materials:**

*For Activity 1*

*General*

* Potato Poster (1 large poster per class, or smaller 11x17 posters)
* Lesson3Biosynthesis.pptx,Slides 1-4

*Per Pair*

* 3 Sticky notes

*For Activity 2*

* Lesson3Biosynthesis.pptx, Slides 5-12

*For Activity 3*

*General*

* Lesson3Biosynthesis.pptx, Slides 13-31

*Per Pair of Students*

* Potato Poster (11x17)
* 10 paper clips
* 1 pair of scissors
* 1 Monomers handout

*For Activity 4:*

*General*

* Movement, Carbon, and Energy in Biosynthesis Worksheet

*For Activity 5:*

* Biosynthesis Quiz

**Lesson 4 Materials:**

*For Activity 1*

* Lesson4Respiration.pptx, Slides 1-5
* <http://www.youtube.com/watch?v=so8LdhbfddQ>

Per Pair:

* 2 test tubes with stoppers/caps
* 1 cup blue BTB
* 2 sprigs of aquatic plants
* Labels for test tubes
* Plants in the Dark Investigation Checklist
* Observations and Conclusions: Plants in the Dark Worksheet

*For Activity 2*

* Lesson4Respiration.pptx
* Three Questions poster (11 x 17)
* Using Molecular Models to Show How Plants Can Move worksheet per student
* Process tool for Molecular Models poster (11 x 17) per group of 4 students
* Molecular models and twisty ties: Enough atoms and bonds per pair of students to make a sugar molecule (C6H12O6) and at least 6 oxygen molecules (O2). Per group of 4 students (two packages from the Molecules of Life kit should have enough):

At least 6 carbon atoms (black)

At least 12 hydrogen atoms (white)

At least 18 oxygen atoms (blue)

At least 28 bonds (white plastic tubes)

At least 12 twisty ties

* Potato Poster (11 x 17), per pair of students

**Lesson 5 Materials**

*For Activity 1:*

*Other Examples of Photosynthesis, Biosynthesis and Cellular Respiration*

* Lesson5OtherExamples.pptx
* Other Examples of Animals Growing and Using Energy to Move worksheet per student

*For Activity 2*

* Plants Unit Post-Test

## Acknowledgments:

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# Unit Pre-Lesson: Investigation Set Up

**Role of this Lesson in Activity Sequence:**

Activity 1: Inquiry: Predicting growing

Activity 2: (Set Up)

**Time/Duration:** 45 minutes

Activity 1: Plant Growth Investigation: Predictions ~15 minutes

Activity 2: Investigation Set Up ~30 minutes

**Lesson Description:**

Students record their initial ideas about how plants grow and set up an investigation in preparation to begin the Plants Unit when plants are ready to harvest (4 weeks later).

**Guiding Question:**

1. How does a plant gain mass?
2. Does plant gain mass from the soil, air, or water?

**Background Information:**

The plants that are set up in this pre-lesson need four weeks or more to grow to a point where they have gained enough mass to produce significant results. *This pre-lesson should be conducted at least four weeks before you plan to begin the Plants Unit.*

**Pre-Lesson Materials**

*For Activity 1*

* Plants\_Pre-Lesson.pptx Slide 1 (for poster)
* Plants\_Pre-Lesson.pptx Slide 2 (for projecting)
* Optional: 1 sticky note per student

*For Activity 2*

*General*

* Vermiculite for growing plants
* 4 large, shallow trays (such as baking sheets) for students to place cups on
* Fluorescent lamp that will provide 24 hours of light to plants
* Liquid nutrients to add to water (see instructions for dilution here: [http://hydrodynamicsintl.com/ionicgrow.htm](http://hydrodynamicsintl.com/ionicgrow.htm" \t "_blank))
* Plant Growth Investigation Set up Checklist
* Plant Growth Investigation: DataTable
* PlantsClassResults.xlsx
* PlantsPosters.pptx (optional)

*Per Group*

* 0.1 g Lettuce seeds
* 1 Aluminum utility cup (rectangular 5” x 6”)
* 2 Handi-wipes (cut into ~1/2 inch x 1.5 inch strips) for wicking
* 1 digital balance (200g; x0.01 sensitivity)
* 1 permanent marker and label

## Activity 1: Plant Growth Investigation: Predictions

**Learning Objectives:**

1. Predict how a plant gains mass.

**Duration:** 15 minutes

**Activity Description:**

This activity elicits ideas about plant growth before the investigation. Student ideas can be revised throughout the unit as students collect evidence of mass change.

**Background Information**:

Students may begin this unit thinking that plants build the majority of their mass from minerals and nutrients in the soil. Although atoms from soil minerals and water contribute trace amounts of materials during biosynthesis, the majority of biomass is built from carbon that comes from CO2 in the air. By growing plants from seed and taking measurements of plant mass and soil mass, this activity gives students evidence that plants do not build the majority of their mass from soil. This leaves students with a question: If plants do not build their biomass from soil or water, where does their mass come from?

**Materials**:

* Plants\_Pre-Lesson.pptx Slide 1 (for poster)
* Plants\_Pre-Lesson.pptx Slide 2 (for projecting)
* Optional: 1 sticky note per student

**Directions:**

1. **Activate Prior Knowledge from Systems & Scale.**

The chemical change students observed in the flame burning and the soda water fizz involved the rearrangement of atoms to form new molecules. When a plant grows, chemical changes also occur! This unit will help us understand the chemical transformations that take place when a plant grows, and how atoms from the air, soil, and water are rearranged to make new molecules in a plant.

1. **Ask the students how they think a plant gains mass.**

Pose the question to the whole class and share responses.

1. **Discuss how a plant gains mass**.

Use 1 of the 2 options below.

|  |  |
| --- | --- |
| Option 1: Poster with sticky notes   * Print slide 2 of Plants\_Pre-Lesson.pptx * Students work in pairs to discuss (a) their ideas and (b) their questions about how a plant gains mass. * Each pair of students puts one idea or question on a sticky note. * One member of each pair puts the note on the poster and explains their idea or question * **Save the students’ notes** to revisit later, preferably in a place in the classroom where their ideas can be referred to as the unit progresses. | Option 2: Recording ideas and questions on a PowerPoint slide   * Open Plants\_Pre-Lesson.pptx and project slide 1. * Students work in pairs to discuss (a) their ideas and (b) their questions about what happens when plants grow. * Each pair of students shares one idea or question * Make a new copy of the slide per class * **Save the slide with students’ ideas** to revisit later |

**FORMATIVE ASSESSMENT**: *Note how many students identify air as the primary source of the plant’s mass, and how many students identify soil or water or other sources as the primary source of a plant’s mass*. *Students who enter this lesson at a* ***Level 2*** *may answer the question by suggesting that plants grow because they have water, light, air, and soil. They may suggest that these enablers are necessary for plant growth, but be unable to explain how these enablers are used to gain mass. Students at* ***Level 3*** *may explain that plants use materials from their environment to build mass, and may be able to describe the role of photosynthesis in making sugar, but may not be clear how or why a majority of the plant’s mass comes from the air or the role of energy in plant growth. Students at* ***Level 4*** *may predict that plants build their mass by converting the carbon from CO2 in the air to glucose during photosynthesis, and that this glucose is combined with other monomers to create polymers that are used to build the cells of the plant.*

1. **Transition to Activity 2.**

Explain to the students that in order to answer their questions scientifically, they will need to conduct their own investigations about how a plant grows. Save the students’ sticky notes or slides. You will use them again in the first lesson of the plants unit.

## Activity 2: Investigation Set Up

**Learning Objectives:**

1. Measure mass changes in plants.

**Duration:** 30 minutes

**Activity Description:**

Students plant seeds, record initial mass, and let seeds grow for 4 weeks. After 4 weeks, the plants will be ready to harvest so the plants unit can begin.

**Background Information**:

Students may begin this unit thinking that plants build the majority of their mass from minerals and nutrients in the soil. Although atoms from soil minerals and water contribute trace amounts of materials during biosynthesis (e.g., nitrogen, potassium, and phosphorous from the soil and hydrogen from the water), the majority of biomass is built from carbon from CO2 in the air. By growing plants from seed and taking measurements of plant dry mass and soil dry mass, this investigation gives students evidence that plants do not build their mass from soil or water. Lessons 2 (Photosynthesis), Lesson 3 (Biosynthesis), and Lesson 5 (Respiration) gives students further evidence that plants build their mass from materials they get from the air.

**Materials**:

*General*

* Vermiculite for growing plants
* 4 large, shallow trays (such as baking sheets) for students to place cups on
* Fluorescent lamp that will provide 24 hours of light to plants
* Liquid nutrients to add to water
* Plant Growth Investigation Set up Checklist
* Plants Investigation: DataTable
* PlantsClassResults.xlsx
* PlantsPosters.pptx (optional)

*Per Group*

* 0.1 g Lettuce seeds
* 1 Aluminum utility cup (rectangular 5” x 6”)
* 2 Handi-wipes (cut into ~1/2 inch x 1.5 inch strips) for wicking
* 1 digital balance (200g; x0.01 sensitivity)
* 1 permanent marker and label

**Directions**:

1. **Divide students into groups of 4.**

Pass out 1 copy of the handout Plant Growth Investigation Set Up Checklist to each group and a copy of the Plant Growth Investigation: Data Table to each student.

1. **Demonstrate the investigation set up.**

Demonstrate the set up with students, step-by-step. Use Plant Growth Investigation Set Up Checklist to guide your demonstration.

1. **Set up the investigation.**

Tell students to set up their group’s investigation by following steps in Plant Growth Investigation Set Up Checklist. Tell students to check and date each step of the investigation. The checklist includes instructions on where and how to record data. *Note: the grow light has space for approximately 24 aluminum cups. This means you may have a total of 24 groups per investigation but no more. If you have multiple classes doing the investigation at the same time, you may need to make larger groups so that you have no more than 24 cups of plants growing at one time.*

1. **Record class data.**

Open PlantsClassResults.xlsx. Project the spreadsheet so all students can see. Ask groups to report their group data. Input class data in the sheet titled “Plant Growth Investigation.” Look for the columns titled “Pre-Lesson Data.” Input class start data here. Alternatively, have students record their data on a class poster that can be posted on the wall during the plants unit for data collection. A data poster can be found in PlantsPosters.pptx.

1. **Transition to Lesson 1.**

Tell students that we need to wait at least 4 weeks before we can harvest our plants and get results. Make sure plants are watered during this time. Monitor the plants as they grow while you are teaching other units/lessons in the 4 week between set up and the beginning of the plants unit.

*Note: During plant growth, put water and liquid nutrients into the large aluminum tray regularly. The wicks will intake water and nutrients into the individual plant containers that sit in the large aluminum trays.*

Group:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_

### Plant Growth Investigation Set Up Checklist

**Plants Pre-Lesson, Activity 2**

Follow the procedures below to set up your investigation. Put a check in the box when each material has been obtained and each step has been completed. Write the date completed in the line next to each box.

**Materials Needed Per Group**

☐ 1 aluminum container

☐ 1 label for each container and marker to write on label

☐ 2 Handi-wipe strips “wicks”

☐ 1 ½ to 2 cups vermiculite

☐ 0.1 g lettuce seeds

☐ 1 digital scale

☐ 1 empty cup or container (for measuring mass of seeds only)

1. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Obtain 1 small aluminum container. Label the container with your group’s name/number using a permanent marker and a label.
2. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Using scissors, make a ½ inch slit in the bottom of the container and on each side of the container. Insert 1 “wick” (Handi-wipe strip) into each slit so half of the wick is inside the container and half is outside. These wicks will keep your plant supplied with water.
3. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Place your aluminum container on the digital scale. Then tare the scale (this means set the scale to “0” when the empty container is on it). Fill the container 2/3 full with vermiculite.
4. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Record the start mass of the vermiculite in your group data table.
5. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Place an empty container on the scale and tare the scale. Add the seeds to the empty container until you have at least 0.1 g of lettuce seeds.
6. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Record the start mass of the seeds in your group data table.
7. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Plant the seeds in the container. Place the seeds just under the surface of the vermiculite and be sure the seeds are spread evenly in the container.
8. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Place your seed cups on trays under the UV light.

Group:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_

### Plant Growth Investigation: Data Table

**Plants Pre-Lesson, Activity 2**

Use this table to record your group’s data from your plant investigation. It is important to make careful measurements of mass change in both the plants and the vermiculite. Double-check all your measurements as you complete the investigation. Remember: how does this investigation tell us how a plant gains mass?

**Our Group Data**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Start** | **End** | **Mass Change** | **Mass change for whole System** |
| **Vermiculite** | Date | Date |  |
| Mass | Mass |
| **Plants** | Date | Date |  |  |
| Mass | Mass |

**GROUP RESULTS**

Describe the **mass** change you observed in your plants and vermiculite after 4 weeks.

|  |
| --- |
|  |

**Our Class Data**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Groups | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Avg |
| Plant Mass Change |  |  |  |  |  |  |  |  |  |
| Vermiculite Mass Change |  |  |  |  |  |  |  |  |  |

**CLASS RESULTS**

What does your class data tell you about how a plant gains mass?

|  |
| --- |
|  |

# Lesson 1: Harvesting our Plants

**Role of this Lesson in the Unit Sequence**

Activity 1: (Pre-test)

Activity 2: Inquiry: Predict, Explain growth

Activity 3: Inquiry: Observe growth

Activity 4: Inquiry: Explain growth

**Time/Duration:** About2 hours total across 4 weeks

Activity 1: Unit Pre-Test ~20 minutes

Activity 2: Plant Growth Initial Explanations and Predictions ~30 minutes

Optional Activity: Water and Biomass ~20 minutes

Activity 3: Harvest ~45 minutes

Activity 4: Explaining your Results ~20 minutes

**Lesson Description:**

Students harvest plants and collect evidence that help them construct arguments about how a plant builds mass.

**Guiding Questions:**

1. How does a plant gain mass?
2. How do atoms move as a plant gains mass?
3. How are carbon and energy transformed as a plant gains mass?

**Background Information:**

Plants build the majority of their mass using CO2 taken in from the air. Coming into this unit, students may incorrectly think that plants build most of their mass using molecules from soil and water. The investigations in this unit aim to help students reformulate these ideas.

**Lesson 1 Materials**

*For Activity 1: Unit Pre-Test*

* Plants Unit Pre-test

*For Activity 2: Initial Predictions and Explanations*

* Computer and Projector
* Initial Explanations and Predictions Worksheet
* Plant growth and movement time lapse videos (on website)

*For Optional Activity:*

* 1 digital scale
* 1 cup water
* 1 sponge
* 1 fresh carrot

*For Activity 3: Harvest*

*General*

* Oven or dehydrator
* Scissors
* Lesson1Harvest.pptx
* PlantsClassResults.xlsx
* PlantsPosters.ppt (optional)

*Per Group*

* Plant Growth Investigation Data Table (started in Pre-Lesson)
* Harvest Checklist
* 1 paper bag
* 1 digital balance
* 1 flat tray, smooth place mat, or piece of paper

*For Activity 4: Explaining our Results*

* Observations and Conclusions Worksheet
* Completed worksheets from Activity 2: Initial Explanations and Predictions Worksheet

### Activity 1: Unit Pre-Test

**Learning Objectives:**

1. Document ideas about plant growth at the beginning of the lesson.

**Duration**: 20-25 minutes

**Activity Description**:

Students take a written pre-test (online or on paper). Your students’ responses will provide a starting point for discussions in the rest of the unit.

**Background Information:**

The purpose of the pre-test is to elicit initial ideas from the students about their understanding of plant growth. No background information is needed to administer the pre-test.

**Materials:**

* Plants Unit Pre-Test

**Directions:**

1. **Introduce the Pre-test.**

Explain to students that they will be taking a pretest that has questions about how plants grow. These will not be graded.

1. **Share the purpose of the pre-test to your students**.

It will help you as a teacher to understand how students think about plant growth.

It will help our research project understand how students think and learn.

It will help students think about what they know and what they would like to learn.

1. **Distribute** **the pre-test**.

The pre-test can be given on paper or online.

1. **Allow students 20 minutes to complete the pre-test.**
2. **Collect and save pre-tests.**

Use the results of the pre-test to track student progress as the unit progresses. Return unit pre-tests to Staci if they were taken on paper.

Teacher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period: \_\_\_\_Grade \_\_\_\_ Date \_\_\_\_\_\_\_\_\_Your initials \_\_\_ \_\_\_ \_\_\_

### Plants Unit Pre-Test

|  |  |  |
| --- | --- | --- |
| 1. Answer these questions about what happens when a plant grows. | Do you think that **materials** (solids, liquids, or gases) are going into the plant? (circle one answer below)  Yes No I’m not sure | Do you think that **energy** is going into the plant? (circle one answer below)  Yes No I’m not sure |
| What **materials** do you think are going into the plant? | What **forms of energy** do you think are going into the plant? |
|  | Do you think that **materials** (solids, liquids, or gases) are coming out of the plant? (circle one answer)  Yes No I’m not sure | Do you think that **energy** is coming out of the plant? (circle one answer below)  Yes No I’m not sure |
| What **materials** do you think are coming out of the plant? | What forms of **energy** do you think are coming out of the plant? |
| How do you think that **materials** are changing inside the plant? | How do you think that **energy** is changing inside the plant? |
|  | What are you **not sure about** in your answers? Explain what you need to know to answer these questions better. | |

2. Answer these true-false questions:

True False Carbon is a kind of atom.

True False Carbon is a kind of molecule.

True False There is carbon in a tree’s leaves.

True False There is carbon in a tree’s roots.

True False There is carbon in the wood of a tree’s trunk.

3. Grass needs energy to live and grow. How does it get its energy?

Which of the following statements is true? Circle the letter of the correct answer.

a. ALL of the grass’s energy came originally from sources outside the plant, OR

b. SOME of the grass’s energy was made by the plant as it grew.

Circle the best choice to complete each of the statements on the next page about possible sources of energy from outside the grass.

|  |  |  |  |
| --- | --- | --- | --- |
| How much of the grass’s energy come from AIR? | All or most | Some | None |
| How much of the grass’s energy come from SUNLIGHT? | All or most | Some | None |
| How much of the grass’s energy come from WATER? | All or most | Some | None |
| How much of the grass’s energy come from SOIL NUTRIENTS? | All or most | Some | None |

Explain your choices. How does the grass get its energy?

4. A mature oak tree can have a mass of 500 kg, or more, even after all the water in the tree is removed. Yet it starts from an acorn that weighs only a few grams. Where did this huge increase in mass come from?

Which of the following statements is true? Circle the letter of the correct answer.

a. ALL of the increase in mass came from matter that was originally outside the tree, OR

b. SOME of the increase in mass came from matter that the tree made as it grew.

Circle the best choice to complete each of the statements about possible sources of mass from outside the tree.

|  |  |  |  |
| --- | --- | --- | --- |
| How much of the increase in dry mass comes from the AIR? | All or most | Some | None |
| How much of the increase in dry mass comes from SUNLIGHT? | All or most | Some | None |
| How much of the increase in dry mass comes from WATER? | All or most | Some | None |
| How much of the increase in dry mass comes from SOIL NUTRIENTS? | All or most | Some | None |

Explain your choices. How does the oak tree gain mass as it grows?

5. When a tree is alive it has energy stored in its living parts (roots, trunk, branches and green leaves). When the tree dies all the parts are still there (including fallen brown leaves). How much of the energy stored in the living tree is still there in the dead tree?

a. ALL of the energy

b. MOST of the energy

c. SOME of the energy

d. A LITTLE of the energy

e. NONE of the energy

Explain your answer.

What kinds of energy are stored in the living tree? Where did they come from?

What kinds of energy are stored in the dead tree (if any)? How are they connected to the energy in the living tree?

### Assessing the Pretest

*We recommend that you NOT grade the pretest. Encourage your students to express their ideas, then look at their tests to assess what they understand about plants. Level 4 (correct) responses to the questions are in blue bold italics below.*

|  |  |  |
| --- | --- | --- |
| 1. Answer these questions about what happens when a plant grows. | Do you think that **materials** (solids, liquids, or gases) are going into the plant? (circle one answer below)  ***Yes*** No I’m not sure | Do you think that **energy** is going into the plant? (circle one answer below)  ***Yes*** No I’m not sure |
| What **materials** do you think are going into the plant?  ***Carbon dioxide, oxygen, water, minerals from the soil*** | What forms of **energy** do you think are going into the plant?  ***Light energy*** |
|  | Do you think that **materials** (solids, liquids, or gases) are coming out of the plant? (circle one answer)  ***Yes*** No I’m not sure | Do you think that **energy** is coming out of the plant? (circle one answer below)  ***Yes*** No I’m not sure |
| What **materials** do you think are coming out of the plant?  ***Carbon dioxide, oxygen, water*** | What forms of **energy** do you think are coming out of the plant?  ***Heat energy*** |
| How do you think that **materials** are changing inside the plant?  ***CO2 is transformed to glucose during photosynthesis. Glucose is transformed to larger organic molecules called polymers (starch, carbohydrate, fats, proteins) during biosynthesis. Glucose is transformed to CO2 and water during respiration.*** | How do you think that **energy** is changing inside the plant?  ***Light energy from the sun is taken into the plant during photosynthesis and stored in the C-H and C-C bonds of glucose during photosynthesis. This chemical energy can either be stored in organic molecules, or released as heat energy when glucose is used during cellular respiration.*** |
|  | What are you **not sure about** in your answers? Explain what you need to know to answer these questions better. | |

2. Answer these true-false questions:

***True*** False Carbon is a kind of atom.

True ***False*** Carbon is a kind of molecule.

***True*** False There is carbon in a tree’s leaves.

***True*** False There is carbon in a tree’s roots.

***True*** False There is carbon in the wood of a tree’s trunk.

3. Grass needs energy to live and grow. How does it get its energy?

Which of the following statements is true? Circle the letter of the correct answer.

a. ***ALL of the grass’s energy came originally from sources outside the plant*,** OR

b. SOME of the grass’s energy was made by the plant as it grew.

Circle the best choice to complete each of the statements about possible sources of energy from outside the grass.

|  |  |  |  |
| --- | --- | --- | --- |
| How much of the grass’s energy come from the AIR? | All or most | Some | ***None*** |
| How much of the grass’s energy come from the SUNLIGHT? | ***All or most*** | Some | None |
| How much of the grass’s energy come from the WATER? | All or most | Some | ***None*** |
| How much of the grass’s energy come from the SOIL NUTRIENTS? | All or most | Some | ***None*** |

Explain your choices. How does the grass get its energy?

***Grass gets its energy from the sun. This comes in the form of light energy and is transformed to chemical energy in the plant during photosynthesis. The energy is stored in high energy C-H and C-C bonds in organic molecules in the plant’s body.***

4. A mature oak tree can have a mass of 500 kg, or more, even after all the water in the tree is removed. Yet it starts from an acorn that weighs only a few grams. Where did this huge increase in mass come from?

Which of the following statements is true? Circle the letter of the correct answer.

a. ***ALL of the increase in mass came from matter that was originally outside the tree***, OR

b. SOME of the increase in mass came from matter that the tree made as it grew.

Circle the best choice to complete each of the statements about possible sources of mass from outside the tree.

|  |  |  |  |
| --- | --- | --- | --- |
| How much of the increase in dry mass comes from the AIR? | ***All or most*** | Some | None |
| How much of the increase in dry mass comes from SUNLIGHT? | All or most | Some | ***None*** |
| How much of the increase in dry mass comes from WATER? | All or most | ***Some*** | None |
| How much of the increase in dry mass comes from SOIL NUTRIENTS? | All or most | ***Some*** | None |

Explain your choices. How does the oak tree gain mass as it grows?

***The majority of a plant’s mass comes from CO2 it takes from the air. During photosynthesis, the carbon is transformed from CO2 into organic molecules that are used to build the mass of the plant. A very small, trace amount of the plant’s mass comes from nutrients in the soil, but most of the mass comes from the air.***

5. When a tree is alive it has energy stored in its living parts (roots, trunk, branches and green leaves). When the tree dies all the parts are still there (including fallen brown leaves). How much of the energy stored in the living tree is still there in the dead tree?

a. ***ALL of the energy***

***b. MOST of the energy***

c. SOME of the energy

d. A LITTLE of the energy

e. NONE of the energy

Explain your answer.

What kinds of energy are stored in the living tree? Where did they come from?

***The tree stores chemical potential energy in the bonds of the organic molecules in the leaves, trunk, and roots of the tree. This energy remains in the dead tree until decomposition occurs and the decomposers release the energy as heat during cellular respiration.***

What kinds of energy are stored in the dead tree (if any)? How are they connected to the energy in the living tree?

***Potential chemical energy is stored in the bonds of the organic molecules that make up the mass of the tree. This is the same energy that was stored in the living tree.***

## Activity 2: Plant Growth Initial explanations and Predictions

**Learning Objective:**

1. Express ideas about movement and transformation of atoms, carbon, and energy when a plant grows before results are known.

**Duration**: 20 minutes

**Activity Description**:

Students record their initial ideas about movement, carbon, and energy during plant growth. These ideas serve as a starting place for assessment and will be revisited when the investigation ends.

**Background Information:**

Students may begin this unit thinking that plants build the majority of their mass from minerals and nutrients in the soil. Although atoms from soil minerals and water contribute trace amounts of materials during biosynthesis (e.g., nitrogen, potassium, and phosphorous from the soil and hydrogen from the water), the majority of biomass is built from carbon from CO2 in the air. By growing plants from seed and taking measurements of plant dry mass and soil dry mass, this investigation gives students evidence that plants do not build their mass from soil or water. Lessons 2 (Photosynthesis), Lesson 3 (Biosynthesis), and Lesson 5 (Respiration) gives students further evidence that plants build their mass from materials they get from the air.

**Materials:**

* Plant growth and movement time lapse videos:

<http://www.youtube.com/watch?v=d26AhcKeEbE>, <http://www.youtube.com/watch?v=so8LdhbfddQ>

* Three Questions Poster

*Per Student*

* Plant Growth Investigation Initial Explanations and Predictions Worksheet
* Optional: Individual Process tool with Three Questions

**Directions:**

1. **Discuss the pre-test.**

Ask students if they had any questions about the pre-test they would like to discuss.

1. **Recall the investigation set up from 4 weeks ago**.

Pass out Plant Investigation Checklist and Plant Investigation Data Table that students completed during the pre-lesson 4 weeks earlier. Review what they did and discuss visible changes in the plants.

1. **Watch a time-lapse video of plants growing and moving.**

Ask students as they are watching to think about what is happening to atoms, carbon, and energy in the plant as it is growing and moving. What materials and energy help the plant grow? What materials and forms of energy help the plant move? How does the plant make this happen?

1. **Remind students of the Three Questions:**Show students the Three Questions Poster (from the *Systems and Scale* unit) and/or ask them to get out their Three Questions Handout (from the *Systems and Scale* unit; also reproduced below). Review the questions, rules to follow, and evidence to look for (all three columns) of the poster. Remind the students that a scientific explanation for plant growth should include answers to the three questions that follow the rules.
2. **Record initial predictions and explanations about plant growth.**

Pass out Plant Growth Investigation Initial Explanations and Predictions Worksheet. Have students complete their predictions and investigations for the movement, carbon, and energy questions on the worksheet individually. Collect and save the worksheets. These can be used for formative assessment.

1. **Transition to Activity 3.**

Tell students we will save their initial ideas and revisit them after the plants have been harvested and we have a chance to discuss results.

### The Three Questions: Explaining Matter and Energy in Combustion and Life

Scientific explanations of processes include answers to three questions:

|  |  |  |
| --- | --- | --- |
| **Question** | **Rules to Follow** | **Evidence to Look For** |
| **The Movement Question: Where are atoms moving?**  Where are atoms moving from?  Where are atoms going to? | **Atoms last forever** in combustion and living systems  All materials (solids, liquids, and gases) are made of atoms | When materials change mass, atoms are moving  When materials move, atoms are moving |
| **The Carbon Question: What is happening to carbon atoms?**  What molecules are carbon atoms in before the process?  How are the atoms rearranged into new molecules? | Carbon atoms are bound to other atoms in molecules  **Atoms can be rearranged to make new molecules** | The air has carbon atoms in CO2  Organic materials are made of molecules with carbon atoms   * Foods * Fuels * Living and dead plants and animals |
| **The Energy Question: What is happening to chemical energy?**  What forms of energy are involved?  How is energy changing from one form to another? | **Energy lasts forever** in combustion and living systems  C-C and C-H bonds have more stored chemical energy than C-O and H-O bonds | We can observe indicators of different forms of energy   * Organic materials with chemical energy * Light * Heat energy * Motion |

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_

### Plant Growth Investigation Initial Explanations and Predictions Worksheet

**Plants Lesson 1, Activity 2**

In this activity you will investigate how a plant grows. On this worksheet, make predictions about mass change and the movement, carbon, and energy questions.

|  |  |
| --- | --- |
| **Predictions about mass changes:**  What objects or materials will *gain* mass during the investigation?  What objects or materials will *lose* mass during the investigation? | **The Carbon Question:** What will happen to carbon atoms as the plant grows? |
| **The Movement Question:** On the picture below, draw arrows to show your ideas about how atoms will be moving as the plant grows.  plant01 | **The Energy Question:** How do you think energy will change from one form to another? |
| Write in words where you think the atoms will be **moving from**.  Write in words where you think the atoms will be **going to**. | **Unanswered questions:** What do you need to learn in order to answer the Three Questions better? |

### Assessing student work on Plant Growth Investigation Initial Explanations and Predictions Worksheet

**Lesson 1, Activity 2**

*Use this to help assess student thinking at the beginning of the lesson.*

|  |  |
| --- | --- |
| **Predictions about mass changes:**  What objects or materials will *gain* mass during the experiment?  *The seeds will gain mass.*  What objects or materials will *lose* mass during the experiment?  *No objects will lose mass.* | **The Carbon Question:** What will happen to carbon atoms as the plant grows?  *L4 students will recognize that CO2 is transformed to glucose during photosynthesis, and that these glucose molecules are transformed to larger organic molecules during biosynthesis. L3 students may understand photosynthesis, but cannot provide complete accounts of how carbon changes. L2 students may suggest that plants gain mass by taking in nutrients from the soil.* |
| **The Movement Question:** On the picture below, draw arrows to show your ideas about how atoms will be moving as the plant grows.  plant01 | **The Energy Question:** How do you think energy will change from one form to another?  *L4 students can tell you that energy taken into the plant comes in in the form of light energy from the sun. This light energy is transformed into chemical potential energy during photosynthesis and stored in the bonds of organic molecules. L3 students may confuse the role of matter and energy in the growth process, saying that matter is turned into energy or vice versa. L2 students may say that plants need and use energy to grow, but have trouble explaining what form the energy is in or where it comes from; L2 students may also be able to repeat that photosynthesis involves energy, but unable to explain what kinds of energy is involved in the process and how energy is transformed.* |
| Write in words where you think the atoms will be **moving from**.  *L4 and L3 students will identify Atoms will be moving from the air. Atoms from the water and micronutrients from the soil will be moving from the ground. L2 students might point only to the soil as a source of atoms coming into the plant.*  In this box, write in words where you think the atoms will be **going to**.  *L4 and L3 students should be able to recognize that atoms are moving out of the leaves of the plant. L2 students may not be able to describe movement out of the plant.* | **Unanswered questions:** What do you need to learn in order to answer the Three Questions better?  *Answers may vary* |

## Optional Activity: Water and Plant Biomass Demonstration

**Learning Objectives:**

1. Distinguish between plant mass (total weight of a plant, including water weight) and plant biomass (weight of plant material only, or dry weight).

**Duration**: 20 minutes (10 minutes in two class periods each, with time in between to allow the carrot and sponge to dry)

**Activity Description:**

The teacher uses the mass of a wet sponge and a dry sponge and a wet carrot and dry carrot to demonstrate the concept of biomass in plants.

**Background Information:**

The water and biomass demonstration is optional, depending on whether this demonstration has already been completed in other units, such as Systems and Scale or Animals. The purpose of the water and biomass demonstration is to reiterate the difference between short-term mass gain by inorganic water and long-term mass gain of organic materials. While water does contribute atoms to building biomass (and consequently, contributes a small percentage to biomass), most of the water found in living organisms only adds to short-term mass gain (i.e., not to biomass). In this activity, students will observe a sponge that is moistened and then dried across a week’s time. The original mass of the sponge material before water was added is the same as the mass of the sponge after the water is removed, allowing for a discussion of how water contributes to mass and the difference between **mass** (weight of the plant with the water) and **biomass** (dry weight).

**Materials:**

* 1 sponge
* 1 digital scale
* 1 fresh carrot
* Water

**Directions:**

1. **Weigh a wet sponge and fresh carrot in front of the class.**

Record the weight of the wet sponge and carrot in a place where students can see. Record this as the MASS of the sponge and carrot.

1. **Allow the sponge and carrot to dry.**

Leave the sponge and carrot in a visible place in the classroom and allow them to dry over a week or more.

1. **Weigh the dry sponge and carrot.**

Record the weight of the dry sponge and dry carrot in the same public space. Record this as the BIOMASS, or DRY MASS of the sponge and carrot.

1. **Discuss the difference between *mass* and *biomass*.**

Ask: What does the dry weights of the sponge and carrot tell us about how water adds mass to plants? Do you think water in our growing plants take adds biomass? Why or why not? At the end of the lesson students should be able to recognize that mass (weight of a plant with water) and biomass (dry weight) are different. When we measure plant growth, we use biomass as an indicator of growth.

## Activity 3: Harvest

**Learning Objectives:**

1. Measure mass changes in plants.

**Duration**: 45 minutes

**Activity Description**:

Students harvest and dry their plants. They record the end mass of the vermiculite and plants in their data table and compare the results to the start mass.

**Background Information:**

Students may begin this unit thinking that plants build the majority of their mass from water and nutrients in the soil (or that they make mass themselves when they grow). Although atoms from soil minerals and water contribute trace amounts of materials during biosynthesis (e.g., nitrogen, potassium, and phosphorous from the soil and hydrogen from the water), the majority of biomass is built from carbon from CO2 in the air. By growing plants from seed and taking measurements of plant dry mass and soil dry mass, this investigation gives students evidence that plants have additional mass (biomass) that does not come from soil or water. Lessons 2 (Photosynthesis), Lesson 3 (Biosynthesis), and Lesson 5 (Respiration) gives students further evidence that plants build their mass from materials they get from the air.

**Materials:**

*General*

* Oven or dehydrator
* Scissors
* Lesson1Harvest.pptx
* PlantsClassResults.xlsx
* PlantsPosters.ppt (optional)

*Per Group*

* Plant Growth Investigation Data Table (started in Pre-Lesson)
* Harvest Checklist
* 1 paper bag
* 1 digital balance
* 1 flat tray, smooth place mat, or piece of paper

**Advance Preparation:**

Plants need to be dried in an oven overnight at no higher than 200°F (60°C). Drying may take up to 24 hours in the oven. If oven space is limited, the samples could be spread on to trays and air-dried over the course of a few days. You can check if a sample is dry by weighing, drying it for another hour, and then weighing it again. The bags are dry when they no longer lose weight. Since drying will likely take more than one night, you may want to start drying (steps 1-4 of the harvest checklist) on a Friday, or plan to have an alternative activity for one day in-between harvest and weighing.

**Directions:**

1. **Recall ideas about how plants gain mass.**

Open Lesson1Harvest.pptx to revisit student ideas about mass gain in plants. Did they think plants gain most of their mass from water? Soil? Use slides 1-2 to recall ideas.

1. **Harvest and dry the plants.**

Distribute Harvest Checklist to each group, and the Plant Investigation Data Table from the Pre-Lesson. After plants have grown for 4 weeks, students will harvest and dry the plants according to the steps in the Harvest Checklist.

1. **Weight the plants.**

After plants have been dried thoroughly, students sort plants from the vermiculite and find the dry weight of the plants, according to steps on the Harvest Checklist.

1. **Record Results.**

Students should record their group results on their group Plant Growth Investigation Data Table. Then, class results should be recorded in PlantsClassResults.xlsx. Alternatively, students can record data on a class poster available in PlantsPosters.ppt (this option might be best if you started a poster in the pre-lesson). Use slides 4-5 in Lesson1Harvest.pptx to guide you through data recording.

1. **Discuss results as a class.**

Use Lesson1Harvest.pptx slides 4-9 to discuss results. Do the numbers show that the plants gained mass? Where did this mass come from? Did the mass come from soil? What evidence do we have to build our conclusions? *Note: if results are not conclusive for some reason (e.g., the plants were not completely dried, there was spillage of vermiculite, etc) you may find it more useful to use the sample data to discuss results. Sample data is located on slides 8-9 of Lesson1Harvest.pptx, PlantsPosters.pptx, and in PlantsClassResults.xlsx. The sample data show that the plant gained more mass than the vermiculite lost which prompts the question: where did this mass come from if not the soil?*

1. **Transition to Activity 4**.

In the next activity, students will have a chance to write their individual observations and explanations about the investigation.

### Harvest Checklist

**Lesson 1, Activity 3**

Follow the procedures below to set up your investigation. Put a check in the box when each material has been obtained and each step has been completed. Write the date completed in the line next to each box.

**Materials (Per Group)**

☐ Your aluminum container with vermiculite and plants (that you started 4 weeks ago)

☐ 1 paper bag

☐ 1 digital Scale

☐ 1 paper clip

☐ 1 empty container for measuring the mass of your plants and vermiculite

☐ Your group’s Plant Growth Investigation Data Table from 4 weeks ago

(Scissors and tweezers are optional)

**Procedure for Harvesting**

1. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Stop watering the plants 1-2 days before harvesting.
2. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Label your paper bag with your group name/number.
3. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Spill the plants and soil into your paper bag. Make sure **all** of the vermiculite goes into the bag. Discard the aluminum tray and wicks. Fold the top of the bag and put the paper clip or staple over the fold to keep the bag closed.
4. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Dry the bags in an oven at no higher than 200°F (60°C) for 12 to 24 hours.
5. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Remove the paper clip from your bag and *very carefully* empty the contents onto a flat, dry surface in your classroom (like a placemat or a tray). Make sure to get all the vermiculite and plants out of the paper bag. Let the plants and vermiculite dry completely. *Note: you may find it easier to cut the paper bag open on the bottom to let the contents spill out.*
6. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Separate your plant material from your vermiculite. *Note: you will not be able to separate them completely. Do the best you can to get the largest chunks of vermiculite off the roots.*
7. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Place an empty container on the digital scale and tare the scale.
8. ☐\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Place all the plant material in the container. Record the plant end mass on your data table.
9. ☐\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Place another empty container on the digital scale and tare the scale. Place all the vermiculite in the container.
10. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Record the vermiculite end mass on your Plant Growth Investigation Data Table.

## Activity 4: Explaining our Results

**Learning Objectives:**

1. Construct arguments that use evidence about mass gain in plants to defend claims about movements of atoms and chemical changes during plant growth and functioning.

**Duration**: 20 minutes

**Activity Description:**

Students construct modified arguments about mass, movement, carbon, and energy using evidence from the plant investigation. They compare their ideas from the beginning of the investigation and note remaining questions.

**Background Information:**

Students may begin this unit thinking that plants build the majority of their mass from minerals and nutrients in the soil. Although atoms from soil minerals and water contribute trace amounts of materials during biosynthesis (e.g., nitrogen, potassium, and phosphorous from the soil and hydrogen from the water), the majority of biomass is built from carbon from CO2 in the air. By growing plants from seed and taking measurements of plant dry mass and soil dry mass, this investigation gives students evidence that plants build additional mass (biomass) that does not come from soil or water. In Lessons 2 (Photosynthesis) and 3 (Biosynthesis) students will learn to explain plants build their mass from materials they get from the air.

**Materials:**

* Observations and Conclusions Worksheet
* How does a plant gain mass? Poster (In PlantsPosters.pptx)

**Directions**:

1. **Introduce the activity.**

Explain that this activity will help them think about their ideas about the predictions they made before the investigation. How have our ideas about atoms, carbon, and energy changed? What questions do we still have?

1. **Hand out copies of** Observations and Conclusions Worksheet

Give students time to complete the worksheet. Tell students they should use evidence from

the plant investigation wherever possible.

1. **Modify Poster/Slides from Pre-Lesson.**

Open the slide/look at poster of initial ideas about plant growth you created as a class in the Pre-Lesson. Go over the ideas in the poster, recalling ideas they developed before the investigation. Modify the poster to reflect new ideas. Big idea: anytime something gains mass, that means atoms are moving.

1. **Whole class sharing.**

Put the How Does a Plant Gain Mass? 3 questions process tool/poster on the wall. Ask students to write some of their ideas from their worksheet on sticky notes and put them on the poster. Look at the ideas on the poster and summarize for the class: what do we know at this point? What parts of our “plant growth” story are still missing?   
***FORMATIVE ASSESSMENT:*** *This is a good opportunity to monitor students’ ideas about how plants change mass. Check in particular for:*

* *A* ***sense of necessity*** *about the Evidence to Look For column on the Three Questions poster: Do students believe that if mass changes, then atoms MUST be moving?*
* *A sense of what the evidence tells them and what it does not tell them. If the plants gain more dry mass than the soil loses, then the dry mass of the plant CANNOT be coming just from soil minerals? Do students understand this argument? Do they also understand that this investigation does not really tell them where the mass IS coming from?*

1. **Looking forward to Lessons 3 and 4.**

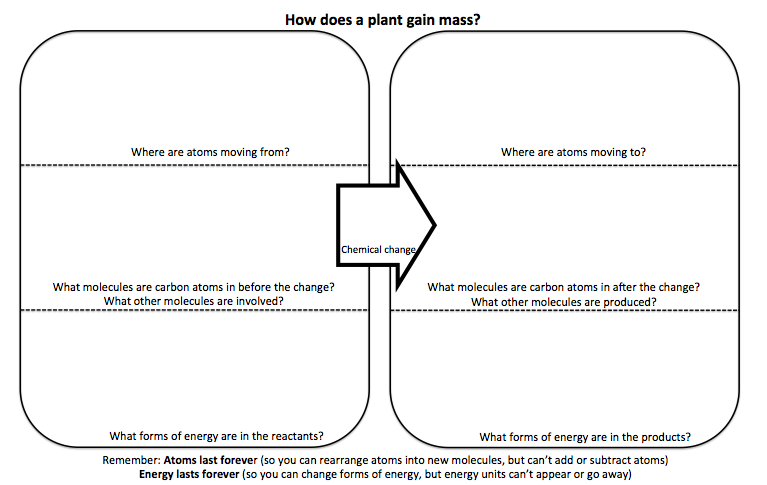
Student ideas about movement, carbon, and energy will still be incomplete at this point. Tell students that the Lesson 3 and 4 will help them answer questions about what happens to atoms, carbon, and energy when a plant grows.

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### Plant Growth Investigation Observations and Conclusions Worksheet

**Lesson 1, Activity 4**

Now that you have conducted the first plant experiment, in each box, write your ideas to answer each question about what happens when a plant gains mass. Note: there may be some boxes that you still don’t know the answer to!



**Question**: Combine your ideas from the graphic and evidence from the plant investigation to explain in words your ideas about how a plant gains mass as it grows.

|  |
| --- |
|  |

**UNANSWERED QUESTIONS:** What questions about movement of atoms, about molecules with carbon atoms, or about changes in forms of energy can you NOT answer based on evidence from the investigation?

|  |
| --- |
|  |

### Assessing Plant Growth Investigation Worksheet

**Lesson 1, Activity 4**

*Students should NOT be expected to have complete explanations at this point. The notes below indicate reasonable conclusions that students might draw based on the evidence from mass changes in the plants and soil.*

### 

**Question**: Combine your ideas from the graphic above to explain in words how a plant gains mass as it grows.

|  |
| --- |
| ***Level 4: A plant gains mass by taking in atoms from the surrounding environment and building its body from these atoms. Carbon atoms are taken in the form of CO2 from the air during photosynthesis. With the help of light energy from the sun during photosynthesis, these carbon atoms are transformed from CO2 into organic molecules in the leaf of the plant. Some of these organic molecules remain in the plant, where they are used to build the body of the plant. Some of the organic molecules are used during cellular respiration, oxidized, and released back into the atmosphere as CO2, a waste product of cellular respiration.***  ***Level 3 students may recognize that plants build mass from the air, soil, and water, but cannot articulate how this happens.***  ***Level 2 students may suggest that plants gain mass by growing, adding cells, using energy, or being alive.*** |

**UNANSWERED QUESTIONS:** What questions about movement of atoms, about molecules with carbon atoms, or about changes in forms of energy can you NOT answer based on evidence from the investigation?

|  |
| --- |
| ***Students will likely not be able to provide complete accounts of the carbon and energy questions. Remember unanswered questions that arise here so they can be addressed in Lessons 3 and 4 where the carbon and energy questions are discussed.*** |

# Lesson 2: Movement, Carbon, and Energy in Photosynethsis

**Role of this Lesson in the Unit Sequence**

Activity 1: Inquiry PEOE: (Predict, Explain, Observe, Explain) for Photosynthesis

Activity 2: Application: Modeling Photosynthesis; Foundational Skills & Knowledge

Activity 3: Application: Coaching Photosynthesis

Activity 4: Photosynthesis Quiz: Application: Fading Photosynthesis

**Time/Duration:**  ~3 hours

Activity 1: Plants in Light Investigation ~60 minutes

Activity 2: Modeling Photosynthesis ~45 minutes

Activity 3: Zooming into a Plant ~60 minutes

Activity 4: Photosynthesis Quiz ~20 minutes

Optional Activity: Famous Studies of Plants ~30 minutes

**Lesson Description:**

Students answer the Three Questions—movement, carbon, and energy—for plants engaging in photosynthesis. A molecular modeling activity helps them visualize how matter and energy are transformed during this process.

**Guiding Questions:**

1. How do atoms move during photosynthesis?
2. How are carbon and energy transformed during photosynthesis?

**Background Information:** This lesson helps middle school and high school students understand something that initially seems impossible—the mass of plants comes mostly from the air! As they model photosynthesis they learn how to explain plant growth in a way that follows the key rules about matter and energy—atoms last forever and energy lasts forever (in chemical changes).

**Lesson 2 Materials**

*For Activity 1*

* Lesson2Photosynthesis.pptx, Slides 1-13
* PlantsClassResults.xlsx OR Results poster (in PlantsPosters.pptx)

*Per Group*

* What is Photosynthesis Checklist
* 2 test tubes with lids
* 1 cup blue BTB
* 1 drinking straw
* 2 sprigs elodea
* 1 marker or pencils
* 2 labels

*Per Student*

* Observations and Conclusions: Plants in the Light Worksheet

*For Activity 2*

* Lesson2Photosynthesis.pptx, Slides 14-34
* Modeling Photosynthesis Checklist
* Process Tool For Molecular Models (in PlantsPosters.pptx)
* Molecular Model Kits, including:
  + 6 carbon atoms
  + 12 hydrogen atoms
  + 18 oxygen atoms
  + 36+ bond links
* 12 Twisty Ties
* 4 energy cards

*For Activity 3*

*General*

* Lesson2Photosynthesis.pptx, Slides 35-52

*Per Student*

* Zooming Into Plants Worksheet

*For Activity 4*

*Per Student*

* Photosynthesis Quiz

*For Optional Activities*

*General*

* FamousStudiesofPlants.pptx

*Per Student*

* Famous Studies of Plants Worksheet

## Activity 1: Plants in the Light Investigation

**Learning Objectives:**

Detect changes in CO2 concentration in plants in the light.

**Duration**: 60 minutes

**Activity Description:** Students conduct an investigation of aquatic plants in the light and discuss how atoms move and how carbon and energy are transformed during photosynthesis.

**Background Information:**

Many students may be familiar with photosynthesis. However, it is likely they do not understand how photosynthesis explains how atoms move and how carbon and energy are transformed during this process. At this point, students should understand that plants cannot get the majority of their dry mass from soil. But if plants don’t get their mass from the soil, where does their mass come from? This investigation suggests another possibility. The results show that plants in the light absorb CO2. The Carbon Question should lead students to wonder: What about the carbon atoms in CO2: Where are they going?

**Materials**:

* Lesson2Photosynthesis.pptx, Slides 1-13
* PlantsClassResults.xlsx OR Results poster (in PlantsPosters.pptx)

*Per Group*

* What is Photosynthesis Checklist
* 2 test tubes with lids
* 1 cup blue BTB
* 1 drinking straw
* 2 sprigs elodea
* 1 marker or pencils
* 2 labels

*Per Student*

* Observations and Conclusions: Plants in the Light Worksheet

**Directions**:

* + - 1. **Recall the movement, carbon, and energy questions.**

Remind students that one of our goals in the unit is to answer how atoms move and how carbon and energy are transformed when a plant grows. Look at the poster on the wall of current ideas: what is missing in our story? Tell students: *there are still unanswered questions in this story. Today, we are going to do an investigation to fill in the gaps in this story.* Slides 1 and 2 of Lesson2Photosynthesis.pptx remind students of the Three Questions and the Rules to Follow in answering them.

* + - 1. **Set up the What is Photosynthesis Investigation.**

Tell students this investigation will help us figure out more about the story. Divide students into groups of 3 or 4. Using the What is Photosynthesis Checklist, model for the students how to set up the investigation. Give them 10 minutes to set up the investigation themselves. Plants should be left under the grow light or in the sun for at least 30 minutes (more if possible).

* + - 1. **Discuss what is in the water and what BTB tells us about materials in water.**

While you are waiting for results, discuss slides 5-9 of Lesson2Photosynthesis.pptx. Key points:

* The water that the plants are in contains many molecules besides H2O, including minerals and dissolved gases from the air. (The role of minerals as plant nutrients will be discussed in Lesson 3.)
* BTB tells about one of those dissolved gases: carbon dioxide.
  + - 1. **Collect test tubes from the light and record results.**

You can record results in the chart in Slide 10 of this activity’s power point Lesson2Photosynthesis.pptx, on a poster that you print to put on the wall from PlantPosters.pptx, or in PlantsClassResults.xlsx (sample data also available here).

* + - 1. **Students record observations and conclusions .**Give students the Observations and Conclusions: Plants in the Light worksheet either for homework or to be done in class.
      2. **Discuss observations and conclusions.**

Use Slides 11-13 to discuss the results and revised answers to the Three Questions with your students. There are two conclusions that they should be able to reach at this point.

* The Carbon Question: Carbon atoms are moving from carbon dioxide into the plant.
* UNANSWERED QUESTIONS: They still do not have evidence about what is happening to carbon atoms inside the plant.

Group: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period: \_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_

### Plants in the Light Investigation Checklist

**Lesson 2, Activity 1**

Follow the procedures below to set up your investigation. Put a check in the box when each material has been obtained and each step has been completed. Write the time completed in the line next to each box.

**Materials (Per Group)**

☐ 2 test tubes

☐ 1 cup BTB

☐ 1 drinking straw

☐ 2 sprigs of Elodea (aquatic plant)

☐ 1 marker or pencil

☐ 2 labels

**Procedure for Set Up**

1. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Label your test tubes with your group name or number.
2. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Put your Elodea into ONE of the test tubes. It should be fairly full, but not too full. 2 sprigs should be enough.
3. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ With a drinking straw, blow CO2 into your cup of BTB until it turns yellow. Remember: BTB turns yellow in the presence of CO2, which you are breathing out.
4. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Fill both of your test tubes with yellow BTB.
5. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Put stoppers into both test tubes.
6. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Place your test tubes under the grow light or in a bright, sunny place outdoors.

**Wait at least 24 hours before getting your plants out of the light.**

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_\_

### Observations and Conclusions: Plants in the Light

**Lesson 2, Activity 1**

**1. Summary of investigation results:** Summarize the pattern that you saw in the class results for plants in the light. What changes in the color of BTB did you see?

**2. Rethinking your answers to the Three Questions.** Explain your answers to the three questions, as well as unanswered questions that you still have.

|  |  |
| --- | --- |
| **The Movement Question: Explaining your predictions about mass changes:** Draw your ideas about how atoms are moving on the picture below. | **The Carbon Question: Explaining your predictions about BTB color changes:** What do you think is happening to molecules that have carbon atoms in them? |
| Where are atoms moving from?  Where are atoms going to? | **The Energy Question: Explaining changes in forms of energy:** How do you think that energy is changing from one form to another? |
| **UNANSWERED QUESTIONS:** What questions about movement of atoms, about molecules with carbon atoms, or about changes in forms of energy can you NOT answer based on evidence from the investigation? | |

5. You collected evidence in your plant growth investigation that plants do not gain biomass from water, and only a very small amount from soil. What new ideas do you have about how a plant gains mass?

|  |
| --- |
|  |

### Assessing the Observations and Conclusions: Plants in the Light

**Lesson 2, Activity 1**

**1. Summary of investigation results:** Summarize the pattern that you saw in the class results for plants in the light. What changes in the color of BTB did you see?

**2. Rethinking your answers to the Three Questions.** Explain your answers to the three questions, as well as unanswered questions that you still have.

|  |  |
| --- | --- |
| **The Movement Question: Explaining your predictions about mass changes:** Draw your ideas about how atoms are moving on the picture below.    *Students should draw arrows showing that CO2 is moving into the plant. They may also add that O2 is moving out of the plant, but there is no evidence of this in the investigation.* | **The Carbon Question: Explaining your predictions about BTB color changes:** What do you think is happening to molecules that have carbon atoms in them?  ***Level 4****: The carbon from the inorganic carbon dioxide was used to make organic glucose molecules. So the carbon was changed from CO2 to C6H12O6*  ***Level 3****: Carbon dioxide came into the plant and was turned into energy and food for the plant (Note: notice the matter-energy conversion here, very typical of Level 3*  ***Level 2****: Photosynthesis breathes in carbon dioxide and lets out oxygen. It breathes like people do, and it breathes in carbon dioxide and gives us oxygen to breathe* |
| Where are atoms moving from?  *Carbon and oxygen atoms are moving from the surrounding BTB.*  Where are atoms going to?  *Carbon and oxygen atoms are going into the plant’s leaves.* | **The Energy Question: Explaining changes in forms of energy:** How do you think that energy is changing from one form to another?  ***Level 4:*** *Light energy from the sun was converted to chemical energy that is stored in the bonds of the glucose molecule in the plant.*  ***Level 3:*** *Light energy is taken in from the sun and converted into food (Note: notice the energy-mass conversion here, typical of Level 3 students).*  ***Level 2:*** *Photosynthesis uses energy from the sun to make food for the plant.* |
| **UNANSWERED QUESTIONS:** What questions about movement of atoms, about molecules with carbon atoms, or about changes in forms of energy can you NOT answer based on evidence from the investigation? | |

5. You collected evidence in your plant growth investigation that plants do not gain biomass from water, and only a very small amount from soil. What new ideas do you have about how a plant gains mass?

|  |
| --- |
| *Level 4 students will recognize that in the plant investigation they learned that water does not contribute to plant dry mass. This means that the bulk of dry mass comes from CO2, which is the input that is used to build sugar that is used to build the plant’s biomass.*  *L3 students will recognize that plants don’t get mass from soil and water and that it comes from air, but may not commit to most of the plant’s mass being built from the air and only some from soil minerals and water. They recognize that photosynthesis creates glucose, but don’t connect the creation of glucose to biomass (this will be covered in more detail in Lesson 4).*  *L2 students may suggest that a plant gains mass from water and soil and that photosynthesis just provides energy for the plant to grow.* |

## Activity 2: Modeling Photosynthesis

**Learning Objectives:**

1. Movement Question: Draw and explain movements of materials in a growing plant, including CO2, O2, H2O, and minerals entering a plant, and CO2, O2, and H2O exiting the plant.
2. Carbon Question: Explain how atoms are rearranged into new molecules in photosynthesis, biosynthesis, and cellular respiration in plants.
3. Energy Question: Explain transformation and conservation of energy during photosynthesis.

**Duration**: 45 minutes

**Activity Description:** Students answer the Carbon Question and the Energy Question for photosynthesis by using molecular model kits, writing a chemical equation, and using the Process Tool.

**Background Information:**

Carbon enters the plant in the form of CO2 from the air. Inside the plant, it is transformed into C6H12O6. (glucose or sugar). Energy enters a plant during photosynthesis in the form of light energy from the sun. This energy is transformed during photosynthesis from light energy into chemical potential energy, and is stored in the bonds of organic molecules that are used to build the plant’s biomass.

**Materials**:

* Lesson2Photosynthesis.pptx, Slides 14-34
* Modeling Photosynthesis Checklist
* Process Tool For Molecular Models (in PlantsPosters.pptx)
* Molecular Model Kits, including:
  + 6 carbon atoms
  + 12 hydrogen atoms
  + 18 oxygen atoms
  + 36+ bond links
* 12 Twisty Ties
* 4 energy cards (below)

**Directions**:

1. **Introduce the Carbon and Energy Questions.**

Use Lesson2Photosynthesis slides 14- 23 to introduce the Carbon and Energy questions. Use the images to recall what is happening to atoms and energy during photosynthesis.

1. **Recall the rules of molecular bonding.**

UseLesson2Photosynthesis.pptx slide 24 to recall the rules of molecular bonding and chemical equations.

1. **Demonstrate how to make molecules using the model kits.**

This should be review from the Systems & Scale unit. Demonstrate for students how to use the molecular model kits by constructing one water molecule and one CO2 molecule. Tie twisty ties on the C-C and C-H bonds. Use slides 5-6 to gives students a visual representation of what they are creating. Slides 25-31 provide images you can use to show students how to use the Process Tool for Molecular Models.

1. **In pairs, students make molecular models of photosynthesis.**

Pass out one copy per group of Modeling Photosynthesis Checklist and give each student a Process Tool for Molecular Models (from PlantsPosters.pptx). Give student pairs10-15 minutes to complete the modeling activity by following steps on the checklist.

1. **Whole class discussion of carbon and energy in photosynthesis.**

After students complete the modeling activity, use slides 32-34 to revisit the carbon and energy questions as a whole class.

1. **Complete Modeling Photosynthesis Checklist.**

Give students 5-10 minutes to complete the questions in their checklist.

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_

### Modeling Photosynthesis: Checklist

**Lesson 2 Activity 2**

Plants photosynthesize when they are in the light. Use the molecular models to figure out carbon and energy change during photosynthesis. First, get the materials. Then, follow the steps in the checklist. Put a check next to each step when you have finished and answer the questions for each step.

Materials

☐ 1 Molecular models poster

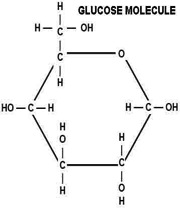
☐ Pieces to make 6 carbon dioxide (CO2) molecules.

☐ Pieces to make 6 water (H2O) molecules.

☐ Energy cards: Light, chemical energy, heat.

☐ 12 twisty ties

Steps

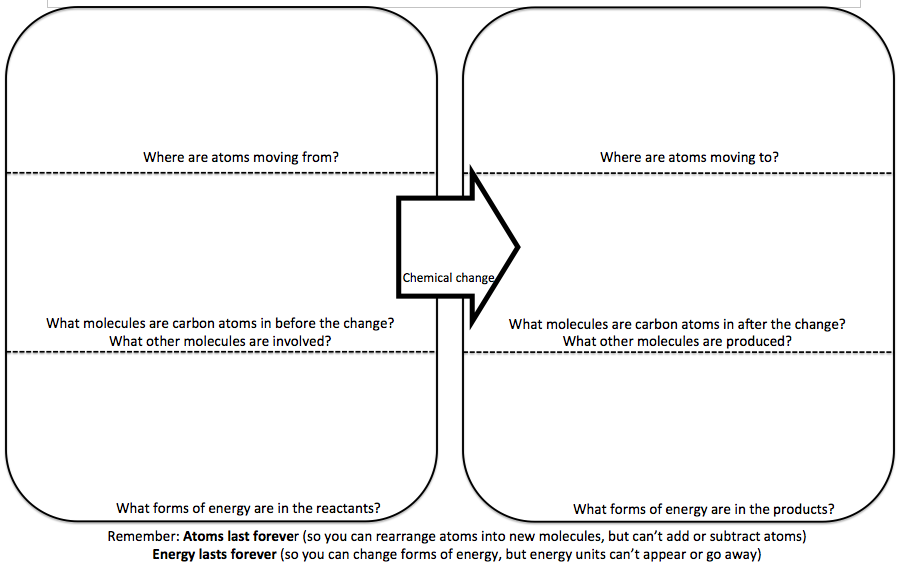
1. ☐ Make models of 6 molecules of carbon dioxide (CO2) and 6 molecules of water (H2O). These are the materials a plant begins with during photosynthesis.
2. ☐ Place your water and carbon dioxide molecules on the “reactants” square on your poster.
3. ☐ Place your twisty ties in the “reactants” square on your poster with a light energy card. These twisty ties represent light energy coming from the sun.
4. ☐ Begin photosynthesis! Take apart your CO2 and H2O molecules and transform them into molecules of C6H12O6 and oxygen (O2). These are the end products that a plant produces after photosynthesis. Remember: **atoms are forever!** You should not need to add or subtract any atoms when you are rearranging the molecules.
5. ☐ Place your glucose and oxygen molecules on the “products” square on your poster.
6. ☐ Add a twisty tie to all the C-C and C-H bonds in the products. These twisty ties represent chemical energy stored in the bonds of the molecules. Put a chemical energy card underneath the glucose molecule.
7. ☐ Use the table below to account for all the atoms and bonds in your models. Write the type of energy for each step of the chemical change.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Matter** | | | **Energy** | |
|  | How many  carbon atoms | How many  oxygen atoms | How many  hydrogen atoms | How many twisty ties? | What forms of energy?  (light, chemical, movement, or heat?) |
| *I Began with…* | | | | | |
| Carbon dioxide |  |  |  |  |  |
| Water |  |  |  |
| Total |  |  |  |  |
| *I Ended with…* | | | | | |
|  | How many  carbon atoms | How many  oxygen atoms | How many  hydrogen atoms | How many twisty ties? | What forms of energy?  (light, chemical, movement, or heat?) |
| Glucose |  |  |  |  |  |
| Oxygen |  |  |  |  |
| Total |  |  |  |  |

1. ☐ How many total atoms did you begin with? \_\_\_\_\_\_\_\_
2. ☐ How many total atoms did you end with? \_\_\_\_\_\_\_\_
3. ☐ Write the complete chemical equation for the photosynthesis reaction:

?CO2 + ?H2O 🡪 C6H12O6 + ?O2

**E. Revising your answers to the Three Questions.** Try revising your answers to the Three Questions using the Process Tool below.



### Assessing the Modeling Photosynthesis: Checklist

**Lesson 2 Activity 2**

Plants photosynthesize when they are in the light. Use the molecular models to figure out carbon and energy change during photosynthesis. First, get the materials. Then, follow the steps in the checklist. Put a check next to each step when you have finished and answer the questions for each step.

Materials

 1 Molecular models poster

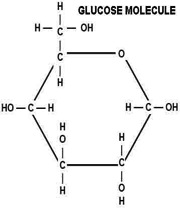
 Pieces to make 6 carbon dioxide (CO2) molecules.

 Pieces to make 6 water (H2O) molecules.

 Energy cards: Light, chemical energy, heat.

 12 twisty ties

Steps

1.  Make models of 6 molecules of carbon dioxide (CO2) and 6 molecules of water (H2O). These are the materials a plant begins with during photosynthesis.
2.  Place your water and carbon dioxide molecules on the “reactants” square on your poster.
3.  Place your twisty ties in the “reactants” square on your poster with a light energy card. These twisty ties represent light energy coming from the sun.
4.  Begin photosynthesis! Take apart your CO2 and H2O molecules and transform them into molecules of C6H12O6 and oxygen (O2). These are the end products that a plant produces after photosynthesis. Remember: **atoms are forever!** You should not need to add or subtract any atoms when you are rearranging the molecules.
5.  Place your glucose and oxygen molecules on the “products” square on your poster.
6.  Add a twisty tie to all the C-C and C-H bonds in the products. These twisty ties represent chemical energy stored in the bonds of the molecules. Put a chemical energy card underneath the glucose molecule.
7. Use the table below to account for all the atoms and bonds in your models. Write the type of energy for each step of the chemical change.

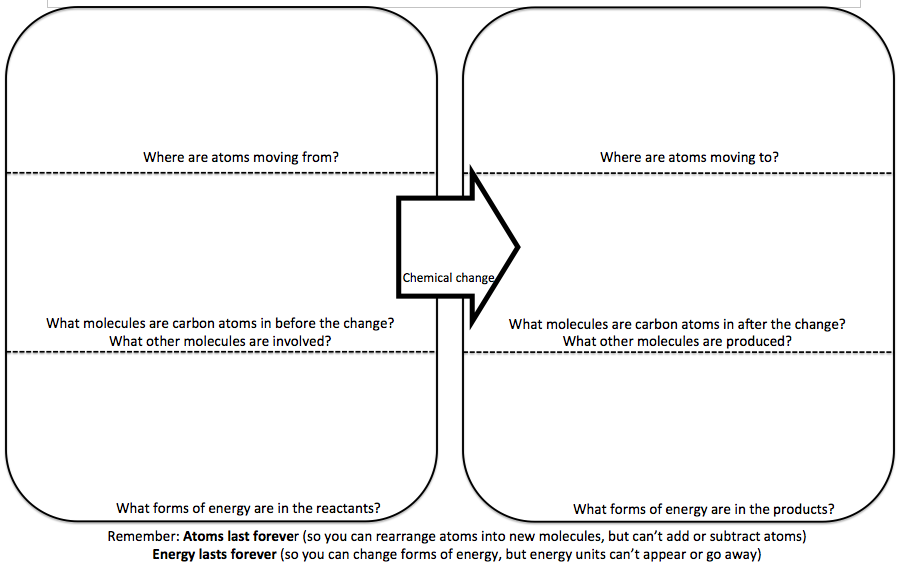
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Matter** | | | **Energy** | |
|  | How many  carbon atoms | How many  oxygen atoms | How many  hydrogen atoms | How many twisty ties? | What forms of energy?  (light, chemical, movement, or heat?) |
| *I Began with…* | | | | | |
| Carbon dioxide | *6* | *12* | *0* | *12* | *Light energy* |
| Water | *0* | *6* | *12* |
| Total | *6* | *18* | *12* | *12* |
| *I Ended with…* | | | | | |
|  | How many  carbon atoms | How many  oxygen atoms | How many  hydrogen atoms | How many twisty ties? | What forms of energy?  (light, chemical, movement, or heat?) |
| Glucose | *6* | *6* | *12* | *12* | *Chemical energy* |
| Oxygen | *0* | *12* | *0* | *0* |
| Total | *6* | *18* | *12* | *12* |

1.  How many total atoms did you begin with? \_\_\_*36*\_\_\_\_\_
2.  How many total atoms did you end with? \_\_\_*36*\_\_\_\_\_
3.  Write the complete chemical equation for the photosynthesis reaction:

?CO2 + ?H2O 🡪 C6H12O6 + ?O2

*6H2O + 6CO2  C6H12O6 + 6O2*

**E. Revising your answers to the Three Questions.** Try revising your answers to the Three Questions using the Process Tool below.



### Energy Label Cards

|  |  |
| --- | --- |
| **Light Energy** | **Heat Energy** |
| **Work or Motion Energy** | **Chemical Energy** |

## Activity 3: Zooming Into Plants

**Learning Objectives**:

1. Describe plant systems and processes in a hierarchy of scales, including atomic-molecular and macroscopic scales.
2. Describe molecules of key materials in plants, including atmospheric gases, soil minerals, water, and organic materials.

**Duration**: 60 minutes

**Activity Description:**

Students zoom into different parts of a plant and seed, using Powers of Ten, and examine where the carbon and energy is stored in a plant.

**Background Information:**

At macro and micro scales, students are unable to see the carbon and energy that plays such a prominent role in this lesson. Zooming into a plant gives students opportunities to refine their stories about matter and energy in a plant at different scales.

**Materials**:

*General*

* Lesson2Photosynthesis.pptx, Slides 35-52

*Per Student*

* Zooming Into Plants Worksheet

**Directions:**

1. **Discuss what plants look like at different scales.**

Use Lesson2Photosynthesis.pptx, Slides 35-39 to zoom from the large scale down to the microscopic scale in plants.

|  |  |  |
| --- | --- | --- |
| Slide 36: Large Scale   * This slide uses the Powers of Ten poster to look at plants from a Farm perspective, or 103 meters. * Answering the carbon question: Where is the carbon in this picture? Can we see carbon?   *Carbon is in the form of fats, carbohydrates, and proteins in this picture. These are the molecules that make up the leaves.* | Slide 37 Macroscopic:   * At 100 meters (1 meter), we see one individual pea plant. * Answering the Carbon Question: What carbon can we see in this picture?   *(Same as large-scale)* | Slide 38: Macroscopic   * This slide shows a seed, o a close up at the macroscopic level, 10-2 meters. Leaves and seeds are visible. * Answering the Carbon Question: What form of carbon is in these seeds?   *Carbon is in the form of fats, carbohydrates, and proteins in this picture. These are the organic molecules that seeds are made of, all of which are carbon-based.* |

1. **Discuss the molecules that plants are made of.**

Use Lesson2Photosynthesis.pptx, Slides 40-49 to discuss with students the key molecules that plants are made of:

* Slides 40-44 present the three kinds of carbohydrates found in plants—sugars, starches, and fiber (cellulose)—and show where they are on nutrition labels of plant products.
* Slides 45 and 46 present the other most abundant kinds of organic molecules found in plants—fats and proteins.
* Slides 47-49 explain how nutrition labels tell us about other materials in plants—minerals, vitamins, and water—and compare organic molecules in plants.

1. **Students complete and discuss Part A of the worksheet.**

Part A of the Zooming into Plants worksheet asks students to use nutrition labels to analyze the organic matter in foods from four different parts of plants: leaves (spinach), seeds (peanuts), stems (celery—actually leaf petioles, but similar in structure to stems), and roots (carrots). Key points that students should get from their analysis:

* Although the amounts of materials are different, all the parts of plants contain the same kinds of organic materials—mostly carbohydrates, fats, and proteins.
* These materials are made mostly from four kinds of atoms: carbon, oxygen, hydrogen, and nitrogen.

1. **Discuss where the atoms and energy in plant molecules come from**

Use Lesson2Photosynthesis.pptx, Slides 50-52 to discuss with students where atoms and energy in plant molecules come from:

* Slide 50 presents calories as the measure of stored chemical energy in plant molecules.
* Slides 51 and 52 pose the question, then trace atoms and energy from sources outside the plant through photosynthesis and glucose to the molecules in plants

1. **Students complete and discuss Part B of the worksheet.**

Part B of the Zooming into Plants worksheet asks students apply the Rules to Follow for the Three Questions—conservation of matter and energy—to explain where the matter and energy from plant molecules came from. Key points:

* Most of the atoms in plant molecules—C, H, and O—come into the plant in carbon dioxide and water.
* Nitrogen and other soil minerals come in through the plant roots
* The chemical energy in plant organic molecules comes into the plant as sunlight, then is converted to high-energy bonds in glucose.

|  |  |  |
| --- | --- | --- |
| Slide 5: Microscopic   * In this slide, cells and chloroplasts are visible. * Answering the carbon Question: *Where carbon in this picture?*   *Carbon molecules like carbohydrates, proteins, and fats are the molecules that make up the cell walls and chloroplasts in this picture.* | Slide 6: Atomic/Molecular Scale   * Answering the energy question: *Where is the energy stored in these molecules?*   *Glucose molecules are combined with other glucose molecules during biosynthesis to make up larger starch molecules. It is in the bonds of these molecules that the plant’s chemical potential energy is stored.* | Slide 7: Atoms   * Where did the carbon atoms in this starch molecule come from?   *The carbon atoms in this starch molecule came from CO2 in the air.* |
| Slide 8: Bonds   * Answering the Energy Question: *Where is the energy stored in this picture*?   *Finally at the atomic/molecular level we see the bonds where the plant’s energy is stored. Energy is stored in C-H and C-C bonds. A starch molecule contains a lot of energy in its bonds!* |

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### Zooming Into Plants Worksheet

**Lesson 2 Activity 3**

**A. What are plants made of?** Use the nutrition labels below to find out what kinds of organic molecules are in different parts of plants.

|  |  |
| --- | --- |
|  | What kinds of organic molecules do you see in **spinach (plant leaves)**?  What atoms are those molecules made of? |
|  | What kinds of organic molecules do you see in **peanuts (plant seeds)?**  What atoms are those molecules made of? |
|  | What kinds of organic molecules do you see in **celery (plant leaf stems)**?  What atoms are those molecules made of? |
|  | What kinds of organic molecules do you see in **carrots (plant roots)**?  What atoms are those molecules made of? |

**B. Where does the matter and energy in plants come from?**

1. Two construction workers, Luis and Ana, were having a discussion while they were building a log house one day. Ana said, “Isn’t it amazing that the mass of these heavy logs came originally from a gas, carbon dioxide in the air?” Luis couldn’t believe his ears. He said, “There’s no way that the mass of these logs came from the air. Air doesn’t weigh anything. You are absolutely crazy Ana! The mass of these logs came from water and nutrients in the soil.” Do you agree with Ana or Luis? Explain your ideas about what provides most of the mass that makes up a log.

|  |
| --- |
|  |

2. You modeled that photosynthesis is a process where plant cells take inorganic matter (water and carbon dioxide molecules) and rearrange the atoms in these molecules into high-energy organic matter (glucose) plus oxygen. Where do plant cells get energy for this process and how does the energy change during photosynthesis?

|  |
| --- |
|  |

3. Do plants create energy during photosynthesis? Explain why you think they do or do not.

|  |
| --- |
|  |

4. The biomass or organic materials in plants is made mostly of four kinds of atoms. Explain where each kind of atom comes from.

Carbon:

Oxygen:

Hydrogen:

Nitrogen:

### Assessing the Zooming Into Plants Worksheet

**Lesson 2 Activity 3**

**A. What are plants made of?** Use the nutrition labels below to find out what kinds of organic molecules are in different parts of plants.

|  |  |
| --- | --- |
|  | What kinds of organic molecules do you see in **spinach (plant leaves)**?  ***carbohydrates (fiber, sugar), protein***  What atoms are those molecules made of?  ***Carbon, hydrogen, oxygen, nitrogen*** |
|  | What kinds of organic molecules do you see in **peanuts (plant seeds)?**  ***Fat, carbohydrates (fiber, sugar) and protein***  What atoms are those molecules made of?  ***Carbon, hydrogen, oxygen, nitrogen*** |
|  | What kinds of organic molecules do you see in **celery (plant leaf stems)**?  ***carbohydrates (fiber, sugar), protein***  What atoms are those molecules made of?  ***Carbon, hydrogen, oxygen, nitrogen*** |
|  | What kinds of organic molecules do you see in **carrots (plant roots)**?  ***carbohydrates (fiber, sugar), protein***  What atoms are those molecules made of?  ***Carbon, hydrogen, oxygen, nitrogen*** |

**B. Where does the matter and energy in plants come from?**

1. Two construction workers, Luis and Ana, were having a discussion while they were building a log house one day. Ana said, “Isn’t it amazing that the mass of these heavy logs came originally from a gas, carbon dioxide in the air?” Luis couldn’t believe his ears. He said, “There’s no way that the mass of these logs came from the air. Air doesn’t weigh anything. You are absolutely crazy Ana! The mass of these logs came from water and nutrients in the soil.” Do you agree with Ana or Luis? Explain your ideas about what provides most of the mass that makes up a log.

|  |
| --- |
| ***Level 4:*** *I agree with Ana. Photosynthesis takes carbon out of the inorganic molecules in the air and transforms it into organic molecules that are used to build the mass of the log.*  ***Level 3****: Ana is probably right. Photosynthesis makes food for the plant and creates glucose out of sugar OR Luis is probably right, because the plant was doing photosynthesis and it got air that helped the plant grow [****Note: L3 students may be able to discuss the details of photosynthesis, but cannot articulate the connection between the carbon taken from inorganic CO2 and the mass of the plant].***  ***Level 2****: I agree with Luis. Plants grow because of water and nutrients they get from the soil. They take these in from the roots. They need air to grow, but the log isn’t made out of air.* |

2. You modeled that photosynthesis is a process where plant cells take inorganic matter (water and carbon dioxide molecules) and rearrange the atoms in these molecules into high-energy organic matter (glucose) plus oxygen. Where do plant cells get energy for this process and how does the energy change during photosynthesis?

|  |
| --- |
| ***Level 4:*** *Plants take light energy from the sun and transform it into chemical energy that is stored in the bonds of organic molecules in the plant.*  ***Level 3:*** *Plants get light energy from the sun, and they turn energy from the sun into food for the plant.*  ***Level 2:*** *Plants use energy they get from photosynthesis to grow and get bigger. They also need air, water, and soil to grow.* |

3. Do plants create energy during photosynthesis? Explain why you think they do or do not.

|  |
| --- |
| ***Level 4:*** *No. Energy is not created, it is transformed from light energy into chemical energy during photosynthesis.*  ***Level 3:*** *No****.*** *Energy is neither created nor destroyed.*  ***Level 2:*** *Yes. Plants make energy during photosynthesis when they make food and sugar.* |

4. The biomass or organic materials in plants is made mostly of four kinds of atoms. Explain where each kind of atom comes from.

Carbon: ***Carbon comes originally from the CO2 molecules taken from the air during photosynthesis.***

Oxygen: ***Oxygen comes originally from CO2 molecules taken into the plant from the air.***

Hydrogen: ***Hydrogen atoms come from water molecules.***

Nitrogen: ***Nitrogen atoms come from nitrate that is taken in from the soil through the roots.***

## Activity 4: Photosynthesis Quiz

**Learning Objectives**:

1. Movement Question: Draw and explain movements of materials in a growing plant, including CO2, O2, H2O, and minerals entering a plant, and CO2, O2, and H2O exiting the plant.
2. Carbon Question: Explain how atoms are rearranged into new molecules in photosynthesis, biosynthesis, and cellular respiration in plants.
3. Energy Question: Explain transformation and conservation of energy during photosynthesis.
4. Describe plant systems and processes in a hierarchy of scales, including atomic-molecular and macroscopic scales.
5. Describe molecules of key materials in plants, including atmospheric gases, soil minerals, water, and organic materials.

**Duration**: 20 minutes

**Activity Description:**

Students complete a quiz on photosynthesis and how photosynthesis provides matter and energy for plant growth.

**Background Information:**

Students should be able to answer the questions on this quiz if they have successfully completed Activities 1-3 in this lesson.

**Materials**:

*Per Student*

* Photosynthesis Quiz

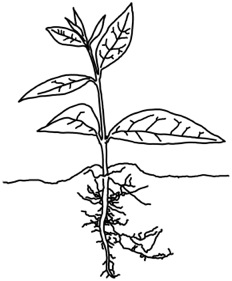
**Directions:**

1. **Students complete the quiz.**

Have students complete the Photosynthesis Quiz, and discuss their responses with them. Note common errors so that you can work on those problems in later lessons.

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Teacher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_

### Photosynthesis Quiz

In this lesson we have studied three questions about movement, carbon, and energy to understand about how a plant gains mass. Use what you have learned in this lesson to answer these questions.

**Part I:** These questions are about how molecules **move** when a plant grows.

1. Draw at least 2 labeled arrows to show which molecules move into the plant as it grows.
2. Draw at least 1 labeled arrow to show which molecules move out of the plant as it grows

**Part II:** These questions are about how a plant gains **mass**.

3. Where do the atoms come from for most of the biomass (organic materials) in the plant? (Circle one)

|  |
| --- |
| Water Soil minerals Air Not Sure |

4. Explain your choice.

**Part III:** These questions are about how **carbon** and **energy** change during photosynthesis.Here is the chemical equation for photosynthesis**:** 6CO2 + 6H2O 🡪 C6H12O6 + 6O2

5. In words (not chemical symbols), describe how carbon is transformed during this process.

|  |
| --- |
|  |

6. In your own words, explain how energy is transformed during this process.

|  |
| --- |
|  |

7. The biomass or organic materials (carbohydrates, fats, and proteins) in plants is made mostly of four kinds of atoms. Explain where each kind of atom comes from.

Carbon:

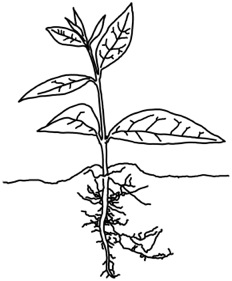
Oxygen:

Hydrogen:

Nitrogen:

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Teacher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_

### Grading the Photosynthesis Quiz

In this lesson we have studied three questions about movement, carbon, and energy to understand about how a plant gains mass. Use what you have learned in this lesson to answer these questions.

**Part I:** These questions are about how molecules **move** when a plant grows.

1. Draw at least 2 labeled arrows to show which molecules move into the plant as it grows.
2. Draw at least 1 labeled arrow to show which molecules move out of the plant as it grows

***Students should draw arrows with CO2 moving into the plant from the air and water moving into the plant from the roots. They should also draw an arrow showing O2 moving out of the plant from the leaves.***

**Part II:** These questions are about how a plant gains **mass**.

3. Where do the atoms come from for most of the biomass (organic materials) in the plant? (Circle one)

|  |
| --- |
| Water Soil minerals ***Air*** Not Sure |

4. Explain your choice.

*Plants build most of their mass from the air, not water. Plants take in water from their roots, but the large organic molecules that plants are built from are made mostly from carbon taken from the air.*

**Part III:** These questions are about how **carbon** and **energy** change during photosynthesis.Here is the chemical equation for photosynthesis**:** 6CO2 + 6H2O 🡪 C6H12O6 + 6O2

5. In words (not chemical symbols), describe how carbon is transformed during this process.

|  |
| --- |
| *Carbon is in the form of inorganic carbon dioxide when it enters the leaves. During photosynthesis, it is transformed into organic glucose or sugar.* |

6. In your own words, explain how energy is transformed during this process.

|  |
| --- |
| *Energy enters photosynthesis in the form of light energy from the sun. During photosynthesis, it is transformed to chemical potential energy that is stored in the bonds of glucose molecules.* |

7. The biomass or organic materials (carbohydrates, fats, and proteins) in plants is made mostly of four kinds of atoms. Explain where each kind of atom comes from.

Carbon: ***Carbon comes originally from the CO2 molecules taken from the air during photosynthesis.***

Oxygen: ***Oxygen comes originally from CO2 taken into the plant from the air.***

Hydrogen: ***Hydrogen atoms come from water molecules.***

Nitrogen: ***Nitrogen atoms come from nitrate that is taken in from the soil through the roots.***

## Optional Activity: Famous Studies of Plants

**Learning Objective:**

1. Synthesize conclusions about plant growth from evidence.
2. Interpret scientific evidence collected over time that tell us what plants are made of.

**Duration**: 30 minutes

**Activity Description:**

Students discuss how studies and evidence of plant growth have evolved over time, beginning with van Helmont’s studies in the 1640’s through Senebier’s work in the late 18th century.

**Background Information**: It is not always possible to conduct firsthand investigations and experiments in class to demonstrate complex scientific principles. But students can examine evidence collected by scientists and see if this evidence supports or contradicts their ideas. While none of these scientists were completely correct in their ideas about plant growth, their findings advanced the field of plant physiology. Each study provides additional evidence for students to consider against their developing models for plant growth.

**Materials**:

* Famous Studies of Plants Worksheet
* FamousStudiesofPlants.pptx

**Directions**:

1. **Recall the results of the plant growth investigation**.

Using PlantsCassResults.xlsx review with students what they found through their Plant Growth Investigation. In particular, point out that the vermiculite did not lose a lot of mass across the investigation even though their plants grown in light gained mass. Tell students that over time many scientists have wondered about where plants get their mass. Tell students that today they will look at experiments scientists have conducted on plant growth and mass gain.

1. **Divide students into groups of 2-3.**

Pass out copies of Famous Studies of Plants Worksheet to each group. Explain to students that they will work in partners or small groups to read about the conclusions of each experiment and then answer questions on their worksheet.

1. **Discuss 4 famous experiments of plants.**

Use FamousStudiesofPlants.pptx to discuss 4 famous experiments of plants. In between each study, have students pause and work in groups to answer the questions on their worksheet that accompany each study.

|  |  |  |
| --- | --- | --- |
| Slide 1: VanHelmont   * Jan Baptiste van Helmont (1640’s)—van Helmont’s studies show that plants gain a lot of mass while soil loses very little mass over time. Van Helmont concluded that water contributes all mass/nutrition to plant.   *Ask students to read this slide and answer questions 1-3 on their worksheet.* | Slide 2: Woodward  Woodward tested van Helmont’s work through a series of studies on plants grown in water (some with additional soil minerals added) and found that plants grow healthier with minerals added. Woodward also found that plants gave off most of the water they take in through transpiration. Woodward concluded that plants get most of their mass/nutrition from soil minerals.  *Ask students to read this slide and answer question 4 on their worksheet.* | Slide 3: Priestly  Joseph Priestley (1770’s)—Priestley did several studies to show that plants change the air around them, finding that over time plants “replenish air” (or produce oxygen).  *Ask students to discuss what evidence Priestly had to come to his conclusions.* |
| Slide 4: Senebeir  Jean Senebier (1790’s)—Senebier did several studies to show that plants take in carbon dioxide and give off oxygen. He placed plants in air with excess carbon dioxide and over several days in sunlight, CO2 levels went down, but O2 levels went up. Senebier concluded that plants “fix” carbon from CO2 and give off the excess O2.  *Students should answer question 5 on their worksheets after discussing the study on this slide.* |

1. **Discuss each experiment as a whole group**.

Concentrate on Study # 1 in comparison to Study #2 and how van Helmont’s data and Woodward’s data relate back to students’ Plant Growth Investigations data. Point out that both scientists found that plants get something—but only a little something—from soil and water. Ask students if they agree with this. Some students may still believe that plants get most of their mass from soil and water, so this is an opportunity to gauge whether the evidence they’ve collected in their own investigation and the experiments they just read about are convincing to them or not.

1. **Review Study #3 (Priestley) and Study #4 (Senebier).**

Discuss the question on students’ worksheet—Can plants get mass from the air? Remind students that in the previous lesson they learned that plants are made of carbon-based organic matter. Ask students if they think it is possible that the carbon in plants comes from the air?

**Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period: \_\_\_\_ Date: \_\_\_\_\_\_\_\_**

### Famous Studies of Plants Worksheet

**Lesson 2 Optional Activity**

Most people would say that plants need water and soil to grow, but they may not know what plants get from these things. Today you will look at several studies on plant growth that happened over the last four centuries. Each study has data you can use to decide what plants get from soil, water, and air. Discuss each study with your classmates, then complete the questions below.

**Reviewing the results of scientists who investigated plant growth**

1. After reading van Helmont’s study, calculate the change in weight of the willow tree and soil.

|  |  |
| --- | --- |
| **WEIGHT CHANGE OF PLANT** | **WEIGHT CHANGE OF SOIL** |
| **\_\_\_\_\_\_\_\_\_\_\_ pounds** | **\_\_\_\_\_\_\_\_\_\_\_ pounds** |

2. Although van Helmont was able to show that plants didn’t simply take mass from the soil, he believed that the plant’s material was somehow composed of water, the only thing he added to the bucket other than soil. What do you think about this idea? Can plant mass come mostly from water?

3. How is van Helmont’s finding similar or different from your findings from your own investigation?

4. van Helmont’s study found that plant mass does not come from soil, but comes from water instead. Woodward’s study found that plants need soil minerals, and that most water does not add mass. Where else might plants get their mass if not from water or soil?

5. Priestley and Senebier found that plants change the air around them and Senebier found that plants take in carbon from carbon dioxide (and give off oxygen). Senebier concluded that some plant mass comes from the air. What do you think of this idea?

### Assessing Famous Studies of Plants Worksheet

Most people would say that plants need water and soil to grow, but they may not know what plants get from these things. Today you will look at several studies on plant growth that happened over the last four centuries. Each study has data you can use to decide what plants get from soil, water, and air. Discuss each study with your classmates, then complete the questions below.

**Reviewing the results of scientists who investigated plant growth**

1. After reading van Helmont’s study, calculate the change in weight of the willow tree and soil.

|  |  |
| --- | --- |
| **WEIGHT CHANGE OF PLANT** | **WEIGHT CHANGE OF SOIL** |
| **\_\_\_\_\_164.3\_\_\_ pounds** | **\_\_\_\_\_1\_\_\_\_ pounds** |

2. Although van Helmont was able to show that plants didn’t simply take mass from the soil, he believed that the plant’s material was somehow composed of water, the only thing he added to the bucket other than soil. What do you think about this idea? Can plant mass come mostly from water?

*No. Water adds to the weight of the plant as a whole, but water itself does not make up the dry biomass of the plant. The cells and materials in the plant are built from Carbon that is taken out of the air which are combined with other atoms to form large organic molecules (during photosynthesis and biosynthesis).*

3. How is van Helmont’s finding similar or different from your findings from your own investigation?

*It is similar in that he noticed that the plant gained mass, but the soil did not lose as much mass as the plant gained. However, he came to incorrect conclusions about the role of water in plant growth.*

4. van Helmont’s study found that plant mass does not come from soil, but comes from water instead. Woodward’s study found that plants need soil minerals, and that most water does not add mass. Where else might plants get their mass if not from water or soil?

*The air*

5. Priestley and Senebier found that plants change the air around them and Senebier found that plants take in carbon from carbon dioxide (and give off oxygen). Senebier concluded that some plant mass comes from the air. What do you think of this idea?

*They’re right! Plants change the air around them by releasing O2, CO2, and water. Mass comes from the Carbon taken out of CO2 in the air.*

# Optional Lesson 3: Movement, Carbon, and Energy in Biosynthesis

**Role of this Lesson in the Unit Sequence**

Activity 1: Application: Establish the problem for biosynthesis

Activity 2: Application: Modeling biosynthesis

Activity 3: Application: Coaching biosynthesis

Activity 4: Application: Fading biosynthesis

Lesson 5 Quiz: Application: Fading biosynthesis

**Time/Duration:** ~2 hours

Activity 1: How can a potato plant make a potato? ~20 minutes

Activity 2: What do water, soil, and air give to plants? ~15 minutes

Activity 3: Modeling Biosynthesis ~30 minutes

Activity 4: Movement, Carbon, and Energy in Biosynthesis ~45 minutes

Activity 5: Biosynthesis Quiz ~20 minutes

**Lesson Description:**

Students develop a story about how matter and energy are taken into the plant during photosynthesis (in the form of high-energy glucose molecules) are transformed into larger organic polymers during biosynthesis.

**Guiding Questions:**

1. How can a potato plant make a potato?
2. What materials move inside a plant?
3. How can plant cells combine small organic molecules with water and minerals to make large organic molecules?

**Background Information:**

During biosynthesis, plants use the atoms in monomers (glucose) and some atoms from the soil (nitrogen) to construct large organic polymers: proteins, fats, and carbohydrates. 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.

**Lesson 3 Materials:**

*For Activity 1*

*General*

* Potato Poster (1 large poster per class, or smaller 11x17 posters)
* Lesson3Biosynthesis.pptx,Slides 1-4

*Per Pair*

* 3 Sticky notes

*For Activity 2*

* Lesson3Biosynthesis.pptx, Slides 5-12

*For Activity 3*

*General*

* Lesson3Biosynthesis.pptx, Slides 13-31

*Per Pair of Students*

* Potato Poster (11x17)
* 10 paper clips
* 1 pair of scissors
* 1 Monomers handout

*For Activity 4:*

*General*

* Movement, Carbon, and Energy in Biosynthesis Worksheet

*For Activity 5:*

* Biosynthesis Quiz

## Activity 1: How Can a Potato Plant Make a Potato?

**Learning Objectives:**

1. Describe molecules of key materials in plant processes, including organic materials.

**Duration:** 20 minutes

**Activity Description:**

Students share ideas about how potato plants could make a potato using molecule cards and a potato poster.

**Background Information:**

Students may wonder why trees are made of wood and other substances and not glucose. Wood is a mixture made of many different substances. The ratio of these substances varies depending on the plant, but in general wood is made of a few key substances—cellulose and lignin. Cellulose can account for more than a third of woody matter (with hemicellulose accounting for even more). Lignin makes up a majority of the rest of wood (often a quarter to a third of dry woody matter). All three of these materials—cellulose, hemicellulose, and lignin—are made of carbon, hydrogen, and oxygen atoms that came originally from glucose. Other plant parts—such as leaves, roots, fruits/seeds—are composed of other substances, including simple sugars, proteins, and starch. Importantly, all of these organic materials are made primarily of three kinds of atoms—CHO—from glucose. Some organic materials (including proteins and nucleic acids like DNA and RNA) contain other kinds of atoms, such as nitrogen and phosphorus. These other atoms come from soil minerals.

Biosynthesis is a carbon-transforming process that uses the atoms from small organic molecules (monomers) to construct large organic molecules (polymers). Glucose, the product of photosynthesis, is the basic building block of biosynthesis. Atoms from glucose molecules and some minerals from the soil are used to create organic monomers, including fatty acids, amino acids, and glycerol. Fatty acids are combined to create fat molecules. Amino acids are combined to create proteins. Glucose molecules are combined to create starches and carbohydrates. This process of biosynthesis is how the plant’s biomass is constructed: the cell walls and organelles of the plant are all made from these polymers created during biosynthesis. Although minerals from the soil (e.g., nitrogen, phosphorous, potassium) contribute a few atoms to polymers (e.g., some proteins contain nitrogen), the majority of these polymers are built from the atoms in glucose molecules, which are built from atoms of CO2 that are taken in during photosynthesis. Bottom line: large organic molecules constructed during biosynthesis are built mainly from atoms that are taken into the plant in the form of CO2 (i.e., plants build their biomass mainly from air).

**Materials:**

*General*

* Potato Poster (1 large poster per class, or smaller 11x17 posters)
* Lesson3Biosynthesis.pptx,Slides 1-4

*Per Pair*

* Molecule cards
* Sticky Notes

**Directions:**

1. **Discuss what potatoes are made of**

Use Slides 1-3 to pose the question: How can a potato plant make a potato. Slides 2 and 3 remind students of what they learned in Lesson 2 about the molecules that all plants are made of.

1. **Collect student ideas about how each part of the plant helps the plant make a potato.**

Show Lesson3Biosynthesis.pptx slide 4. Give students a sticky note. Ask them to write how either the 1) stem, 2) leaves, or 3) roots help the potato plant make a potato. Invite students to put their sticky notes on the poster. When all students have contributed, read through the sticky note ideas to the class and summarize the ideas.

1. **Use molecule cards to demonstrate how a plant makes a potato.**

Divide students into pairs. Give each pair a potato poster and a set of molecule cards. Have students show where each molecule enters or originates in a plant by placing the molecules in the appropriate location on the poster. After this is established, have the students show how these molecules move through the plant. Finally, ask students to explain how these molecules are used to make the potato.

***FORMATIVE ASSESSMENT: USING THE THREE QUESTIONS.*** *You should not expect students to be able to tell a complete story at this point, but are they trying to follow the rules on the Three Questions poster? In particular, to they recognize that the atoms in the potato MUST come from somewhere?*

1. **Transition to Activity 3**

Tell students there may still be some unanswered questions about how these molecules get into plants and how they are used to make a potato. In the next activity, we will explore these ideas further.

## Activity 2: What do Soil, air, and water give to plants?

**Learning Objectives:**

1. Describe molecules of key materials in plant processes, including atmospheric gases, soil minerals, water, and organic materials.
2. Draw and explain movements of materials in a growing plant, including CO2, O2, H2O, and minerals entering a plant.

**Duration**: 15 minutes

**Activity Description:**

Students review ideas about plant growth that they studied in Lesson 2 and apply them to growth of a potato as part of a potato plant.

**Background Information**: Plants are composed of materials that they get from water, soil minerals, and air. Given the range of experiences young children may have with plants, it is interesting that most develop the same story about plant growth—that small seeds are planted in soil and, given water, grow into mature plants over the course of weeks and months. Sunlight is also necessary for plants to grow. It is no wonder that most students believe most plant mass comes from soil and water since these are the visible inputs they see given to plants. Students are not completely wrong about soil and water. Much of a plant’s total mass is actually water. This water contributes to short-term mass gain, but most water does not contribute to long-term building of plant biomass. The biomass is carbon-based substances. This carbon does not come from soil or water, but rather from carbon dioxide taken in from the air. Scientists have traced specific carbon atoms (Carbon-14) from glucose back to CO2. Scientists have also shown that most oxygen in glucose comes originally from CO2. The O2 plants give off comes mostly from water. Water does contribute some to biomass, through hydrogen atoms, but most of the atoms from water eventually leave the plant. Some minerals—like nitrogen—do add trace amounts of mass when incorporated into proteins inside the plant.

* **Water**- can potentially contribute oxygen or hydrogen (in reality water contributes only hydrogen atoms).
* **Soil** Minerals-can potentially contribute phosphorus, calcium, magnesium, etc. (note that students may also say oxygen although oxygen in soil is tied up in phosphates and other compounds).
* **Air**—can potentially contribute carbon, oxygen, or hydrogen (in reality plants get their carbon and oxygen atoms from air, but their hydrogen from water).

**Materials**:

* Lesson3Biosynthesis.pptx, Slides 5-12

**Directions**:

1. **Activate prior knowledge.**

Tell students that while we may have some ideas about how a plant uses its food, water, and minerals to make a potato, we still don’t have a complete story. Ask them to offer what they *do* know about how a plant makes a potato.

1. **Review the materials that enter a plant’s roots.**

Display slide 5 of the power point. Ask students which materials enter the plant through the roots. Stress that only water and minerals enter through the roots. Formative Assessment: check to see if there are any students who suggest that plants take in food from their roots (carbon of any kind). If this is the case, be sure to have them identify the types of atoms that enter the roots (use slides 6-8 to do this).

1. **Have students identify the atoms of molecules that enter a plant through its roots.**

Use Slides 6, 7, and 8 to remind students that ONLY water and inorganic minerals enter the potato plant through its roots. In this lesson, we focus on water and nitrogen as the main inorganic materials that enter through the roots.

1. **Review the process of photosynthesis in plant leaves.**

Ask students to share which molecules enter a plant through its leaves. Formative assessment: check to see if there are any students who do not make the connection that the carbon that enters the plant’s leaves is the same carbon that is used to make “food” and also the same carbon that is used to build the plant’s body as it gains mass.

1. **Have students identify the atoms that enter the plant through its leaves.** Use Slides 9-12 to remind students of what materials go into and out of the leaves of the potato plant. Point out that sugar goes out of the leaves to the rest of the plant and ask students for their ideas about what the plant does with the sugar. Be sure to ask about the role of nitrogen in the air: plants do not take nitrogen in from their leaves—this comes in through the roots!
2. **Transition to Activity 3.**

Tell students they will use some of these ideas to show how molecules move on a potato poster in the next activity.

## Activity 3: Modeling Biosynthesis

**Learning Objectives:**

1. Draw and explain movements of materials in a growing plant, including:

* CO2, O2, H2O, and minerals entering a plant
* Glucose, H2O, and minerals moving within a plant, and

2. Explain how atoms are rearranged into new molecules in biosynthesis in plants.

**Duration:** 30 minutes

**Activity Description:**

Students examine the chemical structure of carbohydrates, fats and proteins and then model how these polymers are built from smaller organic monomers using paper clips.

**Background Information:**

Students have learned that photosynthesis builds glucose molecules from carbon in the air. What happens to these glucose molecules once they are in the plant’s cells? Plants rearrange the atoms of glucose, water, and soil minerals to build larger organic molecules: fats, carbohydrates, and proteins. 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 large organic molecules. These large organic molecules (proteins, carbohydrates, and fats) are called polymers. The building blocks of these polymers (amino acids, glucose, fatty acids, and glycerol) are called monomers.

**Materials:**

*General*

* Lesson3Biosynthesis.pptx, Slides 13-31

*Per Pair of Students*

* Potato Poster (11x17)
* 10 paper clips
* 1 pair of scissors
* 1 Molecule Card (below)

**Directions:**

1. **Activate Prior knowledge**

Remind students that we have talked about which molecules come into a plant where, but we still have remaining questions about how these molecules are used to make a potato.

1. **Students put glucose, water, and minerals at their starting points on the plant poster.**

Glucose, water, and soil nutrients are the starting blocks for a plant’s biomass. Use Slide 13 to prompt students to cut up the monomers handout and put glucose and water molecules and nitrate and other minerals ions at their appropriate starting points—leaves for glucose, roots for other materials

1. **Students move glucose, water, and minerals through the plant to the potato.**

Use Slide 14 to prompt students to move their molecules to the potato.

1. **Students convert glucose and minerals to other monomers.**

Use slides 15-23 to discuss with students how the cells inside the potato can make all the monomers—small organic molecules—that they need from glucose and soil minerals.

Use Slide 24 to prompt students to prepare to make polymers by putting their monomers into paper clips. Demonstrate to the class how to make one monomer by putting a monomer square into a paper clip.

|  |  |  |
| --- | --- | --- |
| Slides 15-18: Guiding Question   * Use these slides to introduce the activity: what happens to glucose, water, and minerals once they enter a plant? * How are these things used to build a plant’s biomass?   *Remember: the atoms and energy in a plant all originated from photosynthesis which took carbon from the air and energy from the sun to build high energy glucose molecules.* | Slide 19 and 20:   * Use these slides to introduce monomers and polymers. * Monomers are small organic molecules (glucose, fatty acids, glycerols, amino acids) that are made from atoms in glucose and some minerals from the soil. * Polymers are large organic molecules that are built from monomers.   *Remember: all of the atoms in the polymers comes from atoms in the monomers (and a tiny bit from the soil and water). All of the energy in the bonds of these molecules originally came from light energy from the sun.* | Slides 21-23   * Use these slided to examine the chemical make up of three polymers: fats, proteins, and carbohydreates. * For each polymer, note which monomers it is built from and that its C-C and C-H bonds contain a lot of chemical energy that is passed from the monomers into the polymers.   *This is a good opportunity to check for adherence to the principles of conservation of energy and matter: the energy and matter in these polymers came from somewhere. The materials came from CO2 in the air, and the energy came from light energy from the sun.* |

|  |  |  |
| --- | --- | --- |
| Slides 24-29   * Use these slides to prompt students to build polymers—starch, fat, and protein, from their monomer molecules   *Remember: all of the atoms in the polymers comes from atoms in the monomers (and a tiny bit from the soil and water). All of the energy in the bonds of these molecules originally came from light energy from the sun.* | Slide 30   * Use this slide to make connections between the monomers and polymers on the students’ desks to a real plant. Students use this poster to tell two stories: * How did a carbon atom from the air get into the potato?   How did light energy from the sun end up in chemical energy in the potato? | Slide 31  Use this slide to connect students’ stories with the Carbon and Energy Questions . |

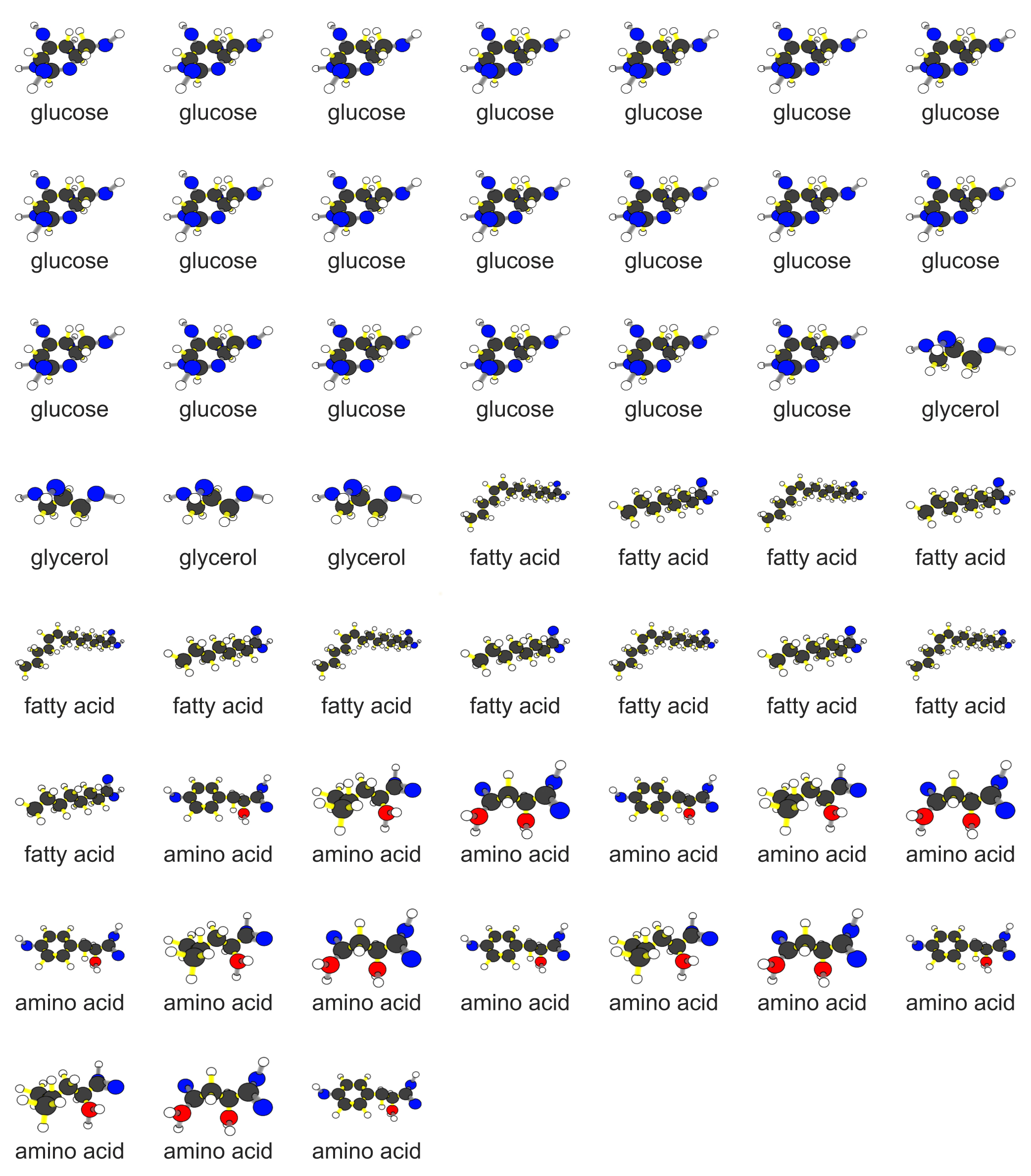
***FORMATIVE ASSESSMENT,*** *When listening to the student’s carbon and energy stories when looking at slide 11, listen for indications of Level 2, 3, and 4 reasoning. Students at level 4 will adhere to the principles of matter and energy conservation: carbon from the air will be traced into glucose and then into the starch molecule. Energy from the sun will be transformed into chemical energy in the bonds of the starch molecule. Level 3 students may confuse the paths of carbon and energy in their story, confusing energy with matter along the way. Level 2 students may imply that the matter and energy in the potato are created as the plant grows, and will be unable to trace the matter and energy from the sun and CO2 into the starch molecules in the potato.*

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### Monomers Handout

**Plants Lesson 3 Activity 3**

Cut out the monomers on the page below with scissors to construct monomers and polymers.

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## Activity 4: Movement, Carbon, and Energy in Biosynthesis

**Learning Objectives:**

1. Draw and explain movements of materials in a growing plant, including:

* CO2, O2, H2O, and minerals entering a plant
* Glucose, H2O, and minerals moving within a plant, and

2. Explain how atoms are rearranged into new molecules in biosynthesis in plants.

3. Explain transformation and conservation of energy during biosynthesis in plants.

**Duration:** 45 minutes

**Activity Description:**

Students combine their ideas from activities in the Biosynthesis lesson into final conclusions and results in preparation for the lesson quiz.

**Background Information:**

The students at this point should have constructed a story about plant growth that includes photosynthesis and biosynthesis. Student ideas here are unlikely to include the final piece of the plant growth story: cellular respiration (coming in lesson 4).

**Materials:**

*General*

* Movement, Carbon, and Energy in Biosynthesis Worksheet

**Directions**:

1. **Recall the three questions.**

Remind students to stick to the rules when answering the questions: atoms are forever! Energy is forever!

1. **Pass out** Movement, Carbon, and Energy in Biosynthesis Worksheet.

Allow students to complete the worksheet in class or for homework.

**Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_**

### Movement, Carbon, and Energy in Biosynthesis Worksheet

**Lesson 3 Activity 4**

Now let’s explain in more detail how atoms move when a plant grows. You will discuss some images in a power point presentation with your class that will answer the questions below.

|  |  |
| --- | --- |
| **Energy:** What molecules involved in biosynthesis have chemical energy?  What happens to that chemical energy during biosynthesis? | **Movement:** Draw arrows to show how carbon atoms and minerals from the soil are used to make large organic molecules in the stem of the plant. **plant01** |
| **Soil:** What kinds of molecules or atoms come come from the soil?  What happens to these molecules or atoms once they enter the plant?  How are the molecules that the plant makes different from the molecules that the plant gets from the soil? |
| **Air:** What kinds of molecules come from the air that are used to build a plant’s mass?  What happens to these molecules once they enter the plant?  How are the molecules that the plant makes different from the molecules the plant gets from the air? | |

### Assessing The Movement and Carbon in Biosynthesis Worksheet

|  |  |
| --- | --- |
| **Energy:** What molecules involved in biosynthesis have chemical energy?  *carbohydrates, fats, and proteins*  What happens to the chemical energy during biosynthesis?  *Chemical potential energy that is stored in the C-C and C-H bonds of monomers is transferred into the bonds of the polymers.* | **Movement:** Draw arrows to show how carbon atoms and minerals from the soil are used to make large organic molecules in the stem of the plant.  *The picture should show the following things going into the plant:*   * *CO2 into leaves* * *Nitrogen into roots* * *Water into roots*   *And the following things moving out of the plant:*   * *O2 from the leaves*   *And the following things moving through the plant:*   * *H2O* * *Sugar/glucose* * *Nitrogen/minerals*   **plant01** |
| **Soil:** What kinds of molecules or atoms come come from the soil?  *Nitrogen, potassium, and phosphorous come from the soil. Water also comes from the soil.*  What happens to these atoms once they enter a plant?  *Once these nutrients get into the plant, they are used during biosynthesis to make larger organic molecules that contain mostly carbon, oxygen, and hydrogen. Water is transferred all over the plant to be used for photosynthesis.*  How are the molecules in the plant different from the molecules that the plant gets from the air?  *Molecules the plant makes are organic (have high energy carbon-hydrogen bonds) and the molecules from the air are inorganic (they do not have C-C or C-H bonds).* |
| **Air:** What kinds of molecules come from the air that are used to build a plant’s mass?  *Carbon dioxide.*  What happens to the molecules once they enter a plant?  *CO2 is used to make sugar during photosynthesis. Then, these sugar molecules are used to build larger organic molecules during biosynthesis.*  How are the molecules that the plant maes different from the molecules the plant gets from the air?  *Atoms in the plant are carbon-based molecules that contain C-H and C-C bonds. The carbon dioxide in the air is inorganic* |

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### Biosynthesis Quiz

1. A student decided to conduct a plant experiment in his backyard. He planted seeds in two pots, made sure they had plenty of water and sun, and allowed them to grow for one year. He weighed the plants and soil at the beginning of the experiment. Here are his data:



1 year

Plant Mass = 3 pounds

Soil Mass = 4.9 pounds

Plant Mass = 1 pound

Soil Mass = 5 pounds

At the end of the experiment, the student concluded that based on his evidence, he thinks that a plant’s biomass is comes mostly from the soil. Are the student’s conclusions correct?

Circle an answer.

|  |
| --- |
| YES NO NOT SURE |

Explain your choice.

|  |
| --- |
|  |

1. Name all the materials from soil, water, or air that plants use to build biomass.

|  |
| --- |
|  |

1. How does the carbon in glucose change during biosynthesis?

|  |
| --- |
|  |

1. Read this dialogue between a teacher and a student:

**Teacher**: How do trees use food to grow?

**Student**: The tree uses food to grow by using the energy in the food to make more branches.

How would you change this student’s answer to make it better?

|  |
| --- |
|  |

### Grading the Biosynthesis Quiz

1. A student decided to conduct a plant experiment in his backyard. He planted seeds in two pots, made sure they had plenty of water and sun, and allowed them to grow for one year. He weighed the plants and soil at the beginning of the experiment. Here are his data:



1 year

Plant Mass = 3 pounds

Soil Mass = 4.9 pounds

Plant Mass = 1 pound

Soil Mass = 5 pounds

At the end of the experiment, the student concluded that based on his evidence, he thinks that a plant’s biomass is built mostly of soil. Is this student’s conclusions correct?

Circle an answer.

|  |
| --- |
| YES ***NO*** NOT SURE |

Explain your choice.

|  |
| --- |
| *Plants get a very small amount of their mass from soil. Most of their mass is built from carbon taken out of the air, which is turned to glucose and then used to build polymers that make up the plant’s mass.* |

1. Name all the materials from soil, water, or air that plants use to build biomass.

|  |
| --- |
| *From soil: nitrates*  *From water: hydrogen*  *From air: carbon, oxygen* |

1. How does the carbon in a glucose molecule change during biosynthesis?

|  |
| --- |
| *Carbon atoms in glucose molecules are used to create polymers like carbohydrates, lipids, and proteins. The carbon is bonded mainly with other carbon, hydrogen, and oxygen atoms to make up the polymers.* |

1. Read this dialogue between a teacher and a student:

**Teacher**: *How do trees use food to grow?*

**Student**: *The tree uses food to grow by using the energy in the food to make more branches.*

How would you change this student’s answer to make it better?

|  |
| --- |
| *Students may suggest that trees use food to grow by transforming glucose (food) into polymers during biosynthesis that make up a plant’s biomass. Light energy is taken from the sun and transformed into chemical energy that is stored in the bonds of monomers and polymers.* |

## 

# Lesson 4: Movement, Carbon and Energy in Cellular Respiration

**Role of Lesson in Unit Sequence**

Activity 1: Inquiry (Predict, Explain, Observe, Explain); Establishing the problem for cellular respiration

Activity 2: Application: Model, Coach, Fade for cellular respiration

**Time/Duration:** ~2 hours

Activity 1: Plants in the Dark Investigation ~60 minutes

Activity 2: Modeling Cellular Respiration in Plants ~45 minutes

**Guiding Questions**:

1. How do plant cells get the energy that they need to grow and function?

**Lesson Description:**

Students gather evidence that shows that plants in the dark give off CO2. This lesson helps answer the reason for this: cellular respiration.

**Background Information:**

When plants engage in cellular respiration they use glucose and oxygen to release CO2 and energy in the form of heat and movement. Before this lesson, students may unaware that plant cells engage in respiration the same as human cells.

**Lesson 4 Materials:**

*For Activity 1*

* Lesson4Respiration.pptx, Slides 1-5
* <http://www.youtube.com/watch?v=so8LdhbfddQ>

Per Pair:

* 2 test tubes with stoppers/caps
* 1 cup blue BTB
* 2 sprigs of aquatic plants
* Labels for test tubes
* Plants in the Dark Investigation Checklist
* Observations and Conclusions: Plants in the Dark Worksheet

*For Activity 2*

* Lesson4Respiration.pptx
* Three Questions poster (11 x 17)
* Using Molecular Models to Show How Plants Can Move worksheet per student
* Process tool for Molecular Models poster (11 x 17) per group of 4 students
* Molecular models and twisty ties: Enough atoms and bonds per pair of students to make a sugar molecule (C6H12O6) and at least 6 oxygen molecules (O2). Per group of 4 students (two packages from the Molecules of Life kit should have enough):

At least 6 carbon atoms (black)

At least 12 hydrogen atoms (white)

At least 18 oxygen atoms (blue)

At least 28 bonds (white plastic tubes)

At least 12 twisty ties

* Potato Poster (11 x 17), per pair of students

## Activity 1: Plants in the Dark Investigation

**Learning Objectives:**

1. Detect changes in CO2 concentration in plants in the dark.
2. Find patterns in data collected by multiple groups about gas exchange in plants.
3. Construct arguments that use evidence about CO2 concentration to defend claims about movements of atoms and chemical changes during plant growth and functioning.

**Duration**: 60 minutes

**Activity Description:** Students conduct an investigation with aquatic plants in the dark and discuss how atoms move and how carbon and energy are transformed during cellular respiration.

**Background Information:**

Students should now be familiar with biosynthesis and photosynthesis, but they are still missing a key piece in the plant story: cellular respiration. Students usually do not think about plants doing cellular respiration. They learn that plants do photosynthesis, and often cellular respiration is overlooked. Students may not even wonder how seeds actually sprout when they have no leaves, no chlorophyll, and no way to photosynthesize. Fully grown plants also undergo cellular respiration on a continuous basis. This is the primary process happening in plants during the night, as well as in winter months, when many trees lose their leaves. During cellular respiration, plants take organic materials and oxidize them, giving off inorganic carbon dioxide and water as wastes. Cellular respiration refers to the process of converting the chemical energy of organic molecules into a form immediately usable by organisms. The process is expressed as:

C6H12O6 + 6O2 🡪 6 H2O + 6 CO2 + energy

All organisms, including plants and animals, oxidize glucose for energy. Often, this energy is used to convert ADP and phosphate into ATP. Some of your students may believe that ATP is a form of energy and not a form of matter, so pay particular attention to how students describe ATP when learning about cellular respiration. ATP is matter with chemical energy stored in the bonds.

**Materials**:

* Lesson4Respiration.pptx, Slides 1-5
* <http://www.youtube.com/watch?v=so8LdhbfddQ>

Per Pair:

* 2 test tubes with stoppers/caps
* 1 cup blue BTB
* 2 sprigs of aquatic plants
* Labels for test tubes
* Plants in the Dark Investigation Checklist
* Observations and Conclusions: Plants in the Dark Worksheet

**Directions**:

1. **Watch time lapse video of plants moving in the dark.**

Watch video (see link above) and ask students what is happening in the movie. Why are plants moving in the dark? Look at the poster on the wall of current ideas: what is missing in our story? Tell students: *there are still unanswered questions in this story that might explain why these plants are able to move in the dark. Today, we are going to do an investigation to fill in the gaps in this story.*

1. **Set up the Investigation.**

Tell students this investigation will help us figure out more about the story. Divide students into groups of 4. Using the Plants in the Dark Investigation Checklist, model for the students how to set up the investigation. Give them 10 minutes to set up the investigation themselves.

1. **Wait 24 hours.**

Plants should be left in the dark for between 24-48 hours. At this point they will not record their predictions, because they are probably unaware of the details of cellular respiration. If you would like to ask them if they have predictions, it may be interesting to hear their ideas at this point.

1. **Bring test tubes out of the dark and record results.**

You can record results in the chart in this activity’s power point Lesson4Respiration.pptx, Slide 4, on a poster that you print to put on the wall from PlantPosters.pptx, or in PlantsClassResults.xlsx (sample data also available here).

1. **Students record observations and explanations.**

Give students the Observations and Conclusions: Plants in the Dark Worksheet either for homework or to be done in class.

1. **Discuss student explanations.**

Use Slide 5 to discuss students’ explanations of the results. Students should observe that the test tube in the dark with the plant turned green or blue, which means that the BTB had an increase in CO2. Why did this happen? Students should be able to conclude that carbon dioxide is moving out of the plant, but they may have unanswered questions about why this is happening. They will be familiar with the fact that photosynthesis removes CO2 from the air, but may be familiar as to why a plant releases CO2 into the air. This is a good lead in to the rest of the lesson, where cellular respiration is explained in more detail.

Group: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period: \_\_\_\_ Date: \_\_\_\_\_\_\_\_

### Plants in the Dark Investigation Checklist

**Lesson 4, Activity 1**

Follow the procedures below to set up your investigation. Put a check in the box when each material has been obtained and each step has been completed. Write the time completed in the line next to each box.

**Materials (Per Group)**

☐ 2 test tubes

☐ 1 cup BTB

☐ 2 sprigs of Elodea (aquatic plant)

☐ 1 marker or pencil

☐ 2 labels

☐ 2-3 drops NaOH (if necessary)

**Procedure for Set Up**

1. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Label your test tubes with your group name or number.
2. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Put your Elodea into ONE of the test tubes. It should be fairly full, but not too full. 2 sprigs should be enough.
3. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Fill both of your test tubes with blue BTB.
4. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Put stoppers into both test tubes.
5. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Label your test tubes with your group number.
6. ☐ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Place your test tubes in a place where they will get NO LIGHT. This might be in a closet that closes completely or in a cupboard under a sink. There should be no holes or openings in the space for light to get in.

**Wait at least 24 hours before getting your plants out of the dark.**

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_\_

### Observations and Conclusions: Plants in the Dark

**Lesson 4, Activity 1**

**1. Summary of investigation results:** Summarize the pattern that you saw in the class results for plants in the dark. What changes in the color of BTB did you see?

**2. Rethinking your answers to the Three Questions.** Explain your answers to the three questions, as well as unanswered questions that you still have.

|  |  |
| --- | --- |
| **The Movement Question: Explaining your predictions about mass changes:** Draw your ideas about how atoms are moving on the picture below. | **The Carbon Question: Explaining your predictions about BTB color changes:** What do you think is happening to molecules that have carbon atoms in them? |
| Where are atoms moving from?  Where are atoms going to? | **The Energy Question: Explaining changes in forms of energy:** How do you think that energy is changing from one form to another? |
| **UNANSWERED QUESTIONS:** What questions about movement of atoms, about molecules with carbon atoms, or about changes in forms of energy can you NOT answer based on evidence from the investigation? | |

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period:\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_\_

### Asssessing Observations and Conclusions: Plants in the Dark

**Lesson 4, Activity 1**

**1. Summary of investigation results:** Summarize the pattern that you saw in the class results for plants in the light. What changes in the color of BTB did you see?

***The BTB changed from yellow to green.***

**2. Rethinking your answers to the Three Questions.** Explain your answers to the three questions, as well as unanswered questions that you still have.

|  |  |
| --- | --- |
| **The Movement Question: Explaining your predictions about mass changes:** Draw your ideas about how atoms are moving on the picture below.    ***Students should draw CO2 leaving the plant.*** | **The Carbon Question: Explaining your predictions about BTB color changes:** What do you think is happening to molecules that have carbon atoms in them?  ***Level 4: The carbon in sugar molecules in the plant is being oxidized and turned into CO2 molecules that are released into the air.***  ***Level 3: Carbon dioxide is released into the air and must come from inside the plant, but I don’t know where.***  ***Level 2: The plant creates carbon dioxide.*** |
| Where are atoms moving from?  ***Atoms are moving from the cells out of the leaves and into the BTB.***  Where are atoms going to?  ***Atoms are moving into the leaves from the BTB.*** | **The Energy Question: Explaining changes in forms of energy:** How do you think that energy is changing from one form to another?  ***Energy is changed from chemical potential energy in the sugar and released as heat and movement.*** |
| **UNANSWERED QUESTIONS:** What questions about movement of atoms, about molecules with carbon atoms, or about changes in forms of energy can you NOT answer based on evidence from the investigation? | |

## Activity 2: Modeling Cellular Respiration In Plants

**Learning Objectives:**

Students will:

* Draw and explain movements of materials during function/movement of a plant, including CO2, O2, water, and minerals entering the plant, and CO2, O2, and water exiting the plant.
* Explain the chemical changes that occur during cellular respiration, representing the changes with molecular models and chemical equations.
* Explain energy transformations during function/movement of a plant: Chemical energy stored in C-C and C-H bonds of organic molecules are transformed into motion and heat.

**Duration**: 45 minutes

**Activity Description:** Students explain the patterns of results in terms of a chemical change: the reaction of sugar and oxygen to produce carbon dioxide and water. They practice describing the chemical change in three different ways: using molecular models, a chemical equation, and the Process Tool.

**Background Information:**

Using energy to move is the macroscopic manifestation of the carbon-transforming processes of cellular respiration. The Movement Question for cellular respiration can be answered as atoms are moving from the plant to the air. The Carbon Question for cellular respiration can be answered as organic carbon in glucose or biomass is rearranged into carbon dioxide. The Energy Question for cellular respiration can be answered as glucose or biomass has chemical energy, but carbon dioxide does not.

**Materials:**

* Lesson4Respiration.pptx
* Three Questions poster (11 x 17)
* Using Molecular Models to Show How Plants Can Move worksheet per student
* Process tool for Molecular Models poster (11 x 17) per group of 4 students
* Molecular models and twisty ties: Enough atoms and bonds per pair of students to make a sugar molecule (C6H12O6) and at least 6 oxygen molecules (O2). Per group of 4 students (two packages from the Molecules of Life kit should have enough):

At least 6 carbon atoms (black)

At least 12 hydrogen atoms (white)

At least 18 oxygen atoms (blue)

At least 28 bonds (white plastic tubes)

At least 12 twisty ties

* Potato Poster (11 x 17), per pair of students

**Directions:**

**1) Remind students of what they know about inputs and outputs of a plant.**

Introduce the activity with the Lesson4Respiration.pptx Slide 6. The new driving question is, “How do plants move?”

**2) Review Important parts of cellular respiration at a macroscopic level.**

Use slides 10-11 and the Potato Poster to discuss the parts of a plant involved in cellular respiration on a macroscopic scale. All parts (all cells) of a plant’s body undergo cellular respiration. The input of oxygen comes in through the leaves. Carbon dioxide and water are released through the leaves as well. Now we will talk about what happens during cellular respiration at an atomic-molecular scale throughout the plant’s body.

**3) Students use molecular models and twisty ties to model reactant molecules: sugar and oxygen.**Pass out molecular models and twisty ties to represent energy to each group. Use Slides 5, 12 and 13 to introduce the task. Students should work in pairs to follow the instructions in Part A of Using Molecular Models to Show How Plants Use Energy to Move worksheet.

**4) Students use molecular models and twisty ties to model changes in matter and energy.**Working in pairs, students model how the atoms of sugar and oxygen can be rearranged into the molecules of the products: carbon dioxide and water. The product molecules have no high-energy bonds, so the chemical energy in sugar is transformed into motion energy and heat. Use Slides 14-16 to introduce the task.

**5) Students account for atoms and energy units and write a balanced chemical equation.** Use Slide 17 to prompt students to account for atoms and write a chemical equation: Parts B and C of the Using Molecular Models to Show How Animals Can Move worksheet. They can compare their equations with the completed equation on Slide 12.

**6) Students use the Process Tool to explain cellular respiration.**

Students use their new knowledge to complete a scientifically accurate account using the Three Questions for cellular respiration in Part D of the Using Molecular Models to Show How Plants Can Move worksheet. You can use slide 21 and 22 to prompt their work.

**7) Connect atomic-molecular level to macroscopic level.**

Revisit the Potato Poster and have the students practice cellular respiration at a macroscopic scale. The reactant oxygen comes in through the plant’s leaves. Glucose is in the plant from photosynthesis. Cellular respiration occurs in all cells of a plant, including leaves, stem, roots, and potato. Have students move the O2 molecules to the any cell where respiration could occur. The reactant CO2 is released through the leaves of the plant. The reactant H2O is excreted through the leaves as well. Have students move the molecules to represent this process.

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Teacher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_

### Modeling Cellular Respiraton in Plants

**Lesson 4, Activity 2**

**A. Using molecular models to show how plants move.** In order for plants to move, they need energy. Plants get energy from chemical energy stored in sugar molecules that are made during photosynthesis. These molecules contain chemical energy stored in their high-energy bonds: C-C and C-H bonds.

When plants use sugar, they use oxygen (O2) to produce carbon dioxide (CO2) and water (H2O). Since carbon dioxide and water have only low-energy bonds (C-O and H-O), the chemical energy is released as motion and heat. Use the molecular models to show how this happens.

1. Work with your partner to make models of the reactant molecules: sugar and oxygen. Sugar is a carbohydrate. Show how chemical energy is stored in the high-energy bonds of sugar.
   1. ☐ Make models of a sugar molecule (C6H12O6) and oxygen molecules (O2, with a double bond). Plants also use oxygen during respiration, so make at least 6 O2 molecules. Put these molecules on the *reactant* side of the Process Tool for Molecular Models poster.
   2. ☐ Use twisty ties to represent chemical energy. Put a twisty tie around **each** high-energy bond (C-C and C-H bonds) in the sugar molecule. Note how many energy units (twisty ties) there are in the sugar molecule.
2. Show how the atoms of the reactant molecules can recombine into product molecules—carbon dioxide and water—and show how chemical energy is released when this happens.
   1. ☐ Take the sugar and some of the oxygen molecules apart and recombine them into carbon dioxide (CO2) and water (H2O) molecules. Put these molecules on the *product* side of the Process Tool for Molecular Models poster. Some things to notice:
      1. How many oxygen molecules reacted with one sugar molecule? \_\_\_\_\_
      2. How many carbon dioxide molecules were produced? \_\_\_\_\_
      3. How many water molecules were produced? \_\_\_\_\_
   2. ☐ Energy lasts forever, so move the twisty ties to the *product* side of the Process Tool for Molecular Models poster. Carbon dioxide and water have only low-energy bonds (C-O and H-O), so what forms does the chemical energy change into?

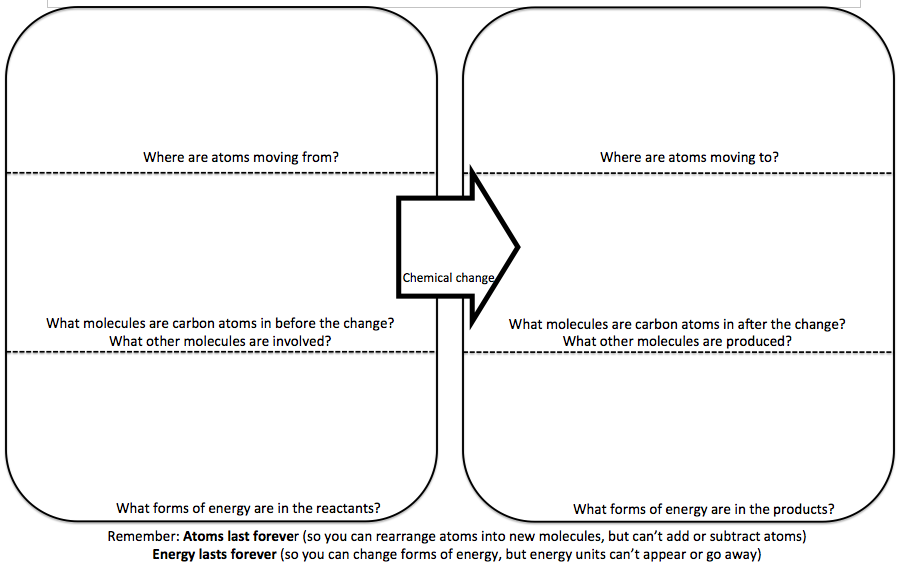
**B. Atoms last forever!!** Check yourself: did your number and type of atoms stay the same at the beginning and end of the chemical change? Use the table below to account for all the atoms and bonds in your models.

**Energy lasts forever!** Write the type of energy for reactants and products in the chemical change.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Matter** | | | **Energy** | |
|  | How many  carbon atoms | How many  oxygen atoms | How many  hydrogen atoms | How many twisty ties? | What forms of energy? |
| *Began with…* |  |  |  |  |  |
| Sugar |  |  |  |  |  |
| Oxygen |  |  |  |  |
| Total in reactants |  |  |  |  |
| *End with…* |  |  |  |  |  |
| Carbon Dioxide |  |  |  |  |  |
| Water |  |  |  |  |
| Total in products |  |  |  |  |

**C. Writing the chemical equation.** Use the molecular formulas (C6H12O6, O2, CO2, H2O) and the yield sign (🡪) to write a balanced chemical equation for the reaction:

**D. Revising your answers to the Three Questions.** Try revising your answers to the Three Questions for CELLULAR RESPIRATION using the Process Tool below. The process is the same for all animals including mealworms and cows.



Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Teacher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_

### Assessing: Modeling Cellular Respiration in Plants

**Lesson 5, Activity 2**

**. Using molecular models to show how plants move.** In order for plants to move, they need energy. Plants get energy from chemical energy stored in sugar molecules that are made during photosynthesis. These molecules contain chemical energy stored in their high-energy bonds: C-C and C-H bonds.

When plants use sugar, they use oxygen (O2) to produce carbon dioxide (CO2) and water (H2O). Since carbon dioxide and water have only low-energy bonds (C-O and H-O), the chemical energy is released as motion and heat. Use the molecular models to show how this happens.

1. Work with your partner to make models of the reactant molecules: sugar and oxygen. Sugar is a carbohydrate. Show how chemical energy is stored in the high-energy bonds of sugar.
   1. ☐ Make models of a sugar molecule (C6H12O6) and oxygen molecules (O2, with a double bond). Plants also use oxygen during respiration, so make at least 6 O2 molecules. Put these molecules on the *reactant* side of the Process Tool for Molecular Models poster.
   2. ☐ Use twisty ties to represent chemical energy. Put a twisty tie around **each** high-energy bond (C-C and C-H bonds) in the sugar molecule. Note how many energy units (twisty ties) there are in the sugar molecule.
2. Show how the atoms of the reactant molecules can recombine into product molecules—carbon dioxide and water—and show how chemical energy is released when this happens.
   1. ☐ Take the sugar and some of the oxygen molecules apart and recombine them into carbon dioxide (CO2) and water (H2O) molecules. Put these molecules on the *product* side of the Process Tool for Molecular Models poster. Some things to notice:
      1. How many oxygen molecules reacted with one sugar molecule? \_\_**6**\_\_\_
      2. How many carbon dioxide molecules were produced? \_\_**6**\_\_\_
      3. How many water molecules were produced? \_\_\_**6**\_\_
   2. ☐ Energy lasts forever, so move the twisty ties to the *product* side of the Process Tool for Molecular Models poster. Carbon dioxide and water have only low-energy bonds (C-O and H-O), so what forms does the chemical energy change into?

**B. Atoms last forever!!** Check yourself: did your number and type of atoms stay the same at the beginning and end of the chemical change? Use the table below to account for all the atoms and bonds in your models.

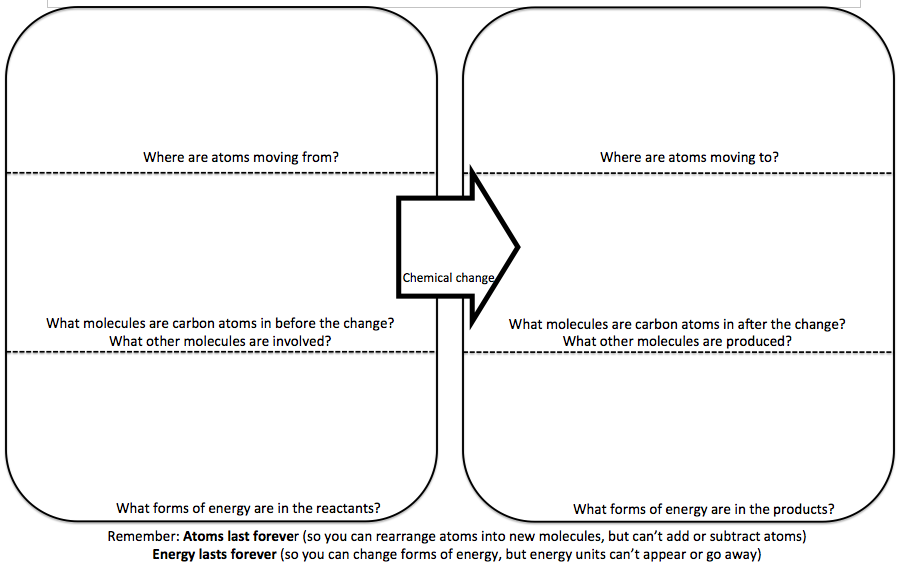
**Energy lasts forever!** Write the type of energy for reactants and products in the chemical change.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Matter** | | | **Energy** | |
|  | How many  carbon atoms | How many  oxygen atoms | How many  hydrogen atoms | How many twisty ties? | What forms of energy? |
| *Began with…* |  |  |  |  |  |
| Sugar | *6* | *6* | *12* | *12* | *Chemical energy* |
| Oxygen | *0* | *12* | *0* | *0* |
| Total in reactants | *6* | *18* | *12* | *12* |
| *End with…* |  |  |  |  |  |
| Carbon Dioxide | *6* | *12* | *0* | *0* | *Motion energy, heat energy* |
| Water | *0* | *6* | *12* | *0* |
| Total in products | *6* | *18* | *12* | *12* |

**C. Writing the chemical equation.** Use the molecular formulas (C6H12O6, O2, CO2, H2O) and the yield sign (🡪) to write a balanced chemical equation for the reaction:

*C6H12O6 + 6O2 🡪 6 CO2 + 6 H2O*

**D. Revising your answers to the Three Questions.** Try revising your answers to the Three Questions for CELLULAR RESPIRATION using the Process Tool below. The process is the same for all animals including mealworms and cows.



*Cow biomass or cow food*

*Air*

*Glucose*

*Carbon dioxide*

*Chemical energy associated with glucose*

*Motion energy and heat energy*

### 

# Lesson 5: Explaining Other Examples of Plant Growth and Functioning

**Role of this Lesson in the Unit Sequence:**

Activity 1: Fading Photosynthesis, Biosynthesis, and Cellular Respiration

Activity 2: (Post-Test)

**Duration:** ~ 45 minutes

Activity 1: Other Examples of Photosynthesis, Biosynthesis, and Respiration ~20 minutes

Activity 3: Plants Unit Post-test ~20 minutes

**Guiding Question:** What happens when plants grow and move?

**Learning Objectives:**

Students will:

* Explain movement of materials, chemical changes, and transformations of energy when other plants grow and move.
* Take a test that assesses key learning objective for the unit

**Lesson Description:**

Students finish the application sequence with the fading stage, by practicing explanations of photosynthesis, biosynthesis and cellular respiration for other plants. Students retake the pretest that they took at the beginning of the unit and assess what they have learned.

**Background Information:**

This activity is the Fading stage of the accounts activity cycle for photosynthesis, biosynthesis and cellular respiration. It serves as formative assessment for you—you will be able to see how well they understood the plant growth investigation and the plants in the light and dark investigation—and gives students additional practice explaining examples with less support than they had during these investigations.

The Post-test is a summative assessment activity. You can track students’ progress by having them retake the unit pre-test as a post-test and comparing the results of the two assessments.

**Lesson Materials:**

*For Activity 1:*

*Other Examples of Photosynthesis, Biosynthesis and Cellular Respiration*

* Lesson5OtherExamples.pptx
* Other Examples of Animals Growing and Using Energy to Move worksheet per student

*For Activity 2*

* Plants Unit Post-Test

## Activity 1: Other Examples of Digestion, Biosynthesis, and Cellular Respiration

**Learning Objectives:**

Students will:

* Explain movement of materials, chemical changes, and transformations of energy when other plants grow and move.

**Duration:** 20 minutes

**Activity Description:**

Students choose—or you choose for them—two examples of other plants growing, then use the forms and procedures they used for the plant growth and plants in the light and dark investigations to explain the carbon transforming process.

**Background Information:**

This activity is the Fading stage of the accounts activity cycle for photosynthesis, biosynthesis and cellular respiration. It serves as formative assessment for you—you will be able to see how well they understood the plant growth and plants in the light and dark investigations—and gives students additional practice explaining examples with less support than they had for these investigations.

Materials:

* Lesson5OtherExamples.pptx
* Other Examples of Plants Growing and Using Energy to Move worksheet per student

**Directions:**

1. **FORMATIVE ASSESSMENT: Discuss general characteristics of photosynthesis, biosynthesis and cellular respiration.** See if your students can articulate a general pattern of what happens when plants grow and use energy to move:
   1. The Materials Question: The food and oxygen enter the animal, carbon dioxide and water vapor leave the animal. In the animal, food molecules move to stomach, and converted into small molecules, and then move to the blood stream, then are re-assembled into animal biomass. Waste leaves the animal.
   2. The Carbon Question: The atoms from CO2 is used to create glucose molecules (photosynthesis), which are either used to assemble larger organic molecules (biosynthesis), or rearranged with atoms of oxygen and hydrogen to release carbon dioxide and water vapor (respiration).
   3. The Energy Question: Light from the sun is stored in high energy C-C and C-H bonds in glucose molecules during photosynthesis. This chemical energy in the bonds of molecules is stored in the molecules in the plant. Energy in these high-energy C-C and C-H bonds can be released as heat and light when the high-energy bonds are replaced by low-energy C-O and H-O bonds during respiration. *Note that breaking bonds* ***requires*** *additional energy. The chemical energy is released when the low-energy C-O and H-O bonds are formed,* ***NOT*** *when the high-energy bonds are broken.*

*Students should be able to articulate the patterns for each of the Three Questions at this point. You can review previous activities if this is difficult for them.*

1. **Present example of other changes when plants grow and move with the class.**

Use the one of the examples below, or one of your own, to work through the Three Questions with the whole class. (For each example, some questions that students should be able to answer by answering the Three Questions are suggested.)

1. The grass is covered with dew when you wake up in the morning to go to school.
2. Morning glories use energy to open their flowers in the morning and close their flowers at night.
3. An acorn is buried by a squirrel. The squirrel can’t find the acorn and it grows into an oak tree. After 10 years, the oak tree weighs more than 500 pounds.
4. Venus fly traps and pitcher plants grow in soil that has little to no nitrogen, but the plants have nitrogen in the proteins of their cells. Where do these plants get the nitrogen they need to build proteins? Why are these plants different from other plants?
5. A venus fly trap shuts to catch a fly.
6. An airline company allows customers to pay for trees to be planted as a “carbon offset.”
7. 1 oz. of peanuts has more calories than 1 oz. of lettuce.
8. A plant from outside is moved into an office with no windows and the plant stops growing.
9. A seed sprouts very far under ground where there is no sunlight.
10. **Two examples of other changes when animals grow and move**

Use the worksheets on the next two pages to have students predict what will happen in two more examples. Use the Lesson5OtherExamples.pptx slide 2 to show students the examples that they can choose from.

1. **Molecular models of chemical change**

(Optional): Use molecular models to show what happens when your plant grows and moves.

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Teacher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_

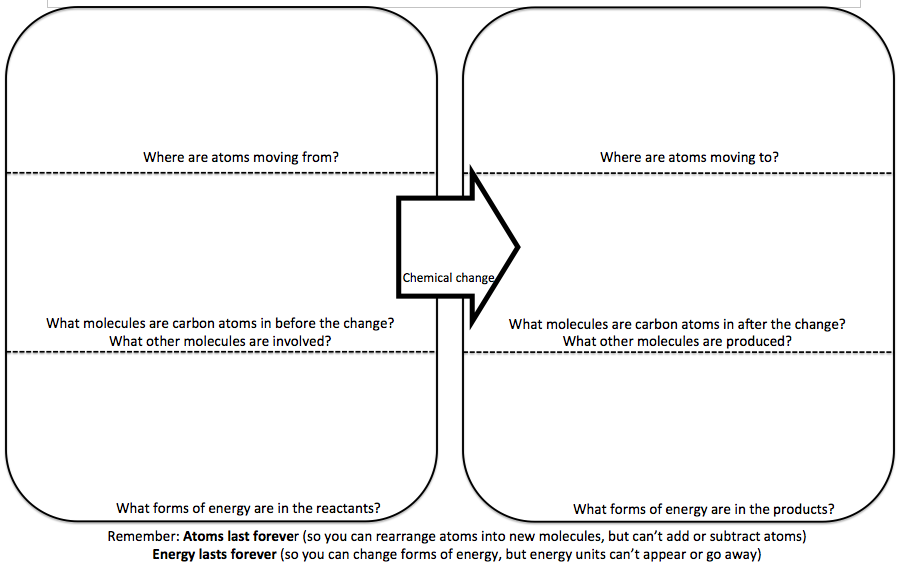
### Other Examples of Plants Growing and Using Energy to Move Worksheet

**Lesson 5, Activity 1**

**Choosing examples.** Choose two examples of plants growing and moving from a list that your teacher will provide.

**A. First example:** What example did you choose? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Answer the Three Questions using the Process Tool below.



**CHECKING YOURSELF:** Does your account follow the rules?

☐ **Atoms last forever:** Do your answers to the questions explain how atoms can move or be rearranged into new molecules, but are not created or destroyed?

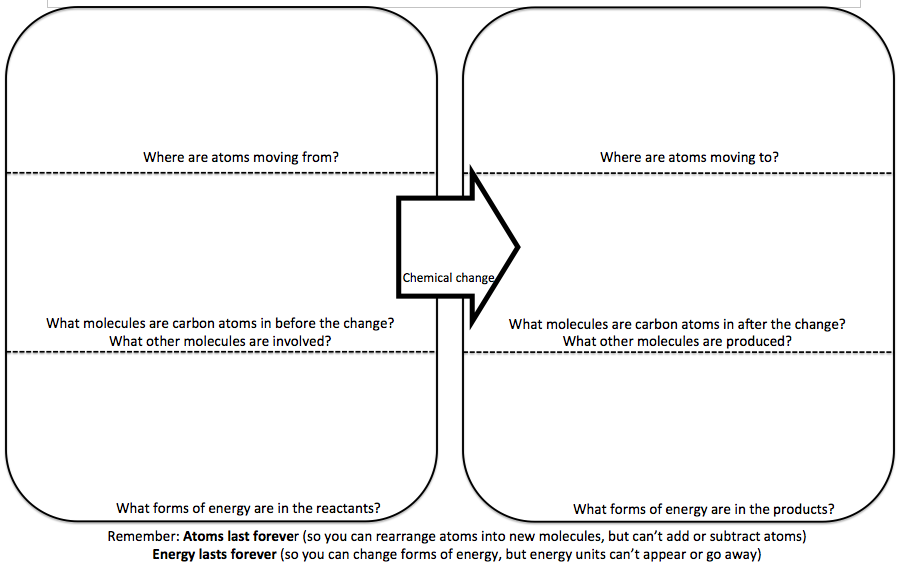
☐ **Energy lasts forever:** Do your answers to the questions explain how energy changes from one form to another, but there is the same amount of energy after the process as before?

**BONUS: Making molecular models.** Make a molecular model of the material you chose and show how it can combine with oxygen to produce the products**.**

**BONUS: Writing the chemical equation.** Use the molecular formulas and the yield sign (🡪) to write a balanced chemical equation for the reaction:

**B. Second example:** What example did you choose? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Answer the Three Questions using the Process Tool below.



**CHECKING YOURSELF:** Does your account follow the rules?

☐ **Atoms last forever:** Do your answers to the questions explain how atoms can move or be rearranged into new molecules, but are not created or destroyed?

☐ **Energy lasts forever:** Do your answers to the questions explain how energy changes from one form to another, but there is the same amount of energy after the process as before?

**BONUS: Making molecular models.** Make a molecular model of the material you chose and show how it can combine with oxygen to produce the products**.**

**BONUS: Writing the chemical equation.** Use the molecular formulas and the yield sign (🡪) to write a balanced chemical equation for the reaction:

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Teacher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_

### Grading Other Examples of Plants Growing and Using Energy to Move Worksheet

**Lesson 5, Activity 1**

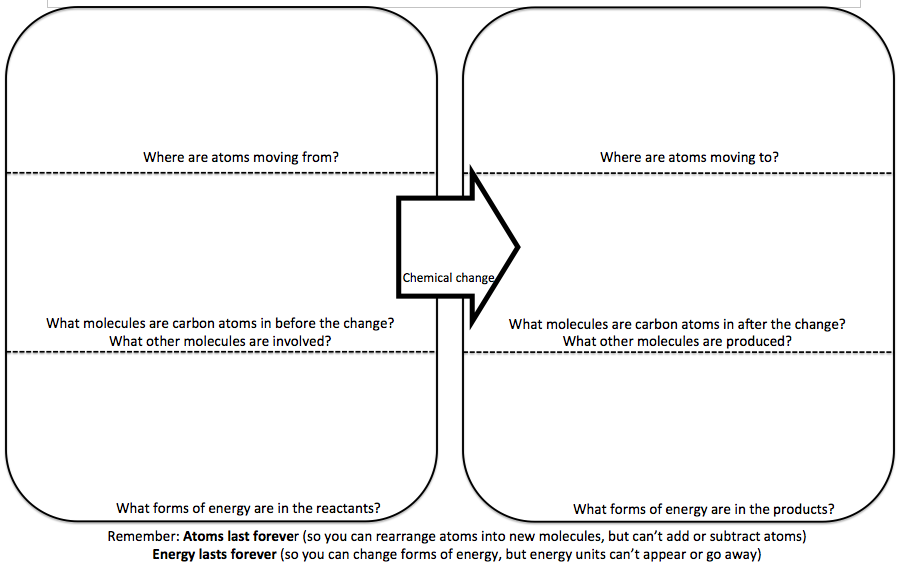
*It is reasonable to grade this assignment. General characteristics of correct responses are in* ***bold blue italics.***

**Choosing examples.** Choose two examples of plants growing and moving from a list that your teacher will provide

**A. First example:** What example did you choose? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Using the Process Tool to answer the Three Questions.** Answer the Three Questions using the Process Tool below.

*For examples that employ photosynthesis (growing):*



*Atoms are moving to the plant cells*

*Atoms are moving from air and soil*

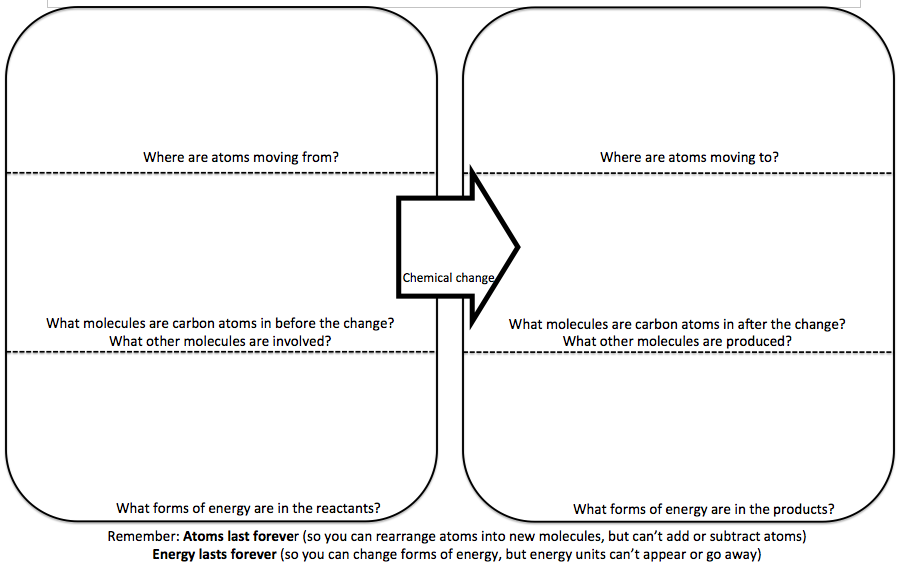
*Carbon atoms are sugars in the plant*

*Carbon atoms are CO2 in the air*

*Chemical energy*

*light energy*

*For examples that employ biosynthesis (growing):*



*Monomers are moving from cells in the leaves*

*To cells in the rest of the plant (leaves, stems, roots, etc)*

*Polymers like starch/carbohydrates, fats, and proteins*

*Glucose, (C6H12O6,) and other monomers, fatty acids, amino acids, and glycerol*

**CHECKING YOURSELF:** Does you account follow the rules?

*Chemical Energy*

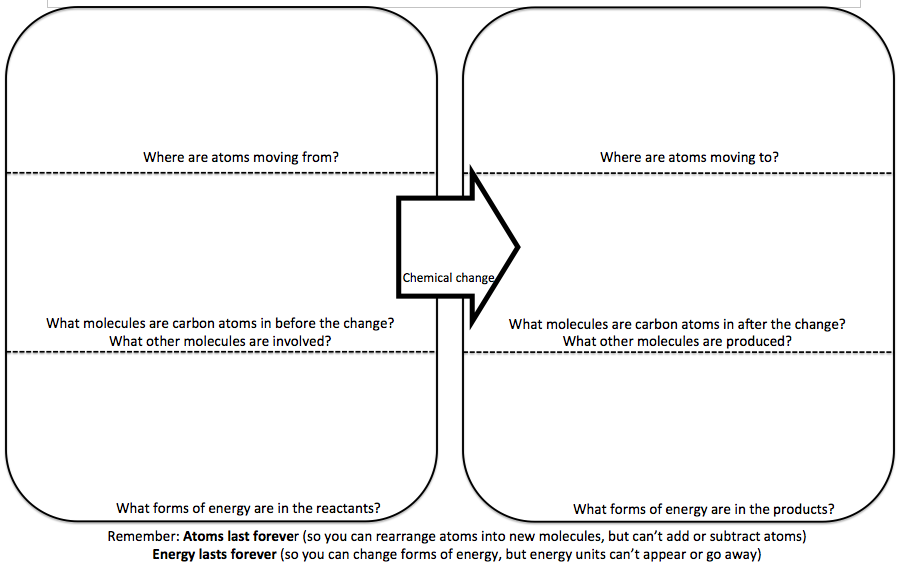
*Chemical Energy*

***Check to be sure that students separate matter and energy in their accounts***

**BONUS: Making molecular models.** Make a molecular model of the material you chose and show how it can combine with oxygen to produce the products**.**

***Some students may be able to make molecular models and write balanced equations, but we do not suggest this as a requirement for all students.***

*For examples that employ cellular respiration (moving):*



*To air from plant (CO2)*

*To air from plant (H2O)*

*CO2 move from the glucose molecules in the plant’s cells*

*Carbon Dioxide*

*Glucose*

**CHECKING YOURSELF:** Does you account follow the rules?

*Chemical energy*

*Glucose, C6H12O6*

*Motion energy, heat energy*

***Check to be sure that students separate matter and energy in their accounts***

**BONUS: Making molecular models.** Make a molecular model of the material you chose and show how it can combine with oxygen to produce the products**.**

***Some students may be able to make molecular models and write balanced equations, but we do not suggest this as a requirement for all students.***

## Activity 2: Unit Post-Test

**Learning Objectives:**

1. Complete the post-test.

**Duration:** 20 minutes

**Activity Description:**

Students take the unit post-test.

**Background Information:**

No background information is needed to administer the post-test.

**Materials:**

* Plants Unit Post-Test

**Directions:**

1. **Pass out** Plants Unit Post-Test to each student.

Remind them to put their initials only on the test (no names).

1. **Students take post test.**

Give students 20 minutes to complete the post test.

Teacher\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date\_\_\_\_\_\_\_ Period \_\_\_\_ Grade \_\_\_\_\_ My Initials: \_\_\_\_ \_\_\_\_ \_\_\_\_

### Plants Unit Post-test

|  |  |  |
| --- | --- | --- |
| 1. Answer these questions about what happens when a plant grows. | Do you think that **materials** (solids, liquids, or gases) are going into the plant? (circle one answer below)  Yes No I’m not sure | Do you think that **energy** is going into the plant? (circle one answer below)  Yes No I’m not sure |
| What **materials** do you think are going into the plant? | What **forms of energy** do you think are going into the plant? |
|  | Do you think that **materials** (solids, liquids, or gases) are coming out of the plant? (circle one answer)  Yes No I’m not sure | Do you think that **energy** is coming out of the plant? (circle one answer below)  Yes No I’m not sure |
| What **materials** do you think are coming out of the plant? | What forms of **energy** do you think are coming out of the plant? |
| How do you think that **materials** are changing inside the plant? | How do you think that **energy** is changing inside the plant? |
|  | What are you **not sure about** in your answers? Explain what you need to know to answer these questions better. | |

2. Answer these true-false questions:

True False Carbon is a kind of atom.

True False Carbon is a kind of molecule.

True False There is carbon in a tree’s leaves.

True False There is carbon in a tree’s roots.

True False There is carbon in the wood of a tree’s trunk.

3. Grass needs energy to live and grow. How does it get its energy?

Which of the following statements is true? Circle the letter of the correct answer.

a. ALL of the grass’s energy came originally from sources outside the plant, OR

b. SOME of the grass’s energy was made by the plant as it grew.

Circle the best choice to complete each of the statements on the next page about possible sources of energy from outside the grass.

|  |  |  |  |
| --- | --- | --- | --- |
| How much of the grass’s energy come from AIR? | All or most | Some | None |
| How much of the grass’s energy come from SUNLIGHT? | All or most | Some | None |
| How much of the grass’s energy come from WATER? | All or most | Some | None |
| How much of the grass’s energy come from SOIL NUTRIENTS? | All or most | Some | None |

Explain your choices. How does the grass get its energy?

4. A mature oak tree can have a mass of 500 kg, or more, even after all the water in the tree is removed. Yet it starts from an acorn that weighs only a few grams. Where did this huge increase in mass come from?

Which of the following statements is true? Circle the letter of the correct answer.

a. ALL of the increase in mass came from matter that was originally outside the tree, OR

b. SOME of the increase in mass came from matter that the tree made as it grew.

Circle the best choice to complete each of the statements about possible sources of mass from outside the tree.

|  |  |  |  |
| --- | --- | --- | --- |
| How much of the increase in dry mass comes from the AIR? | All or most | Some | None |
| How much of the increase in dry mass comes from SUNLIGHT? | All or most | Some | None |
| How much of the increase in dry mass comes from WATER? | All or most | Some | None |
| How much of the increase in dry mass comes from SOIL NUTRIENTS? | All or most | Some | None |

Explain your choices. How does the oak tree gain mass as it grows?

5. When a tree is alive it has energy stored in its living parts (roots, trunk, branches and green leaves). When the tree dies all the parts are still there (including fallen brown leaves). How much of the energy stored in the living tree is still there in the dead tree?

a. ALL of the energy

b. MOST of the energy

c. SOME of the energy

d. A LITTLE of the energy

e. NONE of the energy

Explain your answer.

What kinds of energy are stored in the living tree? Where did they come from?

What kinds of energy are stored in the dead tree (if any)? How are they connected to the energy in the living tree?

### Grading the Posttest

|  |  |  |
| --- | --- | --- |
| 1. Answer these questions about what happens when a plant grows. | Do you think that **materials** (solids, liquids, or gases) are going into the plant? (circle one answer below)  ***Yes*** No I’m not sure | Do you think that **energy** is going into the plant? (circle one answer below)  ***Yes*** No I’m not sure |
| What **materials** do you think are going into the plant?  ***Carbon dioxide, oxygen, water, minerals from the soil*** | What forms of **energy** do you think are going into the plant?  ***Light energy*** |
|  | Do you think that **materials** (solids, liquids, or gases) are coming out of the plant? (circle one answer)  ***Yes*** No I’m not sure | Do you think that **energy** is coming out of the plant? (circle one answer below)  ***Yes*** No I’m not sure |
| What **materials** do you think are coming out of the plant?  ***Carbon dioxide, oxygen, water*** | What forms of **energy** do you think are coming out of the plant?  ***Heat energy*** |
| How do you think that **materials** are changing inside the plant?  ***CO2 is transformed to glucose during photosynthesis. Glucose is transformed to larger organic molecules called polymers (starch, carbohydrate, fats, proteins) during biosynthesis. Glucose is transformed to CO2 and water during respiration.*** | How do you think that **energy** is changing inside the plant?  ***Light energy from the sun is taken into the plant during photosynthesis and stored in the C-H and C-C bonds of glucose during photosynthesis. This chemical energy can either be stored in organic molecules, or released as heat energy when glucose is used during cellular respiration.*** |
|  | What are you **not sure about** in your answers? Explain what you need to know to answer these questions better. | |

2. Answer these true-false questions:

***True*** False Carbon is a kind of atom.

True ***False*** Carbon is a kind of molecule.

***True*** False There is carbon in a tree’s leaves.

***True*** False There is carbon in a tree’s roots.

***True*** False There is carbon in the wood of a tree’s trunk.

3. Grass needs energy to live and grow. How does it get its energy?

Which of the following statements is true? Circle the letter of the correct answer.

a. ***ALL of the grass’s energy came originally from sources outside the plant*,** OR

b. SOME of the grass’s energy was made by the plant as it grew.

Circle the best choice to complete each of the statements about possible sources of energy from outside the grass.

|  |  |  |  |
| --- | --- | --- | --- |
| How much of the grass’s energy come from the AIR? | All or most | Some | ***None*** |
| How much of the grass’s energy come from the SUNLIGHT? | ***All or most*** | Some | None |
| How much of the grass’s energy come from the WATER? | All or most | Some | ***None*** |
| How much of the grass’s energy come from the SOIL NUTRIENTS? | All or most | Some | ***None*** |

Explain your choices. How does the grass get its energy?

***Grass gets its energy from the sun. This comes in the form of light energy and is transformed to chemical energy in the plant during photosynthesis. The energy is stored in high energy C-H and C-C bonds in organic molecules in the plant’s body.***

4. A mature oak tree can have a mass of 500 kg, or more, even after all the water in the tree is removed. Yet it starts from an acorn that weighs only a few grams. Where did this huge increase in mass come from?

Which of the following statements is true? Circle the letter of the correct answer.

a. ***ALL of the increase in mass came from matter that was originally outside the tree***, OR

b. SOME of the increase in mass came from matter that the tree made as it grew.

Circle the best choice to complete each of the statements about possible sources of mass from outside the tree.

|  |  |  |  |
| --- | --- | --- | --- |
| How much of the increase in dry mass comes from the AIR? | ***All or most*** | Some | None |
| How much of the increase in dry mass comes from SUNLIGHT? | All or most | Some | ***None*** |
| How much of the increase in dry mass comes from WATER? | All or most | ***Some*** | None |
| How much of the increase in dry mass comes from SOIL NUTRIENTS? | All or most | ***Some*** | None |

Explain your choices. How does the oak tree gain mass as it grows?

***The majority of a plant’s mass comes from CO2 it takes from the air. During photosynthesis, the carbon is transformed from CO2 into organic molecules that are used to build the mass of the plant. A very small, trace amount of the plant’s mass comes from nutrients in the soil, but most of the mass comes from the air.***

5. When a tree is alive it has energy stored in its living parts (roots, trunk, branches and green leaves). When the tree dies all the parts are still there (including fallen brown leaves). How much of the energy stored in the living tree is still there in the dead tree?

a. ***ALL of the energy***

***b. MOST of the energy***

c. SOME of the energy

d. A LITTLE of the energy

e. NONE of the energy

Explain your answer.

What kinds of energy are stored in the living tree? Where did they come from?

***The tree stores chemical potential energy in the bonds of the organic molecules in the leaves, trunk, and roots of the tree. This energy remains in the dead tree until decomposition occurs and the decomposers release the energy as heat during cellular respiration.***

What kinds of energy are stored in the dead tree (if any)? How are they connected to the energy in the living tree?

***Potential chemical energy is stored in the bonds of the organic molecules that make up the mass of the tree. This is the same energy that was stored in the living tree.***

1. This statement simplifies chemists’ understanding of the nature of chemical potential energy. It would be more accurate to say that chemical potential energy is transformed to light and molecular motion (thermal energy) when organic materials are oxidized. In the Earth’s oxidizing atmosphere, however, reduced materials that can be oxidized are the limiting reactants in most environments, and C-C and C-H bonds signal the presence of reduced carbon and hydrogen. [↑](#footnote-ref-1)