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# K-12 Partnership Lesson Plan

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# *Where Does Plant Mass Come From?*

# *Photosynthesis and respiration in germinating bean seeds*

## Overview

Students will learn the products and reactants of photosynthesis and respiration. They will generate a circular diagram showing the cycle of carbon through carbon dioxide and sugars (the hypothesis). They will generate predictions from this hypothesis that refer to specific treatments in the experiment they will set up. They will set up an experiment with germinating bean seeds in petri plates (with or without water, in the light or in the dark), collect data over two weeks, and analyze the results graphically and verbally.

**Objectives**

At the conclusion of the lesson, students will be able to:

* Explain that respiration causes the loss of dry biomass (sugars)
* Explain that photosynthesis causes the gain of dry biomass
* Understand the carbon (carbohydrates) from carbon dioxide in the atmosphere makes up most of the dry mass of plants

**Length of Lesson**

Two one-hour class periods, separated by about two weeks of bean growing time and one week of bean drying time. During those three weeks, students will need 5-10 minutes each day to check on their beans, and 30 minutes one day to stop the experiment.

**Grade Levels**

High school

**Standards covered (NGSS)**

Disciplinary Core Ideas:

* **HS-LS1-5**: use a model to illustrate how photosynthesis transforms light energy into stored chemical energy
* **HS-LS1-6**: construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or large carbon-based molecules

Cross Cutting Concepts:

* Patterns
* Scale, proportion, and quantity
* Energy and matter in systems

Science and Engineering Practices

* Asking questions and defining problems
* Planning and carrying out investigations
* Analyzing and interpreting data
* Using mathematics and computational thinking
* Engaging in argument from evidence

***Previous Michigan Standards Met:***

* **B1.1B:** evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.
* **B1.1C:** conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measured the desired quantity- length, volume, weight, time interval, temperature- with the appropriate level of precision).
* **B1.1D:** identify patterns in data and relate them to theoretical models
* **B1.1E:** describe a reason for a given conclusion using evidence from an investigation
* **B1.1f**: predict what would happen if the variables, methods, or timing of an investigation were changed
* **B1.1g**: use empirical evidence to explain or critique the reasoning used to draw a scientific conclusion or explanation
* **L2.p1B**: explain the importance of both water and the element carbon to cells
* **L2.p3A**: explain the significance of carbon in organic molecules
* **L2.p3B:** explain the origins of plant mass
* **L2.p5B**: identify the most common complex molecules that make up living organisms
* **B2.1A**: explain how cells transform energy (ultimately obtained from the sun) from one form to another through the process of photosynthesis and respiration. Identify the reactants and products in the general reaction of photosynthesis
* **B2.1B**: compare and contrast the transformation of matter and energy during photosynthesis and respiration
* **B2.5C**: describe how energy is transferred and transformed from the sun to energy-rich molecules during photosynthesis
* **L3.p3C**: explain how biotic and abiotic factors cycle in an ecosystem (water, carbon, oxygen, and nitrogen)
* **B3**.**1A**: describe how organisms acquire energy directly or indirectly from sunlight
* **B3.1B**: illustrate and describe the energy conversion that occur during photosynthesis and respiration
* **B3.1C**: recognize the equations for photosynthesis and respiration and identify the reactants and products for both
* **B3.1e**: write the chemical equation for photosynthesis and cellular respiration and explain in words what they mean
* **B3.1f**: summarize the process of photosynthesis

**Materials**

* Petri plates (4 per group)
* Paper towels
* Balances (1 per group)
* Eye droppers (1 per group)
* Graduated cylinders for measuring 10mL water (1 per group)
* Food dehydrator
* Empty cupboard or cardboard box for putting some seeds in the dark
* Shelf by window for putting some seeds in the light

**Background**

Why do we care about photosynthesis and respiration? Why do we care about where plant biomass comes from? We eat plant biomass, and almost all other living organisms depend on sugars such as glucose and other carbohydrates that result from photosynthesis. So, photosynthesis powers us and other ecosystems.

The master diagram is:

**Water (H20)**

**Photosynthesis**

Light

**Respiration**

**Oxygen gas (O2)**

**Carbon Dioxide gas (CO2)**

Energy

**Glucose (C6H12O6)**

Teachers should point out the form of carbon as it cycles through the diagram, from solid sugar to gaseous CO2. Teachers could make a link to ecosystem ecology by tracing energy and carbon through producers (photosynthesis) to consumers/decomposers (respiration).

### Activities of the session

1. Discuss the background information, filling out the questions in the Introduction section of the student worksheet. If possible, have students generate the master diagram as you draw it on the board by discussing what they already know about what humans breathe in and breathe out (resulting from cellular respiration), what photosynthesis needs in order to happen (light, CO2, water), what photosynthesis produces (sugar), what elements carbohydrates contain (CHO). Be sure to distinguish between cellular respiration (what almost all cells do) and respiration/breathing (what animals do to get rid of the waste products of cellular respiration). “Dry weight” is the weight of something without water (after it has been dried). Carbon-containing carbohydrates make up most of the dry weight of plants. The chemical equations are:

Photosynthesis: 6CO2 + 12 H2O 🡪 C6H12O6 + 6O2 +6H2O

Respiration: C6H12O6 + 6O2 🡪 6CO2 + 6H2O

1. The master diagram is the hypothesis—have the students translate the hypothesis into words: Respiration breaks down sugars and reduces dry biomass; Photosynthesis makes sugars and increases dry biomass. Students may be confused because these hypotheses are presented as fact in the textbook—in fact they are hypotheses that are very, very well supported by data (theories).
2. Have the students generate predictions with reference to the specific treatments in the experiment. (They may be partially embedded in the hypotheses, as they are above, if the students are most familiar with IF-THEN hypotheses.) Respiration -> Petri plates without both light and water will respire and have reduced biomass; Photosynthesis -> Petri plates with both light and water will photosynthesize and increase biomass.
3. Set up experiment as described in Methods section of student worksheet. To save time, you can have each group put 10mL of water in the petri plates receiving water rather than have them add 1mL at a time.
4. Each day after this, have students check the plates and add water if necessary, recording the amount of water added in the Student worksheet. Students should also record the number of beans with roots emerging, and number of beans with leaves emerging.
5. When the beans are too big to fit in the petri plates, end the experiment. Have students fold paper envelopes (4 per group) and put the beans from each petri plate into an envelope, recording the treatment on each envelope. Dry these envelopes full of beans in the food dehydrator for about a week.
6. When the beans are dry, have students mass the dry beans and fill out the results table, calculating the mass gained.
7. Compare the results across all groups and calculate an average and standard deviation for each group (using Excel worksheet). Calculate mean and standard deviation for data that you enter from 3 different classes. Explain that standard deviation is a measure of the variability within each treatment and is necessary for comparing the averages of two groups.
8. Make a bar graph of the results. Students can make bar graphs by plotting the top of the bar (or bottom, if mass was lost and you are dealing with negative numbers) at the mean and drawing lines above and below the mean that are the length of the standard deviation.
9. Discuss your results, filling out the questions in the Discussion section of the student worksheet. You may choose to have students answer some questions in small groups and others with the class all together. If observations/data/results do not match predictions, then either the hypothesis is wrong (very unlikely in this case; we are pretty sure that photosynthesis and respiration work the way we think they do), OR the conditions were not right to allow photosynthesis or respiration to happen. For example, the seeds died (didn’t get watered enough). Or, sprouts weren’t old enough to develop photosynthetic capacity (were the leaves green?) All seeds should respire for a while until they are big/old/developed enough to photosynthesize. If you feel you need to end the experiment before much photosynthesis has had time to happen because sprouts are getting too big for the petri plates, you could transplant seeds into party cups full of potting soil and keep the same treatments.
10. Reinforce the objectives, that photosynthesis produces sugars from atmospheric carbon dioxide and respiration breaks down sugars giving off atmospheric carbon dioxide.
11. Collect the student worksheets and use them to assess student learning. OR, pass out the post-assessment quiz (which can also be used as a pre-assessment).

**Resources**

* Student worksheet, outline of activities, pre-assessment, student lab report, and student worksheet are available on the “Where does plant mass come from?” lesson page on the KBS Gk-12 website
* Excel can be used for calculations and generating figures