



Investigating Photosynthesis and Respiration through Kinesthetics and Inquiry

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Grade Level:
Middle-High School

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Photosynthesis:

6 CO₂ 6 molecules of carbon dioxide	+	6 H₂O 6 molecules of water	(sunlight) → (in the presence of sunlight yields)	C₆H₁₂O₆ 1 molecule of glucose	+	6 O₂ 6 molecules of oxygen	
----- Reactants -----				----- Products -----			

Respiration:

6 O₂ 6 molecules of oxygen	+	C₆H₁₂O₆ 1 molecule of glucose	→ yields	6 CO₂ 6 molecules of carbon dioxide	+	6 H₂O 6 molecules of water	+	energy (ATP)
----- Reactants -----				----- Products -----				

Purpose:

To provide middle or high school students with a situation in which they can explore the relationship between photosynthesis and respiration.

Objectives:

Part I

Students will be able to:

- recognize the photosynthesis equation is basically the respiration equation “backwards.”
- realize that the very same carbon molecules that heterotrophs breathe out are the carbon molecules that make up the backbone of the glucose molecule.
- write the equations for photosynthesis and respiration with coefficients and subscripts (study time is required).

Part II

Students will be able to:

- infer that humans breathe out carbon dioxide and plants take in carbon dioxide and give off oxygen (during the light reactions).
- conclude that bromothymol blue turns yellow in the presence of carbon dioxide and turns back to blue in the presence of oxygen.

Materials:**Part I:**

- three pieces of blue construction paper (cut each piece in half so you have six pieces on which to write “C” to represent carbon [six molecules of carbon])
- six pieces of red construction paper (cut each piece in half so you have 12 pieces on which to write “H” to represent hydrogen [12 molecules of hydrogen])
- nine pieces of green construction paper (cut each piece in half so you have 18 pieces on which to write “O” to represent oxygen [18 molecules of oxygen])
- one piece of yellow construction paper (draw a sun to represent energy coming from the sun)
- one piece of white construction paper with a “+” on it
- one piece of white construction paper with an arrow to represent the yields sign in the equation
- posterboard with the equation for photosynthesis on one side and the equation for respiration on the opposite side (to be held up so that students know where to position themselves)
- one piece of construction paper that reads “carbon dioxide”
- one piece of construction paper that reads “water”
- one piece of construction paper that reads “glucose”
- one piece of construction paper that reads “oxygen”

Part II: Materials(for each group of four or fewer students)

- bromothymol blue (approximately 3 ml)
- one sprig of Elodea (or other aquatic plant that does not have needle-like leaves)
- two 50-ml beakers
- 20 ml of water
- carbonated water
- one straw

Preparation (teacher):

Students are not required to have background knowledge about photosynthesis and respiration to participate in this activity. I give my students the following warm-up activity:

1. Write the equations for photosynthesis.
2. Write the equation for respiration.
3. Define: atom, element, molecule and compound.

Aquatic plants can be purchased from most pet stores that sell fish. Bundles of four to five sprigs of Elodea cost about \$1.50. For best results, purchase the plants the afternoon before you plan to do the lab. Materials are organized for a class of 28 divided into 7 groups of four students each.

Part I can be completed in 15-25 minutes depending on the size of your class and their familiarity with the concepts presented. Part II takes approximately 25-30 minutes to complete.

Procedure:

Part I. Kinesthetic activity. Each student is given the role of a molecule of carbon, hydrogen, or oxygen. Depending on the size of your class, some students may need to be assigned the role of two molecules of the same element. For example, you may need to give one student two “H’s” instead of one “H.” If you have a large open area in your classroom, you can conduct this part of the activity inside. Otherwise, you will need to plan to go outdoors, into the hallway, or even to the school gymnasium or cafeteria. Once you arrive at your destination, hold up the posterboard with the equation for photosynthesis facing the students. First, instruct the students to position themselves so that they represent the **reactants of the photosynthesis equation**. (Remember to assign a student to the role of “sun,” “+” and “yields”.) Once students have gotten into the correct positions give each group of molecules the name of the substance that they represent (carbon dioxide or water). Next, have the students position themselves so that they represent the **products of the photosynthesis equation**. Once the students have positioned themselves correctly give each group of molecules the name of the substance they represent (glucose or oxygen). The idea is that students will realize that the very same carbon atoms that make up carbon dioxide make up the backbone for the glucose molecule.

Now hold up the respiration equation. First have the students position themselves to represent **the reactants for respiration**. Again, when they are correctly positioned, give the names of the substances that they represent to the groups of molecules (oxygen and glucose). Next, have the students position themselves so that they **represent the products of the respiration equation**. Once the students have positioned themselves, give the groups of molecules the names of the substances they represent (carbon dioxide and water).

Part II. Inquiry activity.

Each group is provided with an instruction sheet and materials. Instructions are sparse by design so that students can have a chance to figure out what bromothymol blue indicates instead of being told. As a facilitator for an inquiry activity you will walk around and give students support (“Yes, you can figure it out.”) and hints when they need them. The key is determining what sort of help students need. You are learning with them. Have fun and remember that you are teaching them to be curious and encouraging them to think!

Safety:

Part I: No special safety equipment is necessary. Be aware that students may become particularly lively once they are outside the classroom. A hand signal (for example, raising your right hand straight up) to let them know they need to be still and quiet may be helpful.

Part II: Students will be working with bromothymol blue, so safety glasses should be worn at all times. Make sure students know that they are only allowed to exhale through the straw. Students should practice this a few times with water before conducting their experiment. Drinking liquids in the lab is prohibited.

Questions to Ask:

Part I:

1. Compare the reactants of the photosynthesis equation to the products of the equation for respiration. What do you notice?
2. Compare the reactants of the respiration equation to the products of the photosynthesis equation. What do you notice?
3. How many molecules of carbon dioxide and how many molecules of water are needed for green plants to synthesize one molecule of glucose and six molecules of oxygen?
4. Name three ways that animals lose water.
5. What type of nutrient is glucose (carbohydrate, protein, nucleic acid or lipid)?
6. What are other sources of carbon dioxide (besides animals exhaling)?

Part II:

1. What color does the bromothymol blue solution turn in the presence of carbonated water?
2. What color does the bromothymol blue solution turn after you exhale into it for approximately two minutes?
3. What do you think would happen if you put the aquatic plant into the bromothymol blue solution?
4. What gas (or gases) can bromothymol blue serve as an indicator for?
5. What gas do you exhale?
6. What gas do plants give off?
7. How long (in seconds) did you have to exhale into the bromothymol blue solution to elicit a color change?
8. How many breaths did it take?
9. Could you produce a graph that illustrates a relationship between number of breaths exhaled into the bromothymol blue solution and the time it took for the solution to change color?

Where to Go From Here:

- **Curriculum tie ins.** This activity provides a good transition into the study of acids and bases, chemical bonding, study of nutrients, and the way that cells and the bodies of animals use energy.
- **Earthy visitors.** You could invite a respiratory therapist or other health care worker to visit your class and describe complications arising from respiratory problems, such as ketoacidosis. A nutritionist could also be a good resource if you want to focus on glucose as a building block for carbohydrates and research the various types of foods glucose is found in.
- **Glucose & humans.** Research or discussions could also be conducted to explore the physiology of diabetes. Warning signs of diabetes include elevated blood glucose levels and glucose present in urine.
- **I can sing!** Students love to sing. Challenge students to include basic concepts about photosynthesis and respiration in a song, poem or rap. My classes do this during exam review. I make up a few songs integrating science concepts, to show them that it can be done, and then let them strut their musical stuff.

Suggestions for Assessment:

Have students complete the Part I worksheet after they complete the kinesthetic activity. To evaluate Part II, have each group describe the procedure that they used to solve the mystery. Place special emphasis on the questions they asked and the steps they took to work out a solution to the mystery. Have every member of each group write out a lab report detailing their purpose, procedure, results, and conclusions. When assigning grades be sure to check the report and listen carefully to the presentation to gauge student understanding and the logic of the steps they took as they searched for an answer to the mystery.

References and Resources:

1. What is Photosynthesis? (This is a great page with over 30 photosynthesis links:) <http://photoscience.la.asu.edu/photosyn/education/learn.html>
2. MIT. Introduction to photosynthesis. (Have those students who always want to know more check it out.) <http://www.mit.edu:8001/afs/athena/course/other/esgbio/www/ps/intro.html>
3. Bookworm Bonanza (Science & general links you don't want to miss!) <http://www.mindspring.com/~mcarswell>
4. Eva's Science Sites (My personal page. Check it out and e-mail me!) <http://www.mindspring.com/~mcarswell/ess.htm>
5. Basics of Photosynthesis. (History, terms & interesting facts) <http://ekcs.neric.org/~jbuckley/apbio/photohistnts.html>
6. Barnhart, R.K. *The American Heritage Dictionary of Science*. Houghton Mifflin Company: Boston. 1986.
7. Audesirk, G. & Audesirk T. *Biology: Life on Earth*. Third Edition. Macmillan Publishing Company: New York. 1993.
8. McLaren, J. E. & Rotundo, Lissa. *Heath Biology*. D.C. Heath and Company: Lexington, Massachusetts. 1989.

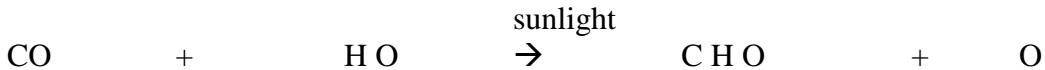
Student Worksheet

Photosynthesis and Respiration

Part I:

You will act out the equations for photosynthesis and respiration (listed below) as a molecule or molecules of the same element.

The equation for _____ is written below. Fill in the missing coefficients and subscripts. Also write the words that can be used to describe the chemical formulas.



The equation for _____ is written below. Fill in the missing coefficients and subscripts. Also write the words that can be used to describe the chemical formulas.



Part II:

You are a crew-member on a space ship that is on an exploration mission searching for life on other planets. The commander of the ship has sent you and three of your crewmates to the surface of a newly discovered planet. Your mission is to solve a mystery. You must find out what gas the other life forms exhale. Your only clue is a CD video clip of one of the other life forms exhaling through a straw into a clear container labeled "bromothymol blue." At the beginning of the video clip the solution inside the "bromothymol blue" container is yellow; however, after the other life form exhales into the container for a period of time the "bromothymol blue" solution turns from yellow to blue.

The atmosphere of this new planet is 21% oxygen and does not contain any known toxins so your commander sends you to the surface without a space suit. You and your team are equipped with a solution of bromothymol blue, safety glasses (four pairs), a clear container, a straw and a plastic bag containing water and a sprig of an aquatic plant. Each member of your team has been assigned one of the following roles: documentation officer, timekeeper, peacekeeper, or materials manager. You have 25 minutes from the time of your arrival on the new planet to solve the mystery and ready yourself to return to your ship.

Upon your return to the ship you must present your findings to your commander. She wants to know what gas the other life forms exhale, and since she is not very trusting, you must be able to prove to her exactly how you arrived at your conclusion. She will want to know what sorts of questions you asked to get started, the steps you took to arrive at your conclusion, and she is particularly fond of the collection of data and presentation of data in graphs.