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What Goes Around Comes Around: Exploring Photosynthesis and the Carbon Cycle

Experiments

Photosynthesis and Respiration

- Go Direct® Carbon Dioxide Gas Sensor

Photosynthesis and Cellular Respiration in Aquatic Plants

- Go Direct Optical DO Probe

Workshop Presenter

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Vernier SCIENCE EDUCATION

Photosynthesis and Respiration

(CO_2 Gas Sensor)

Plants make sugar, storing the energy of the sun into chemical energy, by the process of photosynthesis. When they require energy, they can tap the stored energy in sugar by a process called cellular respiration.

The process of photosynthesis involves the use of light energy to convert carbon dioxide and water into sugar, oxygen, and other organic compounds. This process is often summarized by the following reaction:

$$6\ H_2O + 6\ CO_2 + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

Cellular respiration refers to the process of converting the chemical energy of organic molecules into a form immediately usable by organisms. Glucose may be oxidized completely if sufficient oxygen is available by the following equation:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ H_2O + 6\ CO_2 + \text{energy}$$

All organisms, including plants and animals, oxidize glucose for energy. Often, this energy is used to convert ADP and phosphate into ATP.

OBJECTIVES

- Use a CO_2 Gas Sensor to measure the amount of carbon dioxide gas consumed or produced by a plant during respiration and photosynthesis.
- Determine the rate of respiration and photosynthesis of a plant.

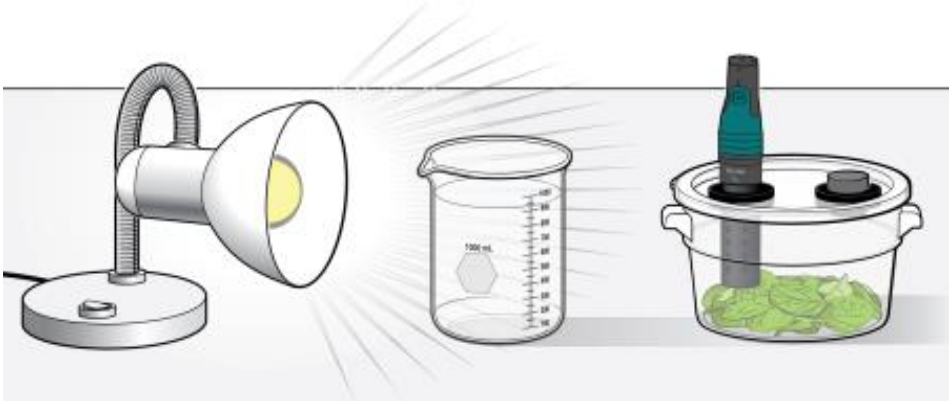

Figure 1

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct CO_2 Gas
BioChamber 2000
600 mL beaker
aluminum foil
lamp with bulb
#6 rubber stopper
spinach leaves
goggles

PROCEDURE

1. Wrap the BioChamber with aluminum foil so that no light will reach the leaves.
   a. Wrap the outside of the chamber with foil.
   b. Cover the lid with foil, poking the holes open to insert the sensor and the rubber stopper.
2. Cover the bottom of the chamber with a one centimeter layer of fresh, turgid spinach leaves.
3. Launch Graphical Analysis. Connect the CO_2 Gas Sensor to your Chromebook, computer, or mobile device.
4. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Rate to 15 samples/min and End Collection to 15 min. Click or tap Done.
5. Change the unit to ppt by clicking or tapping the CO_2 meter and choosing ppt from the Units menu.
6. Secure the lid on the chamber. Insert the CO_2 Gas Sensor into one the holes and the rubber stopper into the other.
7. Wait five minutes for the sensor to equilibrate, then click or tap Collect to start data collection. Data will be collected for 15 minutes.
8. When data collection is complete, determine the rate of respiration/photosynthesis.
   a. Click or tap Graph Options, , and choose Apply Curve Fit.
   b. Select Linear as the curve fit. Click or tap Apply.
   c. Enter the slope of the line, *m*, as the rate of respiration/photosynthesis in Table 1.
   d. Dismiss the Linear curve fit box.
9. Make a heat sink by filling a 600 mL beaker with water.
10. Set up the lamp and heat sink as shown in Figure 1. **Important**: Do not turn the lamp on until instructed to do so.

11. Remove the aluminum foil from the respiration chamber.

12. Turn on the lamp.

13. Repeat Steps 8–10 to collect and analyze data for photosynthesis. **Note**: The previous data set is automatically saved.

14. Graph both runs of data on a single graph.

    a. To display multiple data sets on a single graph, click or tap the y-axis label and select the data sets you want to display. Dismiss the box to view the graph.

    b. Use the displayed graph and Table 1 to answer the questions below.

15. Clean and dry the respiration chamber.

DATA

Table 1	
Leaves	Rate of respiration/photosynthesis (ppt/min)
In the dark	
In the light	

QUESTIONS

1. Were either of the rate values a positive number? If so, what is the biological significance of this?

2. Were either of the rate values a negative number? If so, what is the biological significance of this?

3. Do you have evidence that cellular respiration occurred in leaves? Explain.

4. Do you have evidence that photosynthesis occurred in leaves? Explain.

5. List five factors that might influence the rate of carbon dioxide production or consumption in leaves. Explain how you think each will affect the rate?

EXTENSIONS

1. Design and perform an experiment to test one of the factors that might influence the rate of carbon dioxide production or consumption in Question 5.

2. Compare the rates of photosynthesis and respiration among various types of plants.

Photosynthesis and Cellular Respiration in Aquatic Plants

Aquatic autotrophs such as plants and algae undergo photosynthesis and cellular respiration much like terrestrial plants. Atmospheric gases used in both processes dissolve in water and can be exchanged with autotrophic tissues.

Photosynthesis involves the use of light energy to convert carbon dioxide (dissolved in water in the form of carbonic acid, H_2CO_3) and water into sugar, oxygen, and other organic compounds. This process can be summarized by the following reaction:

$$6\ H_2O + 6\ CO_2 + \text{light energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

Cellular respiration involves converting the chemical energy of organic molecules such as glucose into a form immediately usable by organisms. Glucose may be oxidized completely if sufficient oxygen is available by the following equation:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ H_2O + 6\ CO_2 + \text{energy}$$

Oxygen dissolves at the interface between the water and the air, and when aquatic autotrophs release oxygen as a byproduct of photosynthesis. This dissolved oxygen can be measured to determine whether aquatic plants are undergoing photosynthesis or cellular respiration under different light conditions.

OBJECTIVES

- Measure the concentration of dissolved oxygen in water using an Optical DO Probe.
- Determine the effect of light on the rate of photosynthesis in aquatic plants.

MATERIALS CHECKLIST

Chromebook, computer, or mobile device
Graphical Analysis app
Go Direct Optical DO Probe
250 mL Nalgene bottle
1 L of aged tap water or DI water
aluminum foil
Stir Station
utility clamp
stir bar
600 mL beaker
lamp with LED plant bulb or halogen bulb
Java moss (*Vesicularia dubyana*) or Christmas moss (*Vesicularia montagnei*)

PROCEDURE

1. Launch Graphical Analysis. Connect the Optical DO Probe to the data-collection interface, and then connect the interface to your Chromebook, computer, or mobile device.

2. Set up the data-collection mode.

   a. Click or tap Mode.

   b. Change the units to minutes.

   c. Change End Collection to 15 min duration.

   d. Click or tap Done.

3. Obtain a golf-ball sized clump of java moss and gently place it in the 250 mL Nalgene bottle along with a stir bar.

4. Fill the 250 mL Nalgene bottle with aged tap water, leaving approximately 2 cm of space at the top of the bottle.

5. Carefully wrap the bottle in aluminum foil, ensuring that the bottom surface of the bottle is flat enough to sit on a Stir Station. Leave space at the neck of the bottle for the dissolved oxygen probe.

6. Place the bottle on the Stir Station and set it to stir at a medium speed.

7. Position the utility clamp on the ring stand post of the stir station above the bottle.

8. Insert the dissolved oxygen probe into the bottle. Stabilize it using the utility clamp, ensuring that it does not interfere with the stir bar. Wait for 1 minute.

9. Click or tap Collect to start data collection.

10. When data collection is complete, turn off the stir station.

11. Click or tap Graph Options and choose Apply Curve Fit. Record the slope of the line in Table 1.

12. Remove the dissolved oxygen probe from the water sample.

13. Remove the foil from the 250 mL bottle.

14. Set up the lamp approximately 30 cm from the bottle.

15. Place a 600 mL beaker of water between the lamp and the bottle to act as a heat sink.

16. Turn on the lamp.

17. Repeat Steps 6–11.

DATA

Table 1	
Java moss	Rate of respiration/photosynthesis (DO mg/L/min)
In the dark	
In the light	

QUESTIONS

1. In the dark, was the rate value for DO a negative number? If so, what is the biological significance of this?

2. In the light, was the rate value for DO a negative number? If so, what is the biological significance of this?

3. Do you have evidence that cellular respiration occurred in aquatic plants? Explain.

4. Do you have evidence that photosynthesis occurred in aquatic plants? Explain.

5. List five factors that might influence the rate of oxygen production or consumption in aquatic plants. Explain how you think each will affect the rate.

Photosynthesis and Cellular Respiration in Aquatic Plants

1. Different styles of dissolved oxygen probes can be used for this experiment: Dissolved Oxygen Probes and Optical DO Probes. This experiment is written for the Optical Dissolved Oxygen Probe.

2. Aquatic mosses are available at many pet stores that sell fish tank supplies. They are also available from mail order suppliers.

3. For best results, the aquatic moss should be placed into fresh water upon arrival and kept at room temperature under a plant light or in a sunny window.

4. To prepare aged tap water, fill a bottle or pitcher with tap water at least 12 hours before class and allow it to sit open at room temperature. This allows excess oxygen to diffuse out of the water prior to the experiment.

5. The type of light bulb is very important for this experiment.

   We recommend 12 W LED grow lights; they give the best results because they provide the correct wavelengths for photosynthesis and produce minimal heat energy.

   35 W halogen, flood-beam bulbs or standard 100 W incandescent bulbs can work. However, both bulbs radiate a lot of heat energy, which can affect the results.

For more information see **www.vernier.com/til/1519**

6. A heat sink is recommended to mitigate temperature changes what type of light source you use. A 600 mL beaker can be used but a tissue culture flask filled with water makes a good heat sink because it is thinner, and will allow the plant to receive much more light from the same lamp than a beaker.

7. It is possible to substitute green algae cultures for aquatic moss in this lab preparation with a few changes. If using marimo algae balls (a naturally occurring colony of *Aegagropila linnaei*), allow for 30 minutes of data collection with a 5 minute acclimation time prior to starting data collection. If using Bio-Rad algae beads, we recommend placing them in a smaller volume container such as a 50 mL flat-bottomed digestion tube, and using a small stir bar. The digestion tube can be placed inside an erlenmeyer flask to prevent tipping over. The waiting time before starting data collection may need to be lengthened depending on the rate of gas production. You may wish to monitor the gas concentrations and start collecting data when the levels of gas begin to move in the correct direction. It may take up to 30 minutes under some conditions.

8. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect your sensor.

9. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.

ESTIMATED TIME

We estimate that setup and data collection can be completed in one 45-minute class period if using aquatic moss, and in one 90 minute class period if using algae.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Disciplinary Core Ideas	Crosscutting Concepts	Science and Engineering Practices
LS1.A: Structure and Function LS1.C: Organization for Matter and Energy Flow in Organisms LS2.B: Cycles of Matter and Energy Transfer in Ecosystems	Cause and Effect Structure and Function Energy and Matter Systems and System Models	Analyzing and Interpreting Data Developing and Using Models

SAMPLE RESULTS

Aquatic Moss	Rate of respiration/photosynthesis (DO mg/L/min)
In the dark	–0.00879
In the light	0.01762

ANSWERS TO QUESTIONS

1. The DO rate value for aquatic plants in the dark was a negative number. The biological significance of this is that O_2 is consumed during cellular respiration. This causes the concentration of DO in the water to decrease as glucose is oxidized for energy.

2. The DO rate for aquatic plants in the light was a positive number. The biological significance of this is that O_2 is produced during photosynthesis. This causes the concentration of DO in the water to increase.

3. Yes, cellular respiration occurred in aquatic plants, since DO decreased when plants were in the dark and photosynthesis was not possible.

4. Yes, photosynthesis occurred in aquatic plants, since DO increased when plants were exposed to light.

5. Answers may vary. They might include:

    - An amount of plants should increase the rate in both the light and dark treatments, since there are more chloroplasts to undergo photosynthesis and more cells to require energy through cellular respiration.
    - A greater light intensity will increase the rate of photosynthesis. It may not affect the rate of cellular respiration, however.
    - Cooler water may decrease both rates, as cellular metabolism decreases in cooler weather.
    - Hot water may decrease both rates, as proteins involved with photosynthesis and cellular respiration may not function if overheated.
    - Blocking certain wavelengths of light may alter photosynthetic rates.