Experiment
31C

Photosynthesis and Respiration

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

In this experiment, you will

- Use an O_2 Gas Sensor to measure the amount of oxygen gas consumed or produced by a plant during respiration and photosynthesis.
- Use a CO_2 Gas Sensor to measure the amount of carbon dioxide consumed or produced by a plant during respiration and photosynthesis.
- Determine the rate of respiration and photosynthesis of a plant.

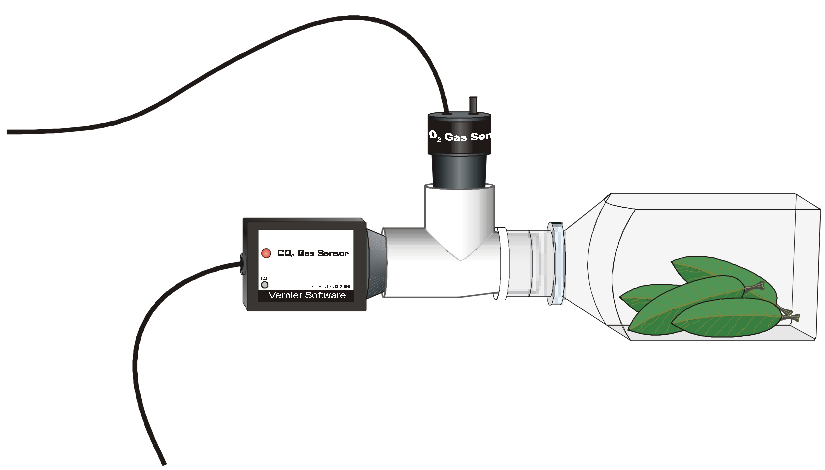

Figure 1

MATERIALS

computer	250 mL respiration chamber
Vernier computer interface	plant leaves
Logger *Pro*	500 mL tissue culture flask
Vernier O_2 Gas Sensor	lamp
Vernier CO_2 Gas Sensor	aluminum foil
CO_2–O_2 Tee	forceps

PROCEDURE

1. Connect the CO_2 Gas Sensor to Channel 1 and the O_2 Gas to Channel 2 of the Vernier computer interface.

2. Prepare the computer for data collection by opening the file "31C Photo (CO2 and O2)" from the *Biology with Computers* folder of Logger *Pro*.

3. Obtain several leaves from the resource table and blot them dry, if damp, between two pieces of paper towel.

4. Place the leaves into the respiration chamber, using forceps if necessary. Wrap the respiration chamber in aluminum foil so that no light reaches the leaves.

5. Insert the CO_2–O_2 Tee into the neck of the respiration chamber. Place the O_2 Gas Sensor into the CO_2–O_2 Tee as shown in Figure 1. Gently push the sensor down into the Tee until it fits snugly. The sensor is designed to seal the Tee without the need for unnecessary force. The O_2 Gas Sensor should remain vertical throughout the experiment. Place the CO_2 Gas Sensor into the Tee directly across from the respiration chamber as shown in Figure 1. Gently twist the stopper on the shaft of the CO_2 Gas Sensor into the chamber opening. Do not twist the shaft of the CO_2 Gas Sensor or you may damage it. Wait 10 minutes before proceeding to Step 6.

6. Click ▶ Collect to begin data collection. Collect data for fifteen minutes and click ■ Stop.

7. When data collection has finished, determine the rate of respiration:

   a. Click anywhere on the CO_2 graph. Move the mouse pointer to the point where the data values begin to increase. Hold down the left mouse button. Drag the pointer to the point where the data ceases to increase and release the mouse button.
   b. Click on the Linear Fit button, , to perform a linear regression. A floating box will appear with the formula for a best fit line.
   c. Record the slope of the line, *m*, as the rate of respiration in Table 1.
   d. Close the linear regression floating box.
   e. Repeat Steps 7a – d for the O_2 graph. However, you will need to move the mouse pointer to the point where the data values begin to decrease. Hold down the mouse button and drag to the point where the data ceases to decrease.

8. Move your data to a stored run. To do this, choose Store Latest Run from the Experiment menu.

9. Remove the aluminum foil from around the respiration chamber.

10. Fill the tissue culture flask with water (not the respiration chamber) and place it between the lamp and the respiration chamber. The flask will act as a heat shield to protect the plant leaves.

11. Turn the lamp on. Place the lamp as close to the leaves as reasonable. Do not let the lamp touch the tissue culture flask. Note the time. The lamp should be on for 5 minutes prior to beginning data collection.

12. After the five-minute time period is up, click ▶ Collect to begin data collection. Collect data for 15 minutes and click ■ Stop.

13. When data collection has finished, determine the rate of photosynthesis:
    a. Click anywhere on the CO_2 graph. Move the mouse pointer to the point where the data values begin to decrease. Hold down the left mouse button. Drag the pointer to the point where the data ceases to decrease and release the mouse button.
    b. Click on the Linear Fit button, , to perform a linear regression. Choose "Latest CO2" and a floating box will appear with the formula for a best-fit line.
    c. Record the slope of the line, *m*, as the rate of photosynthesis in Table 1.
    d. Close the linear regression floating box.
    e. Repeat steps 13a-d for the O_2 graph. However, you will need to move the mouse pointer to the point where the data values begin to increase, hold down the mouse button and drag to the point where the data ceases to increase.

14. Print a graph showing your photosynthesis and respiration data.
    a. Label each curve by choosing Text Annotation from the Analyze menu. Enter "Photosynthesis" in the edit box. Repeat to create an annotation for the "Respiration" data. Drag each box to a position near its respective curve. Adjust the position of the arrow heads.
    b. Print a copy of the graph, with both data sets displayed. Enter your name(s) and the number of copies of the graph you want.

15. Remove the plant leaves from the respiration chamber, using forceps if necessary. Clean and dry the respiration chamber.

DATA

Table 1		
Leaves	CO_2 rate of production/consumption (ppt/min)	O_2 rate of production/consumption (ppt/min)
In the dark		
In the light		

QUESTIONS

1. Were either of the rate values for CO_2 a positive number? If so, what is the biological significance of this?

2. Were either of the rate values for O_2 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 oxygen 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 oxygen production or consumption in Question 5.

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

TEACHER INFORMATION

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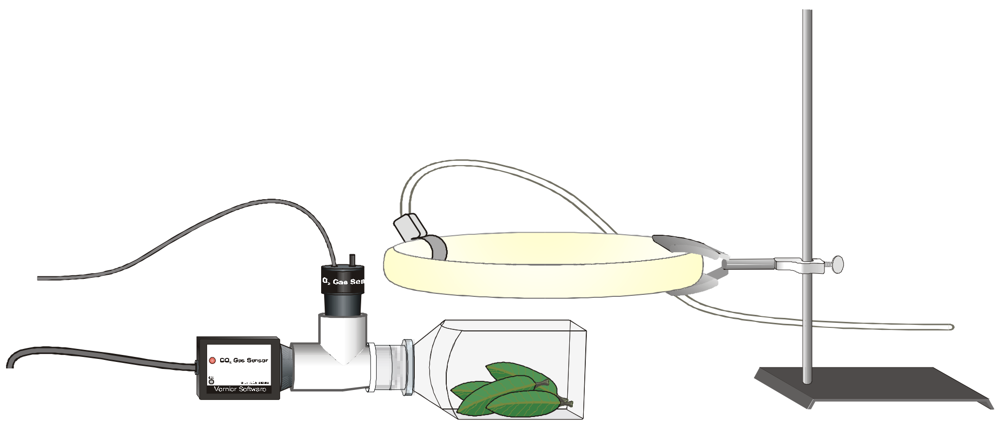
Photosynthesis and Respiration

1. Spinach leaves purchased from a grocery store work very well and are readily available any time of the year. Do not purchase the pre-packaged spinach in a bag. For best results, keep the leaves cool until they are to be used. Just before use, expose the leaves to bright light for 5 minutes.
2. A fluorescent ring lamp works very well since it bathes the plant in light from all sides and it gives off very little heat. When using a ring lamp as shown below, it is not necessary to use a heat shield.



3. If tissue culture flasks are not available, a beaker or flask of water will also work. The tissue culture flask is very thin, however, and will allow leaves to receive much more light from the same lamp.
4. On a nice, sunny day, this experiment may be performed using sun light. If so, no heat shield is needed.
5. To extend the life of the O_2 Gas Sensor, always store the sensor upright in the box in which it was shipped.
6. The waiting time before taking data may need to be adjusted depending on the rate of diffusion of the oxygen gas and the carbon dioxide gas. 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 15 minutes for the Oxygen Gas level to begin increasing once the light is turned on.

7 When students are placing the probe in the respiration chamber, they should gently twist the stopper into the chamber opening. Warn the students not to twist the probe shaft or they may damage the sensor.

8. To conserve battery power, we suggest that AC Adapters be used to power the interfaces rather than batteries when working with the CO2 Gas Sensor. An AC Adapter is shipped with each LabPro interface at the time of purchase.

SAMPLE RESULTS

Table 1		
Leaves	CO_2 rate of production/consumption (ppm/min)	O_2 rate of production/consumption (%/min)
In the dark	XXXX	XXXX
In the light	XXXX	XXXX

ANSWERS TO QUESTIONS

Answers have been removed from the online versions of Vernier curriculum material in order to prevent inappropriate student use. Graphs and data tables have also been obscured. Full answers and sample data are available in the print versions of these labs.