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:

\[ 6 \text{H}_2\text{O} + 6 \text{CO}_2 + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2 \]

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:

\[ \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2 \rightarrow 6 \text{H}_2\text{O} + 6 \text{CO}_2 + \text{energy} \]

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\textsubscript{2} Gas Sensor to measure the amount of oxygen gas consumed or produced by a plant during respiration and photosynthesis.
- Use a CO\textsubscript{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.
Experiment 31C

MATERIALS

| LabPro interface | 250 mL respiration chamber |
| Palm handheld    | plant leaves |
| Data Pro program | 500 mL tissue culture flask |
| Vernier O₂ Gas Sensor | lamp |
| Vernier CO₂ Gas Sensor | aluminum foil |
| CO₂–O₂ Tee      | forceps |

PROCEDURE

1. Plug the O₂ Gas Sensor into Channel 1 of the LabPro interface. Plug the CO₂ Gas Sensor into Channel 2 of the LabPro interface. Connect the handheld to the LabPro using the interface cable. Firmly press in the cable ends.

2. Press the power button on the handheld to turn it on. To start Data Pro, tap the Data Pro icon on the Applications screen. Choose New from the Data Pro menu or tap [New] to reset the program.

3. Set up the handheld and interface for an O₂ Gas Sensor and CO₂ Gas Sensor.
   a. If the handheld displays O2 GAS (ppt) in CH 1 and CO2 GAS(ppt) in CH 2 proceed directly to Step 4. If it does not, continue with this step to set up your sensor manually.
   b. On the Main screen, tap [Setup].
   c. Tap [CH1:] to select Channel 1.
   d. Press the Scroll buttons on the handheld to scroll through the list of sensors.
   e. Choose OXYGEN GAS(ppt) from the list of sensors.
   f. Tap [CH2:] to select Channel 2.
   g. Press the Scroll buttons on the handheld to scroll through the list of sensors.
   h. Choose CO2 GAS(ppt) from the sensor menu.
   i. Tap [OK] to return to the Main screen.

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

5. 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.

6. Insert the CO₂–O₂ Tee into the neck of the respiration chamber. Place the O₂ Gas Sensor into the CO₂–O₂ Tee as shown in Figure 1. Insert the sensor snugly into the Tee. The O₂ Gas Sensor should remain vertical throughout the experiment. Place the CO₂ 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 CO₂ Gas Sensor into the chamber opening. Do not twist the shaft of the CO₂ Gas Sensor or you may damage it.

7. Wait ten minutes, then tap [Start] to begin data collection.

8. When data collection has finished, remove the aluminum foil from around the respiration chamber.
9. Fill the tissue culture flask with water and place it between the lamp and the respiration chamber. The flask will act as a heat shield to protect the plant leaves.

10. Turn the lamp on. Place the lamp as close to the leaves as reasonable. Do not let the lamp touch the tissue culture flask.

11. Tap on the y-axis of the displayed graph and choose CH1: O2 GAS(ppt). A graph of oxygen gas vs. time. Sketch a copy of your graph in the Graph section below.

   Tap on the y-axis of the displayed graph and choose CH2: CO2 GAS(ppt). A graph of carbon dioxide gas vs. time. Sketch a copy of your graph in the Graph section below.

12. Perform a linear regression to calculate the rate of respiration/photosynthesis.
   a. Tap \[\text{Analyze}\] then tap \[\text{Curve Fit}\].
   b. Note that CH2: CO2 GAS(ppm) is the Data to Fit. The linear regression statistics displayed will be for the CO\(_2\) Gas Sensor.
   c. Choose Linear as the Fit Equation.
   d. From the Fit Equation menu, choose Linear. The linear-regression statistics for these two data columns are displayed for the equation in the form
      \[y = ax + b\]
   e. Enter the value of the slope, \(a\), as the rate of respiration/photosynthesis for the CO\(_2\) Gas Sensor in Table 1.

13. Calculate the rate of respiration/photosynthesis for the O\(_2\) Gas Sensor.
   a. At the top of the screen, tap CH2: CO2 GAS(ppt) and choose CH1: O2 GAS(ppt) as the Data to Fit.
   b. The linear-regression statistics for these two data columns are displayed for the equation in the form
      \[y = ax + b\]
   c. Enter the value of the slope, \(a\), as the rate of respiration/photosynthesis for the O\(_2\) Gas Sensor in Table 1.
   d. Tap \[\text{OK}\] to view the fitted curve with your data.
   e. Tap \[\text{OK}\] once again to return to the Graph screen.

14. Repeat Steps 8 – 13 to collect data with the plant exposed to light.

15. Remove the plant leaves from the respiration chamber, using forceps if necessary. Clean and dry the respiration chamber.
Experiment 31C

DATA

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<tr>
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<td>CO₂ rate of</td>
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**GRAPHS**

**Darkness**

O₂ Gas vs. Time

CO₂ Gas vs. Time

**Light**

O₂ Gas vs. Time

CO₂ Gas vs. Time

**QUESTIONS**

1. Were either of the rate values for CO₂ a positive number? If so, what is the biological significance of this?

2. Were either of the rate values for O₂ 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.
Photosynthesis and Respiration

1. Spinach leaves purchased from a grocery store work very well and are readily available any time of the year. 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. To extend the life of the O\textsubscript{2} Gas Sensor, always store the sensor upright in the box in which it was shipped.

5. 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.

6. The stopper included with the CO\textsubscript{2} Gas Sensor is slit to allow easy application and removal from the probe. When students are placing the probe in the CO\textsubscript{2}–O\textsubscript{2} Tee, they should gently twist the stopper into the adapter opening. Warn the students not to twist the probe shaft or they may damage the sensing unit.

7. To conserve battery power, we suggest that AC Adapters be used to power the interfaces rather than batteries when working with the CO\textsubscript{2} Gas Sensor. An AC Adapter is shipped with each LabPro interface at the time of purchase. If you are using the CBL 2, you can purchase a Vernier AC Adapter for $10 (order code–IPS).
Experiment 31C

SAMPLE RESULTS

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GRAPHS

Darkness

O₂ Gas vs. Time

CO₂ Gas vs. Time

Light

O₂ Gas vs. Time

CO₂ Gas vs. Time

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.