Aerobic cellular respiration is the release of energy from organic compounds by metabolic chemical oxidation in the mitochondria within each cell. Cellular respiration involves a series of enzyme-mediated reactions. All organisms, including plants and animals, oxidize glucose for energy. Often, this energy is used to convert ADP and phosphate into ATP. It is known that peas undergo cell respiration during germination.

The equation below shows the complete oxidation of glucose. Oxygen is required for this energy-releasing process to occur.

\[
C_6H_{12}O_6 + 6 \text{O}_2(g) \rightarrow 6 \text{H}_2\text{O} + 6 \text{CO}_2(g) + 686 \text{ kilocalories of energy/mole glucose oxidized}
\]

By studying the equation above, you will notice there are three ways cellular respiration could be measured. One could measure the:

- Consumption of O₂
- Production of CO₂
- Release of energy during cellular respiration

Using a CO₂ and an O₂ Gas Sensor, you will monitor the carbon dioxide produced by peas during cell respiration. Both germinated and non-germinated peas will be tested. Additionally, cell respiration of the germinated peas at two different temperatures will be tested.

**GUIDING QUESTIONS**

- How do dormancy and germination affect respiration rate?
- How does the rate of cellular respiration relate to the activity in a cell?
- What effect does temperature have on respiration rate?
- How does the detection of CO₂ and O₂ relate to cell respiration?

**MATERIALS**

- LabQuest
- LabQuest App
- Vernier CO₂ Gas Sensor
- Vernier O₂ Gas Sensor
- 25 germinated peas
- 25 non-germinated peas
- BioChamber 250
- ice cubes
- two 100 mL beakers
- thermometer
- paper towels
**PROCEDURE**

**Part I Germinated and Non-Germinated Peas at Room Temperature**

1. If your CO₂ Gas Sensor has a switch, set it to the Low (0–10,000 ppm) setting. Connect the O₂ Gas Sensor and the CO₂ Gas Sensor to LabQuest using the Channel ports on the top of the LabQuest. It does not matter which sensor goes into which port.

2. Choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor. To do this manually:

   a. Stay in the Meter mode and select Sensors → Sensor Setup…. → A sensor set-up screen will appear showing all the available probe ports (Fig. 1a).
   b. Select the channel that the O₂ Gas sensor is plugged into (ex. CH1 for channel 1), and tap the arrow to the side of the channel box.
   c. A list of compatible probes will appear in alphabetical order. Scroll down the list and select “O₂ Gas Old”. Select OK → to return to the Meter mode screen.
   d. Repeat this procedure (1a.-c.) for the other channel if the CO₂ sensor is not detected automatically.
   e. A red and blue box will now be in this window displaying the channel the O₂ and CO₂ sensors are plugged into (Fig. 1b). The LabQuest is reading in % O₂ and CO₂ (ppm).
   f. (Optional) For comparison reasons, you might want to have both sensors read in the same units. Tap the CO₂ box on the Meter screen (red or blue, depending on which channel port it is in). Choose Change Units → ppt. Do the same for the O₂ sensor, selecting ppt as the measurement unit.

3. To the right of the Meter screen, check the gray Length box to see if it is reading 300 seconds (s). If not, tap the Length box. This will bring up the Data Collection screen (Fig. 2). Change the data-collection length to **300 seconds** using the touch keypad. Select OK → to return to the Meter mode screen when you are finished.

4. Measure the room temperature using a thermometer and record the temperature in Table 1.
5. Obtain 25 germinated peas and blot them dry between two pieces of paper towel.

6. Place the germinated peas into the respiration chamber.

7. Place the O₂ Gas Sensor into the BioChamber 250 as shown in Figure 3. Insert the sensor snugly. The O₂ Gas Sensor should remain vertical throughout the experiment. Place the CO₂ Gas Sensor into the neck of the BioChamber 250, supported by the Styrofoam block underneath it.

   Figure 3. Set-up of BioChamber with the CO₂ and O₂ gas sensors.

8. Wait two minutes, and then tap the Start icon to begin data collection. The LabQuest screen will go to the Graph mode, and will display a separate graph for both the CO₂ and O₂ sensors vs. time. Data will be collected for 5 minutes. The LabQuest will automatically stop taking data after this time.

9. When data collection has finished, two separate graphs will be displayed; one of CO₂ vs. time(s) and the other of % O₂ vs. time(s).

10. Remove the sensors from the respiration chamber. Place the peas in a 100 mL beaker filled with cold water and an ice cube.

11. Use a notebook or notepad to fan air across the openings in the probe shaft of the CO₂ Gas Sensor for 1 minute. **Do not skip this step!**

12. Perform a linear regression to calculate the rate of respiration. If the entire data set is not linear, press and drag the stylus across a linear portion of the curve. A gray-shaded section will appear; this is the portion of the graph that will be analyzed.
   a. While still in the Graph mode, choose Curve Fit from the Analyze menu.
   b. Select Linear for the Fit Equation. The linear-regression statistics for these two data columns are displayed for the equation in the form

   ![Figure 3. Set-up of BioChamber with the CO₂ and O₂ gas sensors.](image-url)
Cell Respiration: Measuring Concentrations of CO$_2$ and O$_2$

\[ y = mx + b \]

where $x$ is time, $y$ is O$_2$ or CO$_2$ concentration, $m$ is the slope, and $b$ is the $y$-intercept.

c. Enter the slope, $m$, as the rate of respiration in Table 2.
d. Select [OK].

13. Store the data from the first run by tapping the File Cabinet icon to the right of the screen. The screen will clear and be ready to take data for your second experimental trial.

14. Repeat Steps 4–13 substituting the germinated peas with non-germinated peas. In Step 10 place the non-germinated peas on a paper towel and not in the ice bath.

Part II Germinated Peas at Cool Temperatures

15. Remove the peas from the cold water and blot them dry between two paper towels.

16. Measure the temperature of the cold water and record it in Table 1. Repeat Steps 4–12 using the cold peas. When you have completed Step 12 skip directly to Step 17.

17. Graph all three runs of data on a single graph.
   a. To view a graph of all three data runs, tap Run 3 and select All Runs. This will display all the data for both the CO$_2$ and the O$_2$ graphs.
   b. All three runs will now be displayed on the same graph axes.
   c. Use the displayed graphs and Tables 1 and 2 to answer the questions below.

REFERENCES


Kelly Redding and David Masterman. Advanced Biology with Vernier. (2008) Cell Respiration (Method 1 – CO$_2$ and O$_2$). Vernier Software & Technology; 13979 S.W. Millikan Way, Beaverton, OR pp. 5-1 to 5-4(CO$_2$ and O$_2$); 5-1T to 5-3T(CO$_2$ and O$_2$).

CREDITS

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DATA SHEET

Name: _______________________
Group: _______________________
Date: _______________________

<table>
<thead>
<tr>
<th>Condition</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room</td>
<td></td>
</tr>
<tr>
<td>Cold</td>
<td></td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Peas</th>
<th>O\textsubscript{2} Rate of respiration (%/s)</th>
<th>CO\textsubscript{2} Rate of respiration (ppm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germinated, rm T</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germinated, cold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-germinated, rm T</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DATA ANALYSIS

1. Do you have evidence that cell respiration occurred in peas? Explain.

2. What is the effect of germination on the rate of cell respiration in peas?

3. What is the effect of temperature on the rate of cell respiration in peas?
4. Why do germinated peas undergo cell respiration?

5. Why do germinated peas undergo cell respiration? Design an experiment to examine the rates of cellular respiration with peas that have been germinating for different lengths of time: 0, 24, 48, and 72 hours. What results would you predict? Why?

6. If you used the same experimental design to compare the rates of respiration of a 25g reptile and a 25g mammal at 10°C, what results would you expect? Explain.