Cell Respiration
(Method 1–CO_2 and O_2)

Cell 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 according to the following equation:

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

All organisms, including plants and animals, oxidize glucose for energy. Often, this energy is used to convert ADP and phosphate into ATP. Peas undergo cell respiration during germination. Do peas undergo cell respiration before germination? Using your collected data, you will be able to answer the question regarding respiration and non-germinating peas.

OBJECTIVES

In this experiment, you will

- Measure gas production.
- Study the effect of temperature on cell respiration.
- Determine whether germinating peas and non-germinating peas respire.
- Compare the rates of cell respiration in germinating and non-germinating peas.

MATERIALS

computer
Vernier computer interface
Logger*Pro*
Vernier CO_2 Gas Sensor
Vernier O_2 Gas Sensor
BioChamber 250
25 germinating peas
25 non-germinating peas
250 mL respiration chamber
ice cubes
thermometer
two 100 mL beakers

PROCEDURE

Using the CO_2 Gas Sensor and O_2 Gas Sensor, you will monitor the carbon dioxide produced and the oxygen consumed by peas during cell respiration. Both germinating and non-germinating peas will be tested. Additionally, cell respiration of germinating peas at two different temperatures will be investigated.

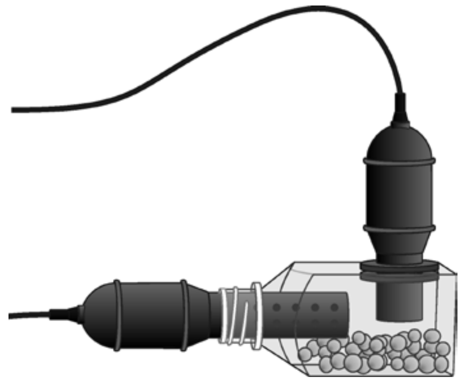


Figure 1

1. If your CO_2 Gas Sensor has a switch, set it to the Low (0–10,000 ppm) setting. Connect the CO_2 Gas Sensor to Channel 1 and the O_2 Gas Sensor to Channel 2 of the Vernier computer interface.

2. Prepare the computer for data collection by opening the file "05 Cell Resp M1 CO2 O2" from the *Advanced Biology with Vernier* folder of Logger*Pro*.

3. Obtain 25 germinating peas and blot them dry between two pieces of paper towel. Use the thermometer to measure the room temperature. Record the temperature in Table 1.

4. Place the germinating peas into the respiration chamber.

5. Place the O_2 Gas Sensor into the BioChamber 250 as shown in Figure 1. Insert the sensor snugly into the grommet. The O_2 Gas Sensor should remain vertical throughout the experiment. Place the CO_2 Gas Sensor into the neck of the respiration chamber as shown in Figure 1.

6. Wait four minutes for readings to stabilize, then begin collecting data by clicking ▶ Collect. Collect data for ten minutes and click ■ Stop.

7. When data collection has finished, remove the sensors from the respiration chamber. Place the peas in a 100 mL beaker filled with cold water and ice.

8. Fill the respiration chamber with water and then empty it. Thoroughly dry the inside of the respiration chamber with a paper towel.

9. Determine the rate of respiration:
   a. Click anywhere on the CO_2 graph to select it. Click the Linear Fit button, , to perform a linear regression. A floating box will appear with the formula for a best fit line.
   b. Record the slope of the line, *m*, as the rate of respiration for germinating peas at room temperature in Table 2.
   c. Close the linear regression floating box.
   d. Repeat Steps 9a–c for the O_2 graph.

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

11. Obtain 25 non-germinating peas and place them in the respiration chamber

12. Repeat Steps 5–10 for the non-germinating peas.

Part II Germinating peas, cool temperatures

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

14. Repeat Steps 5–9 to collect data with the germinating peas at a cold temperature.

15. To print a graph of concentration *vs.* volume showing all three data runs:
    a. Click anywhere on the CO_2 graph. Label all three curves by choosing Text Annotation from the Insert menu, and typing "Room Temp Germinated" (or "Room Temp Non-germinated", or "Cold Germinated") in the edit box. Then drag each box to a position near its respective curve. Adjust the position of the arrow head.
    b. Print a copy of the graph, with all three data sets and the regression lines displayed. Enter your name(s) and the number of copies of the graph you want.
    c. Click on the O_2 graph and repeat the process to print a copy of the O_2 graph.

DATA

Table 1	
Condition	Temperature (°C)
Room	

Table 2		
Peas	CO_2 Rate of respiration (ppt/min)	O_2 Rate of consumption (ppt/min)
Germinating, room temperature		
Non-germinating, room temperature		
Germinating, cool temperature		

QUESTIONS

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 germinating peas undergo cell respiration?

EXTENSIONS

1. Compare the respiration rate among various types of seeds.
2. Compare the respiration rate among seeds that have germinated for different time periods, such as 1, 3, and 5 days.
3. Compare the respiration rate among various types of small animals, such as insects or earthworms.

Experiment
5

TEACHER INFORMATION

Cell Respiration (Method 1–CO_2 and O_2)

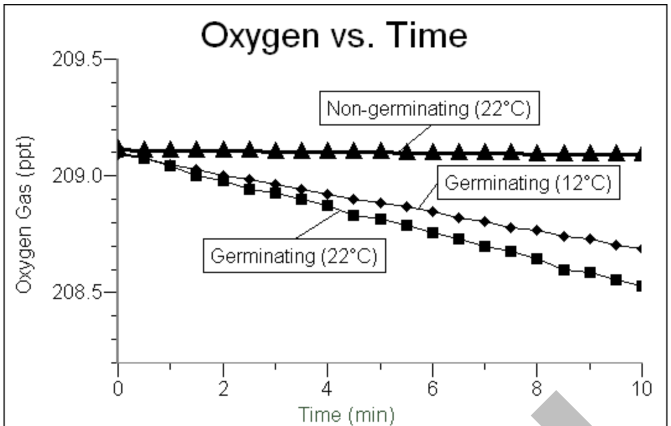
1. This experiment correlates with Lab 5 in the 2001 College Board's AP Biology Lab Manual.
2. The student pages with complete instructions for data collection using LabQuest App, Logger *Pro* (computers), and EasyData (calculators) can be found on the CD that accompanies this book. See *Appendix A* for more information.
3. If you are using calculators for data collection, this activity can be performed with calculators from the TI-83 Plus or TI-84 Plus families and a LabPro or CBL 2. It can not be performed with Easy products because the CO_2 Gas Sensor is not supported by EasyLink.
4. Allow the seeds to germinate for three days prior to the experiment. Prior to the first day, soak them in water overnight. On subsequent days, roll them in a moist paper towel and place the towel in a paper bag. Place the bag in a warm, dark place. Check each day to be sure the towels remain very moist. If time is short, the peas can be used after they have soaked overnight. For best results, allow them to germinate for the full three days.
5. The O_2 Gas Sensor should always be stored upright in the box in which it was shipped.
6. The morning of the experiment, fill a 1 L beaker with ice and water so that students will have cold water. Students will also need access to ice.
7. The calibrations stored in this experiment file for both sensors work well for this experiment. Initial readings that seem slightly high or low will still reflect an accurate change in gas levels.
8. The stopper included with the older-style CO_2 Gas Sensor is slit to allow easy application and removal from the probe. 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 sensing unit.
9. To conserve battery power, we suggest that AC Adapters be used to power the interfaces rather than batteries when working with the older-style CO_2 Gas Sensor.

Ideas for Inquiry

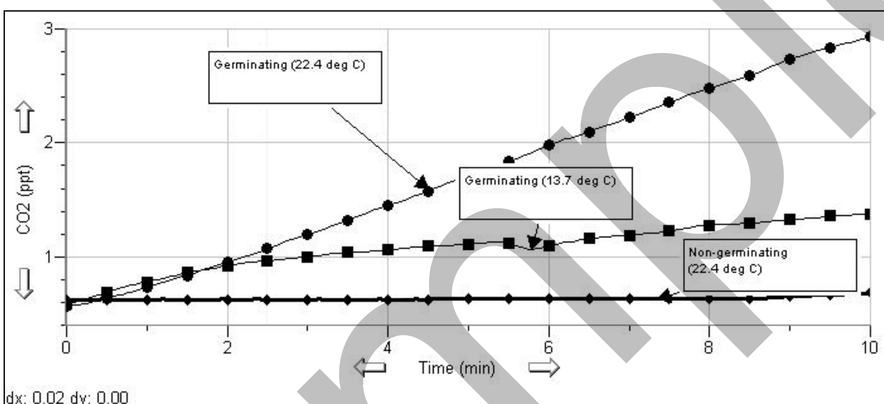
This experiment lends itself well to development into an inquiry investigation. Some possible investigations include:

- How does temperature affect pea respiration rate?
- What is the optimal temperature for pea respiration?
- How does germination duration affect the rate of CO_2 production?
- How does the presence of gibberellin (kinetin, zeatin) in the germination medium affect cellular respiration in peas?
- How does the presence of mannitol (sucrose) in the germination medium affect cellular respiration in peas?

SAMPLE RESULTS



O_2 consumed by germinated peas



CO_2 levels of germinating and non-germinating peas

Table 1	
Condition	Temperature (°C)
room	22.4
cold water	13.7

Table 2		
Peas	CO_2 rate of respiration (ppt/min)	O_2 rate of consumption (ppt/min)
Germinating, room temperature	0.249	–0.152
Non-germinating, room temperature	0.003	–0.002
Germinating, cool temperature	0.066	–0.087

ANSWERS TO QUESTIONS

1. Yes, the oxygen concentration *vs*. time graph clearly indicates that oxygen is being consumed at a steady rate when germinating peas are in the respiration chamber. The carbon dioxide concentration *vs.* time graph indicates that carbon dioxide is being produced at a steady rate.

2. Germination greatly accelerates the rate of cellular respiration. This reflects a higher rate of metabolic activity in germinating seeds. In most experiments, non-germinating seeds do not seem to be respiring.

3. Warm temperatures increase the rate of respiration. This reflects a higher rate of metabolic activity in warm germinating seeds than in cooler seeds.

4. It is necessary for germinating seeds to undergo cellular respiration in order to acquire the energy they need for growth and development. Unlike their mature relatives, seeds do not yet have the necessary photosynthetic abilities needed to produce their own energy sources.