

Cell Respiration

OVERVIEW

In the preliminary activity, students investigate the respiration of germinating peas using a CO₂ Gas Sensor. A student handout for the preliminary activity can be found at the end of the experiment.

During the subsequent Inquiry Process, students will investigate various aspects of cell respiration of germinating seeds.

LEARNING OUTCOMES

In this inquiry experiment, students will

- Identify variables, design and perform the experiment, collect data, analyze data, draw a conclusion, and formulate a knowledge claim based on evidence from the experiment.
- Determine the effect of temperature on the cell respiration of germinating seeds.

CORRELATIONS

AP Environmental Science Topic Outline Correlation

II. The Living World, B. Energy Flow (Photosynthesis and cellular respiration)

IB Environmental Systems Syllabus Correlation

2.2.2 Describe photosynthesis and respiration in terms of inputs, outputs, and energy transformations

THE INQUIRY PROCESS

Suggested time to complete the experiment

See the section in the introduction, Doing Inquiry Experiments, for more information on carrying out each phase of a guided inquiry experiment.

I	Preliminary Activity	35 minutes
II	Generating Researchable Questions	15 minutes
III	Planning	15 minutes
IV	Carrying out the Plan	40 minutes
V	Organizing the Data	15 minutes
VI	Communicating the Results	30 minutes
VII	Conclusion	15 minutes

MATERIALS

Make the following materials available for students to use. Items in bold are needed for the preliminary activity.

data-collection interface
data-collection program
Vernier CO₂ Gas Sensor
germinating peas
250 mL respiration chamber
non-germinating peas
germinating seeds of various types

non-germinating seeds of various types
warm water
ice cubes
1 L beaker
thermometer or temperature probe
100 mL beakers
others as requested by students

I Preliminary Activity

This inquiry begins with an activity to reinforce prior knowledge of the use of Vernier data-collection technology and to introduce a method with which to collect respiration rate data. Students should use the auto-ID data-collection settings that are loaded when an auto-ID CO₂ Gas Sensor is connected to a data-collection interface. If you are using non-auto-ID CO₂ Gas Sensors, you will need to instruct the students to set up the data-collection program to collect data once every ten seconds for a ten minute period.

Sample Results

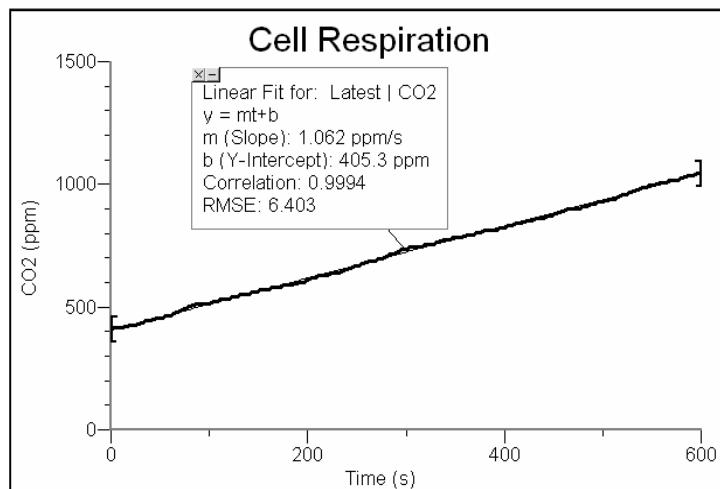


Figure 1 CO₂ respired by germinating peas at 22°C

Answers to the Questions

1. Yes, the carbon dioxide concentration vs. time graph clearly indicates that carbon dioxide is being produced at a steady rate when germinating peas are in the respiration chamber.
2. Germination greatly accelerates the rate of cell respiration. This reflects a higher rate of metabolic activity in germinating seeds. In most experiments, non-germinating seeds do not seem to be respiring. Occasionally, however, some respiration is detectable.
3. 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 product their own energy sources.

4. Answers will vary.
5. Answers will vary but may include temperature, type of seed, number of peas, and more.

II Generating Researchable Questions

See page xiii in the Doing Inquiry Experiments section for a list of suggestions for generating researchable questions. Some possible researchable questions for this experiment are:

- How does temperature affect pea respiration rate?
- Is there a maximum permitted temperature for pea respiration?
- What is the optimal temperature for pea respiration?
- Do germinating peas respire at temperatures below 0°C?
- How would an O₂-rich environment affect cellular respiration rate?
- How would an O₂-deprived environment affect cellular respiration rate?
- How does the rate of O₂ consumption compare with the rate of CO₂ production during cellular respiration?
- How does salinity of the germination medium affect cellular respiration in peas?
- How does the pH of the germination medium affect cellular respiration in peas?
- How does the DO of the germination medium affect cellular respiration in peas?
- 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?
- How does germination duration affect the rate of CO₂ production?

There are many more possible researchable questions. Students should choose a researchable question that addresses the learning outcomes of your specific standards.

III Planning

During this phase students should formulate a hypothesis, determine the experimental design and setup, and write a method they will use to collect data. Circulate among the student groups asking questions and making helpful suggestions.

IV Carrying out the Plan

During this phase, students use their plan to carry out the experiment and collect data. Circulate among the student groups asking questions and making helpful suggestions.

V Organizing the Data

See page xiv in the Doing Inquiry Experiments section for suggestions concerning how students can organize their data for their inquiry presentations.

VI Communicating the Results

See page xv in the Doing Inquiry Experiments section for a list of inquiry-presentation strategies.

VII Conclusion

See page xv in the Doing Inquiry Experiments section for a list of suggestions concerning assessment and ways to utilize the results in subsequent instruction.

SAMPLE RESULTS

Here are some sample results of germinating peas at different temperatures. Student results will vary depending on experimental design.

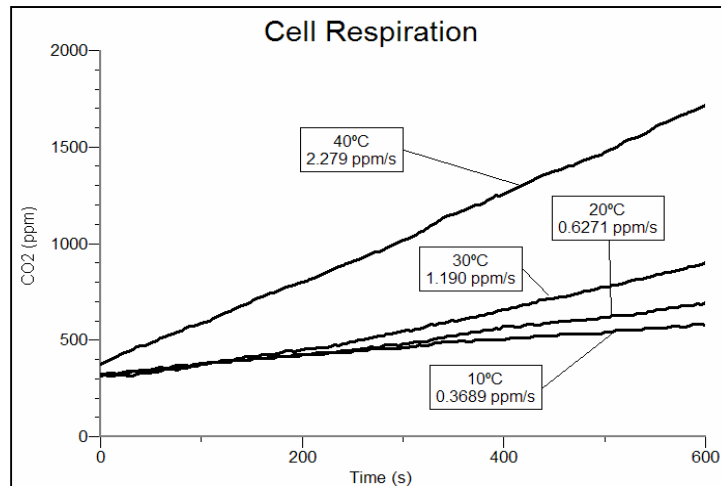


Figure 2 CO₂ respired by peas at different temperatures

Table 1: The Effect of Temperature on Respiration Rate	
Peas	Rate of Respiration (ppm/s)
Germinating, cool temperature (10°C)	0.37
Germinating, room temperature (20°C)	0.63
Germinating, cool temperature (30°C)	1.19
Germinating, warm temperature (40°C)	2.28

This investigation addresses the question, “How does temperature affect pea respiration rate?” Over the range of 10°C to 40°C, pea respiration rates increased with increasing temperature.

Table 2: CO ₂ Production Rates (ppm/s)				
	Percent NaCl			
Trial	0	0.1	1	3
1	2.573	2.075	1.867	1.897
2	2.495	1.984	1.871	1.883
3	2.589	2.349	2.072	1.479
Average	2.221	2.349	1.937	1.753

Pea (*pisum sativum*) samples were soaked in distilled water and NaCl solutions (0.1, 1, and 3%) overnight. The peas were then allowed to germinate at room temperature in a dark cabinet for three days while rolled in paper towels moisten with the same solution and placed in paper bags. The moistened paper towels were replaced after the first and second days. After three days of germination, data were collected using a procedure similar to that shown in the Preliminary Activity. Twenty peas were used in each trial.

This investigation was prompted by the question, “How does the salinity of the germination medium affect cellular respiration in peas?” Cellular respiration generally decreased as the salinity of the germination medium increased.

Table 3: Three-Day Germination Results				
	Percent NaCl			
	0	0.1	1	3
Percent Germinated	92	94	76	0
Average sprout length (mm)	22.8	22.9	7.5	0

Percent germination and average sprout length were also determined after three days of germination.

TIPS

Experiment Information

1. 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.
2. The recommended numbers of peas for use in this experiment are 10–15 peas for the original Carbon Dioxide Gas Sensor (range 0–5,000 ppm) and 25 peas for the newer dual-range Carbon Dioxide Gas Sensor (low range 0–10,000 ppm). These numbers can vary depending on the type of peas and the length of time they have been germinating. For best results, do a trial run and adjust the number of peas accordingly.
3. Heavy condensation buildup in the respiration chamber can interfere with readings from the CO₂ Gas Sensor. This can be a source of error if the peas are very wet when placed in the respiration chamber. If necessary, blot the peas dry with a paper towel before placing them in the respiration chamber.
4. A hair dryer and a funnel can be used to expel excess CO₂ prior to data collection.
5. Avoid using the respiration chamber at temperatures above 50°C. The respiration chamber will deform.
6. Graphs can be copied and pasted into a Microsoft Word document. If your students collect data on a TI graphing calculator, have them import the data to *Logger Pro* or do a screen capture using TI Connect. If you students collect data on a Palm® handheld, have them import the data in to *Logger Pro*.

Sensor Information

1. The CO₂ Gas Sensor requires a 90 second warm-up period before data collection can begin.
2. The calibration loaded with an auto-ID CO₂ Gas Sensor is ideal for this experiment.
3. The older style CO₂ Gas Sensor without a switch has a range of 0 to 5000 ppm. The sensor cannot take readings at a CO₂ concentration higher than 5000 ppm. Once the CO₂ concentration reaches this level, the computer, calculator, or handheld will continue to display a reading of ~5000 ppm until the actual level drops below 5000 ppm again.
4. The newer style CO₂ Gas Sensor with a switch measures gaseous carbon dioxide levels in the range of 0 to 10,000 ppm (low range setting) or 0 to 100,000 ppm (high range setting). Use the low range setting for this experiment.
5. Human breath has a concentration of approximately 50,000 ppm. Do not blow in the respiration chamber. To remove CO₂ from the chamber, fill the bottle with water and dry with a paper towel or use a blow dryer or fan to expel the CO₂.
6. The stopper included with the older style CO₂ 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. It does not need to be perfectly air tight. Warn the students not to twist the probe shaft or they may damage the sensing unit.

7. The CO₂ Gas Sensor relies on the diffusion of gases into the probe shaft. Students should allow a couple of minutes between trials so that gases can diffuse from the probe. Alternatively, the students can use a firm object such as a book or notepad to fan air through the probe shaft.

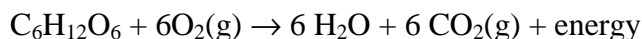
Sensor Check

Here is an easy way to check that your CO₂ Gas Sensor is working correctly:

1. Connect the sensor to the interface.
2. Start the data-collection program and allow the sensor to warm up for at least 90 seconds.
3. Blow directly on the shaft of the sensor. You should see an increase in CO₂ levels.
4. Older style sensors will max out at 5000 ppm.
5. An increase in CO₂ levels indicates the sensor is functioning correctly

**PRELIMINARY ACTIVITY FOR
Cell Respiration**

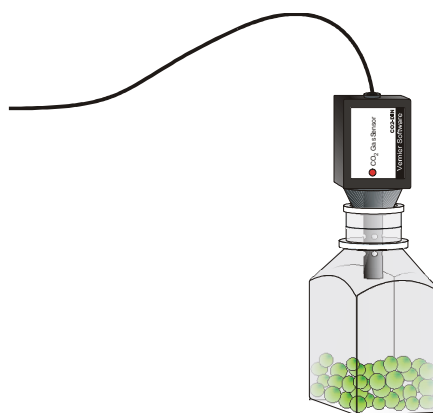
Cell respiration refers to the process of converting the chemical energy of organic molecules into a form immediately usable by organisms. Glucose may be oxidized completely if sufficient oxygen is available by the following equation:



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.

PROCEDURE

1. If CO₂ Gas Sensor your sensor has a switch, set it to the low range setting. Connect the sensor to the data-collection interface.
2. Place 10–15 germinating peas in the respiration chamber that ships with the CO₂ Gas Sensor. Insert the CO₂ Gas Sensor in the neck of the respiration chamber. Start the data-collection program. Wait 90 seconds for the sensor to warm up and begin collecting data.
3. After data are collected, use the linear regression function to determine the rate of respiration.



After completing the Preliminary Activity, you will first use reference sources to find out more about germination and cell respiration before you choose and investigate a researchable question. Some topics to consider in your reference search are:

- germination
- cell respiration
- carbohydrates
- glucose

QUESTIONS

1. Do the results of this experiment verify that germinating peas respire? How do you know?
2. What do you expect would happen to the rate of respiration if you repeated this experiment with non-germinating peas?

Experiment 14

3. Why do germinating peas undergo cell respiration?
4. Use a concept map or other organizing tool to list your prior knowledge of cell respiration.
5. List at least one researchable question for this experiment.