AP Investigation 6

CELLULAR RESPIRATION Big Idea 2

What factors affect the rate of cellular respiration in multicellular organisms?

BACKGROUND

Living systems require free energy and matter to maintain order, to grow, and to reproduce. Energy deficiencies are not only detrimental to individual organisms, but they cause disruptions at the population and ecosystem levels as well. Organisms employ various strategies that have been conserved through evolution to capture, use, and store free energy. Autotrophic organisms capture free energy from the environment through photosynthesis and chemosynthesis, whereas heterotrophic organisms harvest free energy from carbon compounds produced by other organisms. The process of cellular respiration harvests the energy in carbon compounds to produce ATP that powers most of the vital cellular process. In eukaryotes, respiration occurs in the mitochondria within cells.

If sufficient oxygen is available, glucose may oxidized completely in a series of enzyme-mediated steps, as summarized by the following reaction:

$$C_6H_{12}O_6 + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O + \text{energy}$$

More specifically,

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 686 \text{ kilocalories of energy/mole of glucose oxidized}$$

The chemical oxidation of glucose has important implications to the measurement of the respiration. From the equation, if glucose is the energy source, then for every molecule of oxygen consumed, one molecule of carbon dioxide is produced.

Suppose you wanted to measure the overall rate of cellular respiration.

Pre-Lab questions.

1. **What specific things could you measure?**
2. **Which of these might be easier or harder to measure?**

In procedures, you will learn how to calculate the rate of cellular respiration by using a respirometer system where you use carbon dioxide and oxygen sensors to measure the changes in these gasses over time as the cells respire

As you work through procedures, think about these questions

3. **What factors can affect the rate of cellular respiration?**
4. **Imagine that you are given 25 germinating pea seeds that have been placed in boiling water for five minutes. Predict the rate of oxygen consumption (i.e., cellular respiration) for these seeds and explain your reasons.**
5. **Imagine that you are asked to measure the rate of respiration for a 25 g reptile and a 25 g mammal at 10°C. Predict how the results would compare, and justify your prediction.**

Do not forget to save your graphs! Data and graphs MUST be in the lab report and in your lab notebook

In Designing and Conducting Your Investigation, you will design and conduct an experiment(s) to investigate at least one of your responses to this question or some other question you have. Your exploration will likely generate even more questions about cellular respiration.

The investigation also provides an opportunity for you to apply and review concepts that you have studied previously, including the relationship between cell structure and function (mitochondria); enzymatic activity; strategies for capture, storage, and use of free energy and the diffusion of gases across cell membranes.

Learning Objectives

- To learn how gas sensors can be used to measure respiration rates in plant seeds or small invertebrates, such as insects or earthworms
- To design and conduct an experiment to explore the effect of certain factors, including environmental variables, on the rate of cellular respiration
- To connect and apply concepts, including the relationship between cell structure and function (mitochondria); strategies for capture, storage, and use of free energy; and the diffusion of gases across cell membranes.

Hypothesis:

The basic Procedure: Respiration rate in germinating vs. non-germinating seeds

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. Turn on the Labquest and set the mode to Time based. Set the duration to 10 minutes, the rate to 2 samples per minute. This should change the interval to 0.5 and give you 20 data points. Click ok when finished with set up.

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 the play arrow on the bottom left – this starts data collection. Collect data for ten minutes and click [stop]

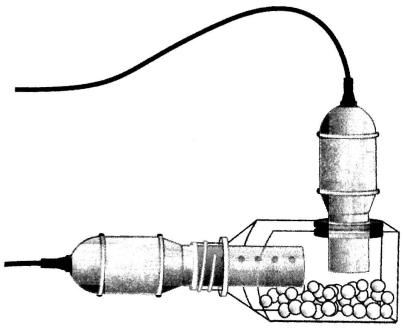

Figure 1

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

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. Tap the analyze button at the top. Chose curve fit.
    b.) Under fit equation choose 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 for germinating peas at room temperature in Table 2.
    d.) Close the linear regression floating box.
    e.) Repeat steps 9a-c for the O_2 graph.

10. View the data table and **copy the data into your lab notebook** or use the wifi link at the bottom of the screen to get a picture of your graph. You will see a QR code and the weblink code. Enter the http://and numbers into your web browser. You will then be able to download your graph as a pdf image.

11. Obtain 25 non-germinating peas and place them in the respiration chamber. When you restart your sensors it will ask you if you want to store or discard your previous data. If you have not recorded your data click store and you will see the new data come up as run 2.

12. Repeat steps 5-10 for the non-germinating peas.

13. When you finish go to file – quit and discard data

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 temp		
Non-germinating, room temp		

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Part II –Inquiry Design and conduct an experiment
Now that you have learned how to measure the rate of cellular respiration in germinating seeds, you have a tool for exploring questions on your own. Think about the process of cellular respiration. Discuss these questions with your partner before you design your experiment.

• When does it occur? Are there any situations when living cells are not respiring?
• Why might some living cells respire more than others?
• Are there differences between major groups of organisms in how fast they respire?
• What is the difference, if any, in the rate of cellular respiration between germinating seeds and non-germinating seeds?
• Does the temperature of germinating seeds affect the rate of cellular respiration?
-Do plant seeds consume more oxygen at higher temperatures than at lower temperatures?
• Do germinating seeds just starting to germinate consume oxygen at a greater rate than seeds that have been germinating for several days (age dependence)?
• Do small seeds of spring flowers, weeds, or grasses respire at a different rate from seeds from summer, fall, or winter plants?
• Can the same respirometer system be used to measure the rate of respiration in small invertebrates, such as insects or earthworms?

Record the following information in your lab notebook. **Question and procedure must be approved – submit via google classroom you need to complete <u>at least 3 trials</u> for your inquiry experiment**

- Question
- Variables
- Hypothesis
- Materials
- Procedure
- **Data and graphs**

DISCUSSION 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?
5. Perform statistical analysis of your data, comparing results of the experimental variable(s) to the controls. You should at least express the uncertainty of your measurements with error bars. You may want to review Chapter 3 for more information about statistical analysis.
6. How was the rate of cellular respiration affected by the experimental variable(s) you chose as compared to the control(s)?
7. Compare class data to explain how different variables affect rates of cellular respiration.
8. What is the difference between an endotherm and an ectotherm? How are respiration rates different between the two groups, give an example to help explain your answer.

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