Cellular Respiration

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, community, 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 vital cellular processes. In eukaryotes, respiration occurs in the mitochondria within cells.

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

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

The chemical oxidation of glucose has important implications to the measurement of respiration. From the equation, if glucose if 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, what specific things could be measured easily in the lab? The consumption of glucose and the formation of water and energy pose special problems that make it difficult to measure them. However, since oxygen and carbon dioxide are both gases, measuring their concentrations in a closed system containing a living organism provide for a much simpler method for quantifying the overall rate of cellular respiration.

As you work through the procedure below, think about this question: What factors can affect the rate of cellular respiration? In designing and conducting an experiment, you'll need to consider different methods for testing a factor you referenced in the previous question. Your experiment will likely generate even more questions about cellular respiration.

Objective(s)

- ✓ to observe the results of a respiring organism
- ✓ to quantify the production of carbon dioxide by a living organism
- ✓ to quantify the consumption of glucose and oxygen by a living organism
- ✓ to connect and apply concepts, including the relationship between cell structure and function (mitochondria); strategies for capture, storage, and use of free energy; diffusion of gases across cell membranes; and the physical laws pertaining to the properties and behavior of gases

Materials

- living organism(s)
- Vernier probe interface
- CO_2 gas sensor
- 250 mL respiration chamber
- electronic balance

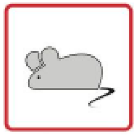
Pre-Lab Questions

Answer the following questions on your lab paper. For actual questions, you must either write out the questions, or include the questions in your responses. Be sure to use complete sentences and show your work for math problems.

1. Write out the Ideal Gas Law. Describe each of its components.
2. Predict how carbon dioxide levels would change in a respiration chamber over time in each of the situations below and provide explanations for each prediction.
   - **a.** the chamber contains a living plant only
   - **b.** the chamber contains a living animal only
   - **c.** the chamber contains a living plant and animal

✓ Use a ruler to recreate the Data Table below neatly on your lab paper, and be sure it is drawn approximately the same size

Safety



Animal hazard

Procedure

1. Determine the mass of the respiration chamber **without** the lid. Record this value in the **Data Table**.
2. Carefully place two crickets in the respiration chamber. Determine the mass of the crickets and chamber and record the value in the **Data Table**, then calculate the mass of the crickets alone.
3. Complete the following steps to prepare and use the CO_2 gas sensor:
    - **a.** Launch the Logger Pro program, plug the Vernier probe interface into the computer via the USB cable, and plug the CO_2 gas sensor into the interface.
    - **b.** Power up the interface by plugging in the power adaptor. The interface should emit an audible tone to indicate that it powered-up correctly. Allow the sensor to **warm up for at least 90 seconds** before attempting to take any readings. While the sensor is warming up, check the switch on its side to be sure it is set to detect the low range of CO_2 levels (0 – 10,000 ppm).
    - **c.** Adjust the collection settings in the Logger Pro program to record measurements every minute for 20 minutes.
    - **d.** With the bottle right-side-up, seat the CO_2 gas sensor securely inside the respiration chamber. Make note of the CO_2 concentration at this point – this will be your initial CO_2 reading.
4. Start the 20-minute detection period and record the CO_2 measurements (in ppm) in your Data Table.

Data Table

mass of bottle and crickets	g
	–
mass of bottle alone	g
	=
mass of crickets alone	g

Time (min)	CO_2 Concentration (ppm)	Time (min)	CO_2 Concentration (ppm)
1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

Clean Up

- ✓ **carefully** return the crickets to their original habitat
- ✓ everything returned to its original location

Results & Analysis

Answer the following questions on your lab paper. For actual questions, you must either write out the questions, or include the questions in your responses. Be sure to use complete sentences and show your work for math problems.

1. Use the mass of the crickets to determine the concentration of CO_2 in parts per million per gram (ppm/g) produced at each time value in the data table. Display these data in a simple chart.
2. Create an appropriate graph to illustrate the production of CO_2 in parts per million per gram (ppm/g) for the 20 minute time period. Use the initial CO_2 value (ppm/g) you made note of from step **3d** as your lowest *y*-axis value.
3. What was the absolute increase in carbon dioxide within the respiration chamber after the 20 minutes elapsed? What can you infer about the consumption and creation of the other molecules involved in cellular respiration: glucose, oxygen, and water?
4. 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.
5. Imagine that you're asked to repeat the reptile/mammal comparison of respiration, but at a temperature of 20˚C. Predict how these results would differ from the measurements made at 10˚C, and explain your prediction in terms of the metabolism of animals.