Effect of Temperature on Cold-Blooded Organisms

In cold-blooded organisms, *poikilotherms*, there is a link between the temperature of the environment and the organism's metabolic rate. Reptiles are a common example of a cold-blooded organism with which most people are familiar. If you have ever seen a lizard or snake in the early morning when the air and ground are cool, you may have noticed how slowly they move. They move slow when the environment is cold because they require heat from their surroundings to increase their internal temperature and metabolism. Once their internal body temperature has warmed, they can metabolize foods more quickly and produce the energy they need. Oxidative respiration is the process of metabolism where sugars are broken down. Under aerobic conditions, respiration yields chemical energy, carbon dioxide, and water.

$$\underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6\ O_2} \longrightarrow \underset{\text{carbon dioxide}}{6\ CO_2} + \underset{\text{water}}{6\ H_2O} + \text{energy}$$

Crickets will be used to study the effect of temperature on the metabolism of cold-blooded organisms. You will determine how temperature affects the respiration rate of crickets by monitoring carbon dioxide production with a CO_2 Gas Sensor.

OBJECTIVES

In this experiment, you will

- Use a CO_2 Gas Sensor to measure concentrations of carbon dioxide gas.
- Determine the rate of respiration by crickets at different temperatures.
- Determine the effect of temperature on metabolism of crickets.

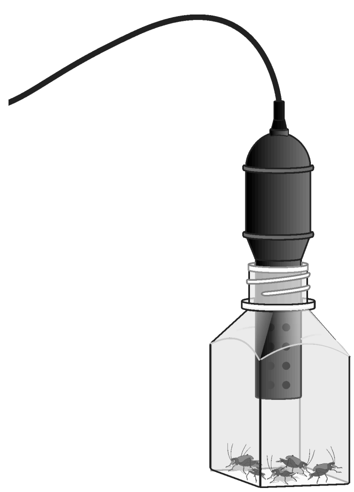

Figure 1

MATERIALS

LabQuest	250 mL respiration chamber
LabQuest App	600 mL beaker
Vernier CO_2 Gas Sensor	1 L beaker
crickets or mealworms	ice
balance	basting bulb
thermometer	Logger *Pro* (optional)

PROCEDURE

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 LabQuest and choose New from the File menu. If you have an older sensor that does not auto-ID, manually set up the sensor.

2. Obtain and weigh ten adult crickets in a 600 mL beaker and record the mass in Table 1.

3. You will collect data at three different temperatures according to your assigned group number (I, II, or III). You will set up a water bath at a different temperature prior to each data collection run until you have collected data at all three assigned temperatures.

   Group I: Cold Temperatures

   - Your group will collect respiration data at 5–10°C, 10–15°C, and 15–20°C. Set up a water bath for the desired temperature. A water bath is simply a large beaker of water at a certain temperature. This ensures that the crickets will remain at a constant and controlled temperature. To prepare the water bath, obtain some cool water and some ice from your teacher. Combine the cool water and ice into the 1 liter beaker until it reaches the desired temperature range. The beaker should be filled with about 600–700 mL water. Leave the thermometer in the water bath during the experiment.
   - Place the 250 mL respiration chamber in the water bath. Be sure to keep the temperature of the water bath constant while you are collecting data. If you need to add more hot or cold water, first remove about as much water as you will be adding or the beaker may overflow. Use a basting bulb or Beral pipet to remove excess water.
   - Record the water bath temperature in Table 1. Perform Steps 4–11 for each of the three temperature ranges.

   Group II: Warm Temperatures

   - Your group will collect respiration data at 20–25°C, 25–30°C, and 30–35°C. Set up a water bath for the desired temperature. A water bath is simply a large beaker of water at a certain temperature. This ensures that the crickets will remain at a constant and controlled temperature. To prepare the water bath, obtain some hot and cold water from your teacher. Combine the hot and cold water into the 1 liter beaker until it reaches the desired temperature range. The beaker should be filled with about 600–700 mL water. Leave the thermometer in the water bath during the experiment.
   - Place the respiration chamber in the water bath. Be sure to keep the temperature of the water bath constant while you are collecting data. If you need to add more hot or cold water, first remove about as much water as you will be adding or the beaker may overflow. Use a basting bulb or Beral pipet to remove excess water.
   - Record the water bath temperature in Table 1. Perform Steps 4–11 for each of the three temperature ranges.

Group III: Hot Temperatures

- Your group will collect respiration data at 35–40°C, 40–45°C, and 45–50°C. Set up a water bath for the desired temperature. To prepare the water bath, obtain some hot and cold water from your teacher. Combine the hot and cold water into the 1 liter beaker until it reaches the desired temperature range. The beaker should be filled with about 600–700 mL water. Leave the thermometer in the water bath during the experiment.
- Place the respiration chamber in the water bath. Be sure to keep the temperature of the water bath constant while you are collecting data. If you need to add more hot or cold water, first remove about as much water as you will be adding or the beaker may overflow. Use a basting bulb or Beral pipet to remove excess water.
- Record the water bath temperature in Table 1. Perform Steps 4–11 for each of the three temperature ranges.

4. Place the crickets into the respiration chamber.
5. Place the shaft of the CO_2 Gas Sensor in the opening of the respiration chamber.
6. Wait one minute for readings to stabilize, then start data collection. Data will be collected for 5 minutes.
7. When data collection has finished, a graph of carbon dioxide gas *vs.* time will be displayed.
8. Remove the CO_2 Gas Sensor from the respiration chamber. Place the crickets in a 600 mL beaker.
9. Use a notebook or notepad to fan air across the openings in the probe shaft of the CO_2 Gas Sensor for 1 minute.
10. Fill the respiration chamber with water and then empty it. Thoroughly dry the inside of the respiration chamber with a paper towel.
11. Perform a linear regression to calculate the rate of respiration.
    a. Choose Curve Fit from the Analyze menu.
    b. Select Linear as the Fit Equation. The linear-regression statistics are displayed to the right of the graph for the equation in the form

    $$y = mx + b$$

    where x is time, y is oxygen concentration, m is the slope, and b is the y-intercept.
    c. Enter the absolute value of the slope, m, as the rate of respiration in Table 2.
    d. Select OK.
12. Set up the water bath for your next assigned temperature as described in Step 3. Repeat Steps 4–11 for your second temperature range.
13. Set up the water bath for your next assigned temperature as described in Step 3. Repeat Steps 4–11 for your third temperature range.

DATA

Table 1			
Temperature (°C)	Actual temperature (°C)	Slope (ppm/s)	Respiration rate (ppm/s/g)
5–10°C			
10–15°C			
15–20°C			
20–25°C			
25–30°C			
30–35°C			
35–40°C			
40–45°C			
45–50°C			

Mass of crickets	_______ g

Table 2: Class averages	
Temperature (°C)	Respiration rate (ppm/s/g)
5–10°C	
10–15°C	
15–20°C	
20–25°C	
25–30°C	
30–35°C	
35–40°C	
40–45°C	
45–50°C	

PROCESSING THE DATA

1. For each temperature you tested, divide the slope of the regression line by the mass of the crickets. Record this value as the rate of respiration in Table 1.
2. Record the temperatures your group tested along with the respiration rates on the class data table. When all other groups have posted their results, calculate the average for each temperature range. Record the average rate values in Table 2.
3. Plot a graph with temperature along the x-axis and the rates of respiration from Table 2 along the y-axis.

QUESTIONS

1. At what temperature was the rate of carbon dioxide production highest? How does this relate to the internal body temperature of warm-blooded organisms?
2. How does temperature affect the rate of respiration in crickets? How does this compare to your prediction?
3. What errors might affect the results of this experiment? How could you help reduce those errors?
4. Predict the rate of respiration for crickets at 60°C. Explain.

EXTENSIONS

1. Perform the same experiment with different species of insects.
2. Investigate the difference in metabolic rate of an insect at different life stages.
3. Compare cellular respiration between insects and plants.