ScienceCube

Metabolic Rate of Insects Depending on Ambient Temperature

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1. **Measure the change in carbon dioxide concentration due to insect respiration at various temperatures and compare metabolic rates based on respiration rates.**
2. **Explain the effect of temperature on metabolism.**

Fundamental Concept

1. Respiration

All living cells constantly respire to obtain energy for various functions. Respiration is the process of converting nutrients and oxygen into adenosine triphosphate (ATP), a chemical energy compound necessary for life activities, while releasing carbon dioxide and water as waste products. The reaction equation for this respiration process is as follows:

Glucose + Oxygen → Carbon Dioxide + Water + Energy

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 12H_2O + 38ATP$$

Respiration is a series of processes that provide the energy needed for life activities, encompassing the chemical changes of material breakdown or synthesis occurring in living organisms, collectively known as metabolism. This process always involves the transfer of energy. Organisms obtain energy through metabolism, synthesizing substances needed for cell composition and physiological regulation, using them for life activities. Unlike chemical reactions, metabolism occurs in multiple steps, allowing energy to be transferred gradually, and proceeds through intermediate products. Metabolism is facilitated by enzymes, enabling reactions to occur at low temperatures within the body's temperature range. High temperatures denature enzymes, so metabolism proceeds quickly at the lower temperature of 37°C, typical of living organisms..

2. Thermoregulation in Ectothermic Animals

Ectothermic animals, which lack the ability to actively regulate their body temperature internally, have body temperatures similar to the external environment. They cannot utilize heat generated from internal metabolic processes, relying instead on external heat sources such as solar heat, water temperature, and geothermal heat to raise their body temperature before becoming active. The advantage of ectothermy is the reduced energy requirement for metabolism, but it also means their activity diminishes during the night or cold seasons as they depend on external heat. Ectotherms possess antifreeze substances in their body fluids to prevent internal water from freezing at sub-zero temperatures. However, there are limits to their thermoregulation, and if the temperature drops too low or rises too high, their metabolism slows, reducing their activity levels. For this reason, frogs, snakes, and lizards hibernate in the ground during cold periods and seek water or shade during hot summers.

Example 1: Desert grasshoppers stretch their bodies to maximize exposure to sunlight in the early morning.

Example 2: Honeybees cluster together to gather heat in cold weather and fan their wings to cool the hive with water on hot days..


3. Crickets

The chirping of crickets in summer sounds lively, but it becomes more melancholy in autumn as the temperature drops, lengthening the intervals between chirps. As ectothermic animals, crickets are sensitive to ambient temperature. Physical activities like muscle contraction are fundamentally chemical reactions that occur faster at higher temperatures. Male crickets chirp loudly to attract females or fend off rivals. Although commonly thought to rub their legs together, they actually produce sound by rubbing their wings together, like playing a violin. The right wing's thick vein rubs against the left wing's scraper plate, producing loud sounds. The wings are raised to spread the sound.

Experiment

Materials Needed

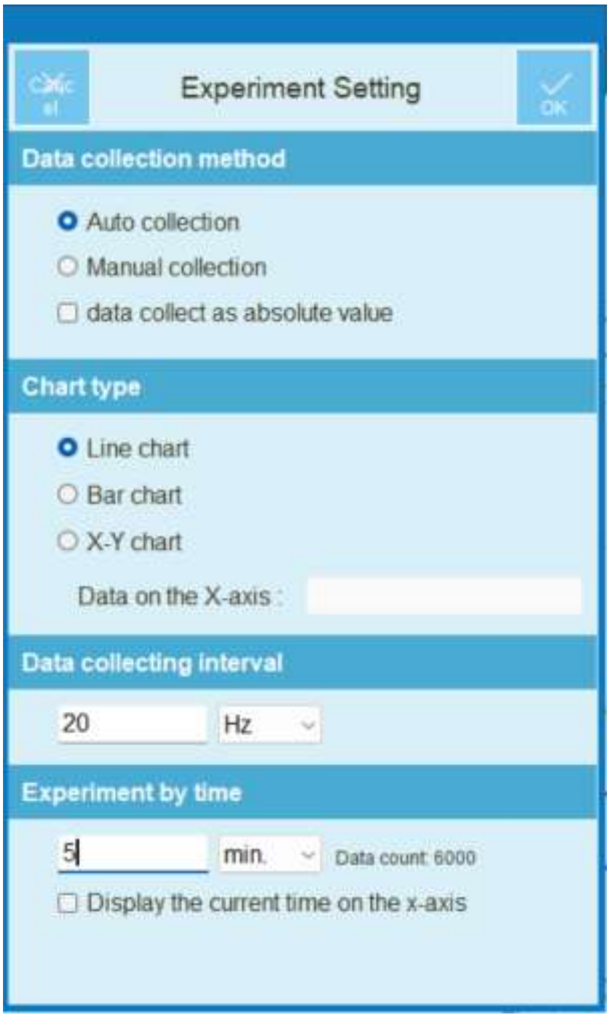
Interface, Science# Program, Temperature Sensor, CO_2 Sensor, Water Tank, Flask (250 mL), Beaker, Heating Device, Ice, Crickets, Fan, Electronic Scale, Paper Towels, Water

Preparation of Experimental Setup

1. Fill the water tank 1/4 full with water and add ice to lower the water temperature.
2. Place the beaker on the electronic scale and measure its weight.
3. Add 10 crickets to the beaker, cover with gauze, and measure the weight again to record the crickets' weight.

Interface Setup

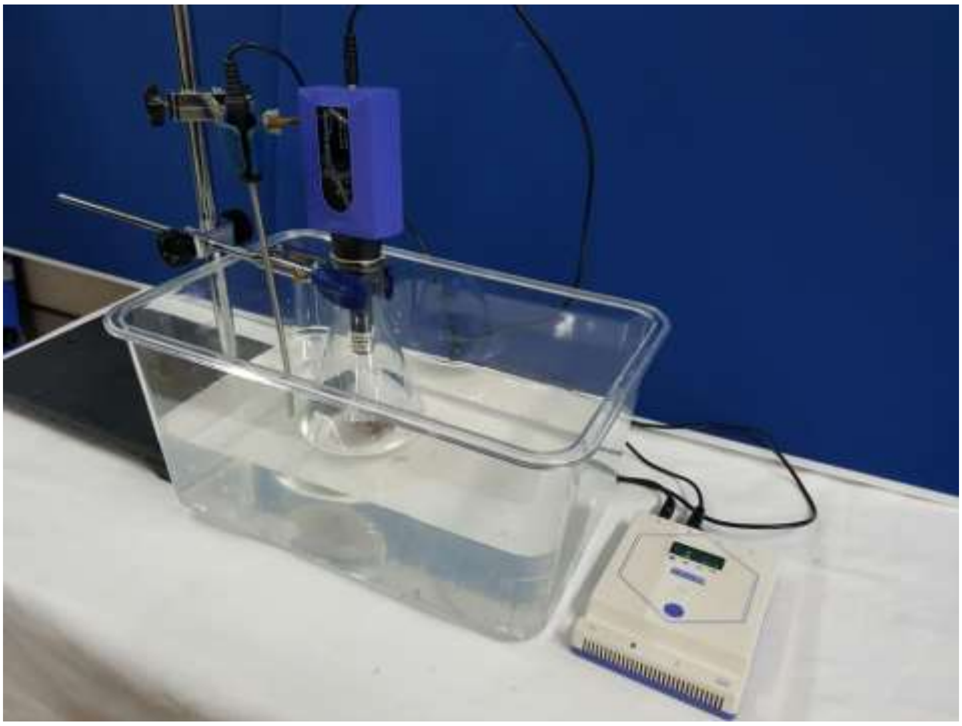
1. Launch the Science# program.
2. Connect the CO_2 sensor and temperature sensor to the interface and connect to the program via Bluetooth or cable.
3. Warm up the CO_2 sensor for 10-15 minutes to stabilize the data.
4. Click  to set up the experimental environment as shown below, or use the automatic setting option.

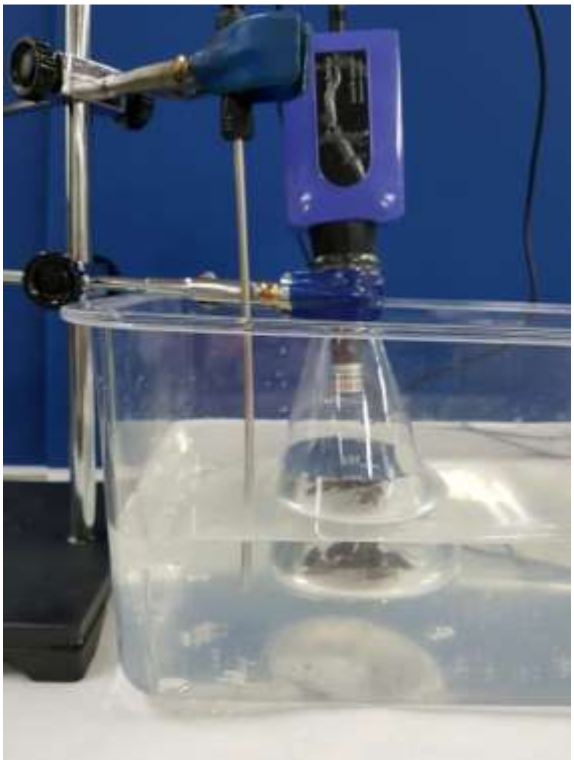


5. Place the temperature sensor in the water tank and adjust the amount of ice to maintain the water temperature between 0 and 10°C.

Data Collection

1. Once the temperature is between 0 and 10°C, place the beaker with crickets and an empty flask in the water for 10 minutes to allow the crickets to adapt to the ambient temperature. Longer adaptation times yield more accurate data.
2. Transfer the crickets from the beaker to the flask and press the start button. Seal the flask's opening with the CO_2 sensor..





3. Collect CO_2 concentration data in the flask for 5 minutes. (The experiment will end automatically after the set time.)
4. After data collection, remove the crickets from the flask and return them to the beaker.
5. Fan the CO_2 sensor for 1 minute to reduce the CO_2 concentration.
6. Fill the flask with water, empty it, and wipe the interior with paper towels to dry it completely. Ensure no water remains inside, as CO_2 dissolves easily in water, affecting accurate CO_2 measurements.
7. Adjust the amount of hot water added to the water tank to maintain temperatures of 10-20°C, 20-30°C, and 30-40°C, repeating the experiment as described..

Data Analysis

Recording Data

1. Measure and record the mass of 10 crickets.

2. Measure the CO_2 concentration change over time at various temperatures and compare them by plotting the data on a graph..

Graph

3. Use the graph analysis function to determine the metabolic rate of crickets at each temperature and calculate the specific metabolic rate per unit mass. Record the data in the following table.

Graph

Temperature (°C)	Measured Temperature	Metabolic Rate (ppm/min)	Specific Metabolic Rate (ppm/min•g)

	(°C)		
0~10(℃)			
10~20(℃)			
20~30(℃)			
30~40(℃)			

>>  Use the analysis function to fit the desired data with a linear graph f(x)=Ax + B and obtain the slope value.

>> The specific metabolic rate is calculated by dividing the metabolic rate (slope) measured at each temperature by the mass of the crickets..

Data Application

1. At which temperature did the CO2 increase rate appear highest? Compare this with the body temperature of endothermic animals and explain.

2. Explain how the metabolic rate of ectothermic animals changes with ambient temperature.

3. Based on the experimental results, explain the relationship between the temperature at which crickets were most active and the highest metabolic rate.

4. Predict how the metabolic rate of crickets would change if the same experiment were repeated at temperatures above 60°C..