

# Cellular Processes: Energy and Communication

## INVESTIGATION 6

# CELLULAR RESPIRATION\*

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 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:



More specifically,




The chemical oxidation of glucose has important implications to the measurement of 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.

- What specific things could you measure?
- 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 (either microrespirometers or gas pressure sensors with computer interface). These measure relative volume (changes in pressure) as oxygen is consumed by germinating plant seeds. As oxygen gas is consumed during respiration, it is normally

\* Transitioned from the *AP Biology Lab Manual* (2001)



replaced by CO<sub>2</sub> gas at a ratio of one molecule of CO<sub>2</sub> for each molecule of O<sub>2</sub>. Thus, you would expect no change in gas volume to result from this experiment. However, in the following procedure the CO<sub>2</sub> produced is removed by potassium hydroxide (KOH). KOH reacts with CO<sub>2</sub> to form the solid potassium carbonate (K<sub>2</sub>CO<sub>3</sub>) through the following reaction:



Thus, as O<sub>2</sub> is consumed, the overall gas volume in the respirometer decreases. The change in volume can be used to determine the rate of cellular respiration. Because respirometers are sensitive to changes in gas volume, they are also sensitive to changes in temperature and air pressure; thus, you need to use a control respirometer. What would be a good control for this procedure? Talk with another student for a minute, and come up with at least one possible control you could use.

As you work through Procedures, think about this question: What factors can affect the rate of cellular respiration? 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; diffusion of gases across cell membranes; and the physical laws pertaining to the properties and behaviors of gases.

## ■ Learning Objectives

- To learn how a respirometer system 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; diffusion of gases across cell membranes; and the physical laws pertaining to the properties and behaviors of gases

## ■ General Safety Precautions

You must wear safety goggles or glasses, aprons, and gloves during this investigation(s) because KOH (or the alternative, NaOH in Drano) is caustic. Follow your teacher's instructions when using the hot glue gun to seal microrespirometers. Do not work in the laboratory without your teacher's supervision.

## THE INVESTIGATIONS

### Getting Started

Your teacher may assign the following questions to see how much you understand concepts related to respiration before you design and conduct your own investigation:

1. Why is it necessary to correct the readings of the respirometers containing seeds with the readings taken from respirometers containing only glass beads? Your answer should refer to the concepts derived from the general gas law:

$$PV = nRT$$

#### Where

P = pressure of the gas

V = volume of the gas

n = number of moles of the gas

R = the gas constant (its value is fixed)

T = temperature of the gas

2. What happens to the volume of the gas being measured (O<sub>2</sub> consumption or CO<sub>2</sub> production) when the temperature or pressure changes during the experiment? If pressure and temperature remain constant, will the volume of gas in the respirometers increase or decrease? Please explain.

**Hint:** Several tutorials and animations explaining the general gas law are available online (e.g., <http://www.nclark.net/GasLaws>).

3. Imagine that you are given 25 germinating pea seeds that have been placed in boiling water for five minutes. You place these seeds in a respirometer and collect data. Predict the rate of oxygen consumption (i.e., cellular respiration) for these seeds and explain your reasons.
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 are asked to repeat the reptile/mammal comparison of oxygen consumption, but at a temperature of 22°C. Predict how these results would differ from the measurements made at 10°C, and explain your prediction in terms of the metabolism of the animals.
6. What difficulties would there be if you used a living green plant in this investigation instead of germinating seeds?