Topic 4: Energetics – 4c. Cellular Respiration of Germinating Seeds

Resources: Miller, K., Levine, J. (2004). *Biology.* Boston, MA: Pearson Prentice Hall.

Park, A. Brown Fat: A Fat That Helps You Lose Weight? *Time Magazine* [Internet]. 8 April 2009. Available from: http://www.time.com/time/health/article/0,8599,1890175,00.html

Building on: All living things require *energy.* Energy is needed to grow, move, reproduce and to combat *entropy.* The ultimate source of energy on our planet is sunlight. Plants and other *producers* can take the energy of the sun and use *photosynthesis* to store that energy in the form of *organic molecules* like *glucose*. *Cellular respiration* and *fermentation* are needed to release the potential energy in those organic molecules and convert it into a useful form of energy capable of doing *work,* usually *ATP*.

Links to Chemistry:
Bond energy
Endothermic versus exothermic reactions
Organic molecules
Conservation of matter
Conservation of energy
Entropy
Oxidation – Reduction reactions
Gas laws
Stoichiometry

Links to Physics:
Work
Potential and kinetic energy
Thermodynamics
Efficiency
Phase changes
Gas laws

Stories: Fat is traditionally thought to be the way the body stores excess calories, but a certain type of fat, brown fat, actually helps to burn calories. Most body fat is white in color, but brown fat has long been identified in newborn babies and rodents. It is called brown fat because of its dark appearance. That dark appearance is due to the high number of mitochondria found in the adipose cells of brown fat. The function of the brown fat is to carry out lots of cellular respiration, not to generate ATP, but to produce heat to maintain core body temperature. This makes sense in newborn babies as their bodies adjust and begin to rely on their own metabolism to maintain homeostasis.

Brown fat was thought to be absent in adult humans except in those suffering from hyperthyroidism and certain cancers. Now we know that even healthy adults have some deposits of brown fat in the front and the back of their neck region. Studies have shown that when the adult is exposed to cold temperatures for an extended period of time, the brown fat cells become more active, breaking down more glucose and burning more calories. It has been estimated that 50 g of brown fat (which is more than is found in a healthy person) has the potential to burn 20% of the daily calories consumed by the average adult.

More research will be needed to determine if this can be used as a viable weight loss strategy. There are many questions to be answered. For more details go to the following website:
http://www.time.com/time/health/article/0,8599,1890175,00.html

Materials for the Lab:

- Small test tubes (If you must use larger tubes, increase the amount of seeds, CaO, and cotton accordingly.)
- Glass beaker to hold the test tubes
- Rubber bands (to hold the test tubes together)
- Germinating seeds (Use mung beans that can be bought at health food stores or Indian groceries; soak the beans for two days.)
- Dry seeds (mung beans)
- Glass beads (craft store or can be ordered through a biological supply company)
- Calcium oxide powder
- Cotton balls
- Colored water (I prefer red food color; it makes it easier to see the water line in the test tubes.)

Instructions for the Teacher of This Lab:

Calcium oxide is a strong oxidizing agent, so students should wear goggles and quickly remove any of the powder from their hands with soap and water. Massing 1.5 g of CaO can be time-consuming, so I often use a small scoop and ask the student to place one or two scoops in each test tube. The actual amount of the CaO is not critical; you just want to be sure that you have enough to absorb all of the carbon dioxide released by the cellular respiration.

When the test tubes are inverted and placed straight down into the colored water of the beaker, the air pressure inside the test tubes prevents the water from rising in the tubes by more than a couple of millimeters. The water line should be visible. As cellular respiration takes place in the germinating seeds, the carbon dioxide given off is in direct proportion to the oxygen being taken up by the seed. However, this carbon dioxide (gas) reacts with CaO to form calcium carbonate (solid), which reduces the amount of gas in the tube and allows the water to rise. The increase in the rise of the water is proportional to the amount of carbon dioxide given off. If you have more advanced students, they can calculate the volume of the gas that was given off and, using the gas laws and stoichiometry, they can calculate the amount of glucose used.

Students may think the germinating seeds will be photosynthesizing, but note that only the seed coat is green. These seeds are relying on the nutrients within the seed itself to get large enough to begin photosynthesis. The dry seeds should not show any cellular respiration as they are dormant and the glass beads are there to demonstrate the influence of air pressure (like a barometer). If the water rises a bit in the tube with the glass beads, that means that the air pressure has increased since the lab was set up. That increase in air pressure reading should be deducted from any reading that you get for the germinating seeds.

When setting up the test tubes, it is important to put the CaO in first. This makes cleanup easier. When students take the test tubes apart at the end of the lab, they can remove the cotton and shake out the seeds into the trash and the glass beads into a container. Then the remainder of the cotton can be removed and the CaO can be rinsed out of the test tube.

Biology
Cellular Respiration in Germinating Seeds

Introduction: Seeds are living organisms. Living organisms require energy to react and interact with their environment. In order to generate energy, cells undergo cellular respiration. Cellular respiration uses oxygen to break apart an energy rich molecule, like glucose, to release energy, water and carbon dioxide. Calcium oxide (CaO) absorbs carbon dioxide forming a solid, calcium carbonate. CaO will be used to determine if the seeds are releasing carbon dioxide and, therefore, undergoing cellular respiration in this experiment.

Purpose: Read the entire lab and then write a purpose stating what you are trying to find out and how you are doing that. **B**e sure to include the words "*to determine*" in your purpose statement.

Hypothesis: Will all of the seeds in this experiment be undergoing cellular respiration? Explain your reasoning.

Descriptive List: State the dependent variable, the independent variable and the control.

Procedure:

1. Get three test tubes and label them with your initials and period number. Also label them tubes 1, 2, and 3.

2. Layer the materials in the test tubes as described below. The materials should not be packed in too tightly, but should be snug enough that they do not fall out when the test tube is inverted.

   Tube 1: 1.5 g CaO, ½ cotton ball, 10 pre-soaked seeds, ½ cotton ball
   Tube 2: 1.5 g CaO, ½ cotton ball, 10 dry seeds, ½ cotton ball
   Tube 3: 1.5 g CaO, ½ cotton ball, 10 glass beads, ½ cotton ball

3. Rubber band the three tubes together so that the "lip" of each tube is even with the others.

4. Pour 25 ml of colored water into a 100 ml beaker.

5. Place the test tubes upside down in the beaker of colored water.

6. Measure and record the height (in mm) that the water rises into each tube.

7. Store the laboratory setup at room temperature for 24 hours.

8. After 24 hours (DO NOT REMOVE THE TUBES FROM THE BEAKER), once again measure and record the height of the water in each tube.

9. Include both a results table and a graph in your lab report. You must decide which type of graph would best represent your results.

10. Answer the analysis questions; write a conclusion and an error analysis (if necessary).

Analysis Questions:

1. What prevented the water from moving up into the test tubes when they initially were inverted and placed in the liquid?

2. CaO absorbs carbon dioxide. Given this information, explain how the cell respiration could be responsible for the water rising into some of the test tubes.

3. What is the purpose of tube 3 and what does it demonstrate?

4. Compare the results of tube 1 and 2. Why is there a difference?

5. Suppose this laboratory was allowed to run an additional day. What might you expect to encounter with each tube? What about after a week?

6. If your test tube setup had been placed in the refrigerator for 24 hours instead of being left at room temperature, how do you think that would have affected the results and why?

7. If you forgot to use the CaO, how do you think the results might have been different for each tube and why?