Name ______________________ Course/Section ______________________

Date ______________________ Professor/TA ______________________

Activity 9.2 Modeling Cellular Respiration: How can cells convert the energy in glucose to ATP?

Using your textbook, lecture notes, and the materials available in class (or those you devise at home), model both fermentation (an anaerobic process) and cellular respiration (an aerobic process) as they occur in a plant or animal cell. Each model should include a dynamic (working or active) representation of the events that occur in glycolysis.

Building the Model

- Use chalk on a tabletop or a marker on a large sheet of paper to draw the cell membrane and the mitochondrial membranes.
- Use playdough or cutout pieces of paper to represent the molecules, ions, and membrane transporters or pumps.
- Use the pieces you assembled to model the processes of fermentation and aerobic respiration. Develop a dynamic (claymation-type) model that allows you to manipulate or move glucose and its breakdown products through the various steps of both fermentation and aerobic respiration.
- When you feel you have developed a good working model, demonstrate and explain it to another student.

Be sure your model of **fermentation** includes and explains the actions and roles of the following:

glycolysis
cytoplasm
electrons
protons
glucose
NAD^+
NADH

ADP
$Ⓟ_i$
ATP
pyruvate
ethyl alcohol (or lactic acid)
substrate-level phosphorylation

Be sure your model of **cellular respiration** includes and explains the actions and roles of the following:

glucose	electron transport chain
oxygen	mitochondria
carbon dioxide	inner mitochondrial membrane
pyruvate	outer mitochondrial membrane
acetyl CoA	H^+
NAD^+	electrons (e^-)
NADH	chemiosmosis
FAD	ATP synthase (proton pumps)
$FADH_2$	cristae
ADP	proton gradients
Ⓟi	oxidative phosphorylation
ATP	substrate-level phosphorylation
water	oxidative phosphorylation

Use your models to answer the questions.

1. The summary formula for cellular respiration is

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{Energy}$$

a. Where is each of the reactants used in the overall process?		b. Where is each of the products produced in the overall process?		
$C_6H_{12}O_6$ +	$6\ O_2$ →	$6\ CO_2$ +	$6\ H_2O$ +	Energy

2. In cellular respiration, the oxidation of glucose is carried out in a controlled series of reactions. At each step or reaction in the sequence, a small amount of the total energy is released. Some of this energy is lost as heat. The rest is converted to other forms that can be used by the cell to drive or fuel coupled endergonic reactions or to make ATP.

a. What is/are the overall function(s) of glycolysis?	b. What is/are the overall function(s) of the Krebs cycle?	c. What is/are the overall function(s) of oxidative phosphorylation?

3. Are the compounds listed here *used* or *produced* in:	Glycolysis?	The Krebs cycle?	Oxidative phosphorylation?
Glucose			
O_2			
CO_2			
H_2O			
ATP			
ADP + Ⓟi			
NADH			
NAD^+			

4. The cell's supply of ADP, Ⓟi, and NAD^+ is finite (limited). What happens to cellular respiration when all of the cell's NAD^+ has been converted to NADH?

5. If the Krebs cycle does not require oxygen, why does cellular respiration stop after glycolysis when no oxygen is present?

6. Many organisms can withstand periods of oxygen debt (anaerobic conditions). Yeast undergoing oxygen debt converts pyruvic acid to ethanol and carbon dioxide. Animals undergoing oxygen debt convert pyruvic acid to lactic acid. Pyruvic acid is fairly nontoxic in even high concentrations. Both ethanol and lactic acid are toxic in even moderate concentrations. Explain why this conversion occurs in organisms.

7. How efficient is fermentation? How efficient is cellular respiration? Remember that efficiency is the amount of useful energy (as ATP) gained during the process divided by the total amount of energy available in glucose. Use 686 kcal as the total energy available in 1 mol of glucose and 8 kcal as the energy available in 1 mol of ATP.

Efficiency of fermentation	Efficiency of aerobic respiration

8. a. Why can't cells store large quantities of ATP? (*Hint:* Consider both the chemical stability of the molecule and the cell's osmotic potential.)

b. Given that cells can't store ATP for long periods of time, how do they store energy?

9. To make a 5 *M* solution of hydrochloric acid, we add 400 ml of 12.5 *M* hydrochloric acid to 600 ml of distilled water. Before we add the acid, however, we place the flask containing the distilled water into the sink because this solution can heat up so rapidly that the flask breaks. How is this reaction similar to what happens in chemiosmosis? How is it different?

Similarities	Differences

10. If it takes 1,000 g of glucose to grow 10 g of an anaerobic bacterium, how many grams of glucose would it take to grow 10 g of that same bacterium if it was respiring aerobically? Estimate your answer. For example, if it takes *X* amount of glucose to grow 10 g of anaerobic bacteria, what factor would you have to multiply or divide *X* by to grow 10 g of the same bacteria aerobically? Explain how you arrived at your answer.

11. Mitochondria isolated from liver cells can be used to study the rate of electron transport in response to a variety of chemicals. The rate of electron transport is measured as the rate of disappearance of O_2 from the solution using an oxygen-sensitive electrode. How can we justify using the disappearance of oxygen from the solution as a measure of electron transport?

12. Humans oxidize glucose in the presence of oxygen. For each mole of glucose oxidized, about 686 kcal of energy is released. This is true whether the mole of glucose is oxidized in human cells or burned in the air. A calorie is the amount of energy required to raise the temperature of 1 g of water by 1°C; 686 kcal = 686,000 cal. The average human requires about 2,000 kcal of energy per day, which is equivalent to about 3 mol of glucose per day. Given this, why don't humans spontaneously combust?