**Activity: 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 cellular respiration (an aerobic process) as it occurs 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 process of 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 aerobic respiration.
* When you feel you have developed a good working model, demonstrate and explain it to another student.

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

glucose

oxygen

carbon dioxide

pyruvate

acetyl CoA

NAD+

NADH

FAD

FADH2

ADP

Pi

ATP

water

electron transport chain

mitochondria

inner mitochondrial membrane

outer mitochondrial membrane

H+

electrons (e-)

chemiosmosis

ATP synthase (proton pumps)

cristae

proton gradients

oxidative phosphorylation

substrate-level phosphorylation

**Use your models to answer the questions.**

1. The summary formula for cellular respiration is

C6H1206 + 6 02 🡪 6 CO2 + 6 H20 + Energy

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| --- | --- | --- | --- | --- |
| 1. Where is each of the reactants ***used*** in the overall process? | | 1. Where is each of the products ***produced*** in the overall process? | | |
| **C6H1206 + 6 02 🡪 6 CO2  + 6 H20 + Energy** | | | | |
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1. 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.

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| 1. What is/are the overall function(s) of glycolysis? | 1. What is/are the overall function(s) of the citric acid cycle? | 1. What is/are the overall function(s) of oxidative phosphorylation? |
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| 1. Are the compounds listed here ***used*** or ***produced*** in: | Glycolysis? | Pyruvate Oxidation and the Citric Acid Cycle? | Oxidative Phosphorylation? |
| Glucose |  |  |  |
| O2 |  |  |  |
| CO2 |  |  |  |
| H2O |  |  |  |
| ATP |  |  |  |
| ADP + Pi |  |  |  |
| NADH |  |  |  |
| NAD+ |  |  |  |

1. The cell's supply of ADP, Pi, and NAD+ is finite (limited). What happens to cellular respiration when all of the cell's NAD+ has been converted to NADH?
2. If the citric acid cycle (Krebs cycle) does not require oxygen, why does cellular respiration stop after glycolysis when no oxygen is present?
3. 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.
4. How efficient is cellular respiration? How efficient is fermentation? 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.

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| Efficiency of Aerobic Respiration | Efficiency of Fermentation |
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1. Why can't cells store large quantities of ATP? (*Hint*: Consider both the chemical stability of the molecule and the cell's osmotic potential.)
2. Given that cells can't store ATP for long periods of time, how do they store energy?
3. 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.
4. 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 02 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?
5. 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?