Welcome to AP Biology:

Welcome to a next-level biology class where we'll be spending a lot of time together this upcoming school year figuring out how the world works. You'll have fun and we'll all learn a lot!

To get the most out of our class, we're going to spend a lot of time developing some skills that are fundamental to performing science at a high level…and it's never too soon to start, so take a look at the next few slides and be ready to use these skills on DAY ONE!!! ☺

Skill One: Fun with graphs or models

You're too clever by half $\longrightarrow$ $U = \frac{2(\text{clever})}{2}$

You Should:

- Create a graph or model and be as creative as you would like…for example, could you put together a one-page guide to making a peanut-butter and jelly sandwich with only pictures & arrows? Could you create a pie chart summarizing your typical summer day? Could you create a graph illustrating the speed at which time travels in relation to the amount of fun you're having???
- Bring your work in on the first day of school, and we'll see who came up with the most interesting idea ☺

Skill Two: Developing your model reading skills…

You Should:

- Scroll down to the pages named “Cellular Respiration—An Overview”
- On these pages, there are three models and 21 questions…
  - CHOOSE *ONE* OF THE FOLLOWING OPTIONS:
    1. See if you can figure out ALL of the questions that go with ONE model…OR…
    2. See if you can figure out FIVE questions overall (and, yes, you should do all parts of a question for it to count ☺)

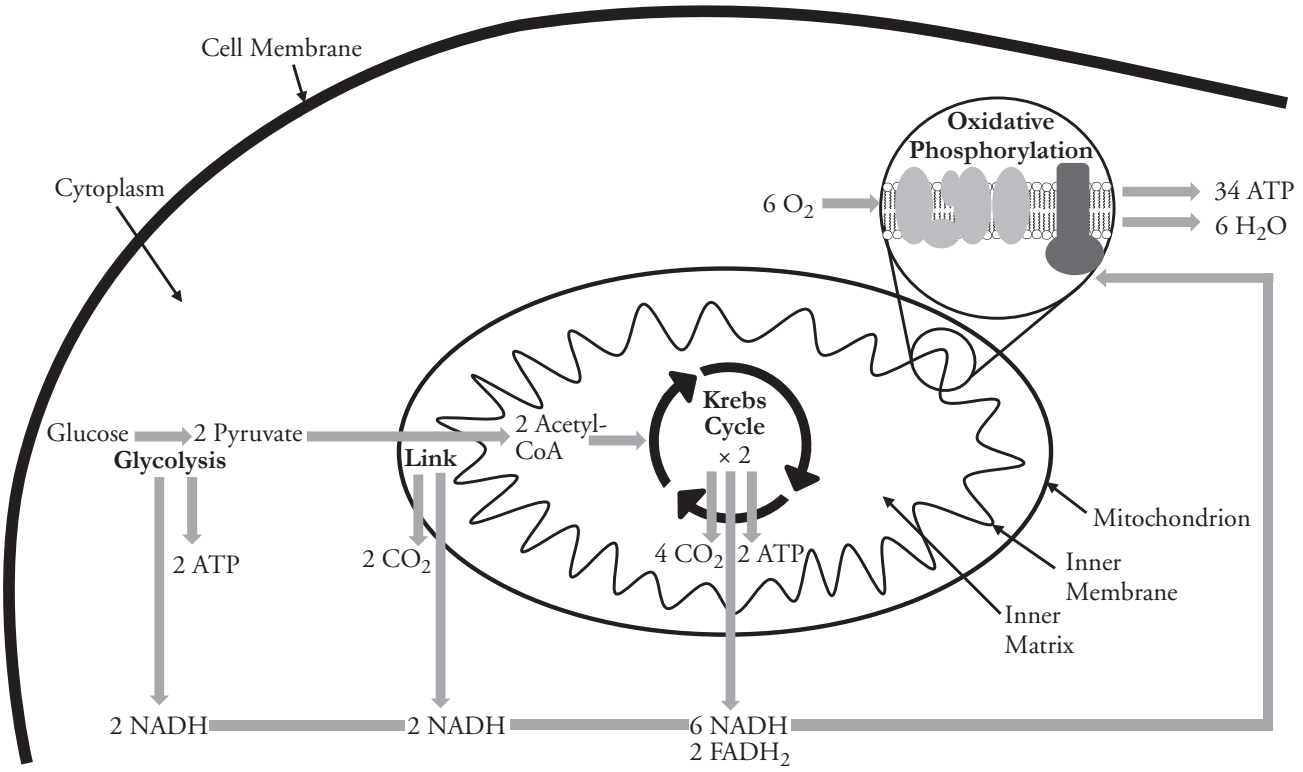
Cellular Respiration—An Overview

What are the phases of cellular respiration?

Why?

All cells need energy all the time, and their primary source of energy is ATP. The methods cells use to make ATP vary depending on the availability of oxygen and their biological make-up. In many cases the cells are in an oxygen-rich environment. For example, as you sit and read this sentence, you are breathing in oxygen, which is then carried throughout your body by red blood cells. But, some cells grow in environments without oxygen (yeast in wine-making or the bacteria that cause botulism in canned food), and occasionally animal cells must function without sufficient oxygen (as in running sprints). In this activity you will begin to look at the aerobic and anaerobic processes that are used by all organisms to produce ATP.

Model 1 – Cellular Respiration



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

1. According to Model 1, what are the reactants of cellular respiration?

2. According to Model 1, what are the products of cellular respiration?

3. Cellular respiration occurs in four phases: **glycolysis**, the **link reaction**, the **Krebs cycle**, and **oxidative phosphorylation**.

   a. Which phase of cellular respiration occurs in the cytoplasm of the cell?

   b. Which phases of cellular respiration occur in the mitochondria?

   c. Which of the four phases of cellular respiration require oxygen?

   d. Which of the four phases of cellular respiration produce carbon dioxide?

   e. Which of the four phases of cellular respiration produce water?

4. The goal of cellular respiration is to provide the cell with energy in the form of ATP.

   a. Which of the four phases of cellular respiration result in the production of ATP?

   b. How many ATPs (total) are produced for every glucose molecule that undergoes cellular respiration?

   c. What reactants of ATP must be available in the cell in order to produce ATP?

   d. Brainstorm several cellular processes for which energy or ATP is necessary.

Read This!

Glucose, or any carbon-based molecule, can be burned in oxygen (oxidized) to produce carbon dioxide and water. Combustion reactions release large amounts of energy. However, the energy release is uncontrolled. An organism would not be able to handle all that energy at once to do the work of the cell. Cellular respiration is essentially the same reaction as combustion, but the oxidation of glucose occurs in several controlled steps. The same amount of energy is ultimately released, but it is gradually released in small, controlled amounts. High potential energy molecules of ATP are produced while the carbon atoms are used to form various other molecules of lower potential energy. Each of these steps is catalyzed by an enzyme specific to that step. Model 1 illustrates the ideal circumstances for cellular respiration. In some situations, however, one glucose molecule may not result in 38 ATP molecules being produced.

5. Consider Model 1. Besides ATP, what other molecules appear to be high potential energy molecules (free energy carriers) during cellular respiration?



Model 2 – Electron Acceptor Molecules

$$_____ + NAD^+ + H^+ \longrightarrow NADH$$

$$_____ + FAD + 2H^+ \longrightarrow FADH_2$$

$$_____ + \tfrac{1}{2}O_2 + 2H^+ \longrightarrow H_2O$$

6. Nicotinamide adenine dinucleotide (NAD^+) and flavin adenine dinucleotide (FAD) are coenzymes used in cellular respiration to transport high potential energy electrons to the electron transport chain (a step in oxidative phosphorylation) in the mitochondria. At the conclusion of cellular respiration, oxygen is the final electron acceptor. The reactions in Model 2 show these electron acceptors in the process of picking up an electron.

   a. How many electrons are in a hydrogen ion (H^+)?

   b. Is a hydrogen ion with its positive charge likely to be attracted to NAD^+, FAD or O_2 without an input of free energy? Explain your reasoning.

   c. Consider the charges in the first reaction in Model 2. Can two positive particles combine to form a neutral particle? Explain your reasoning.



7. The reactions in Model 2 are missing very important particles—electrons.

   a. What is the charge on an electron?

   b. For each reaction in Model 2, predict the number of electrons that must be involved in the reaction to make the charges in the reaction balance.

   c. Add electrons to each reaction in Model 2 on either the reactant or product side of the equation to complete the reactions.

Read This!

Oxidation is a loss of electrons. Reduction is a gain of electrons. The two processes must go hand-in-hand. In other words, electrons cannot be added to something from thin air, they must have been taken off of something first.

8. Are the reactions in Model 2 oxidation or reduction reactions?

9. Which form of nicotinamide adenine dinucleotide is the "reduced" form, NAD^+ or NADH? Explain your reasoning.

10. According to Model 1, glucose undergoes the following changes during cellular respiration. In each step NADH or $FADH_2$ is produced. Is glucose being oxidized or reduced during cellular respiration? Explain your reasoning.

    Glucose ⟶ pyruvate ⟶ acetyl-CoA ⟶ carbon dioxide

11. Historically, the term "oxidation" was derived from the combination of a substance with oxygen. Question 10 addressed which molecule is the "more oxidized form." Validate your answer to Question 10 by comparing the ratio of carbon atoms to oxygen atoms in the chemical formulas of glucose ($C_6H_{12}O_6$) versus carbon dioxide (CO_2).



12. Model 1 shows ten NADH molecules being produced during cellular respiration. What reactants must be available in the cell for these molecules to be produced?

13. The hydrogen ions and electrons that were carried by NADH and $FADH_2$ are used in oxidative phosphorylation.

    a. What molecules are produced as the hydrogen ions and electrons are removed from NADH and $FADH_2$?

    b. Is the removal of hydrogen ions and electrons from NADH and $FADH_2$ oxidation or reduction? Explain your reasoning.

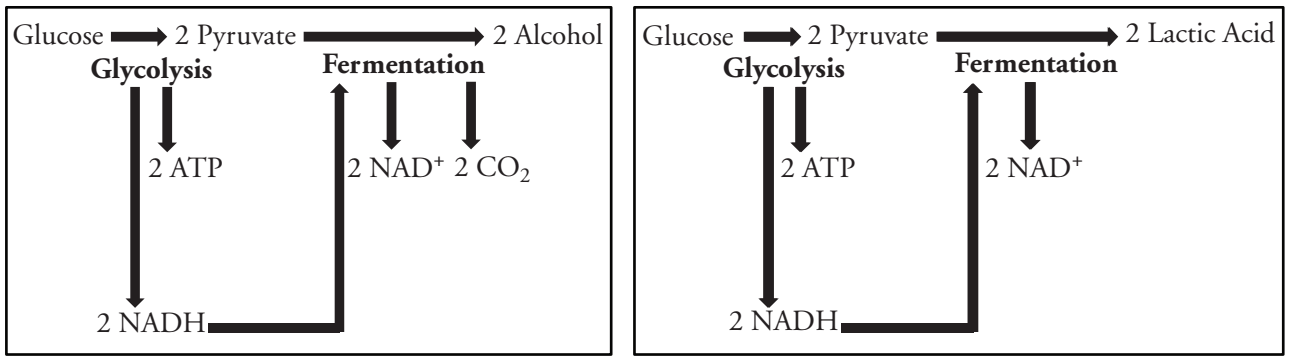
    c. Predict what happens to those product molecules after they "drop off" their hydrogen ions and electrons.

14. Cells can survive for short periods without oxygen. Only the glycolysis phase of cellular respiration occurs in those circumstances.

    a. Predict the number of ATP molecules that could be produced from one glucose molecule if oxygen were not available.

    b. Since oxidative phosphorylation no longer occurs when oxygen is not available, predict what would eventually happen to the supply of NAD^+ in the cell if only glycolysis were occurring?

Model 3 – Energy in Anaerobic Environments



15. Examine the two anaerobic processes in Model 3. Is oxygen used in either process?

16. What is the definition of anaerobic?

17. Compare the energy output (in the form of ATP) for a single glucose molecule that undergoes glycolysis and fermentation to that of a glucose molecule undergoing cellular respiration.

18. The efficiency of a cell is dependent on the cyclic nature of NAD^+ and NADH. Building NAD^+ molecules from raw materials each time one was needed would require a huge amount of free energy and resources. Even though the fermentation steps shown in Model 3 do not provide any ATP, they are critical to the energy production of the cell. Predict what would happen to the energy supply in a cell if fermentation did not happen under anaerobic conditions.

Extension Questions

19. The muscle "burn" that you feel when doing strenuous activity (sprints for example) is caused by a buildup of lactic acid in the muscle tissue of your body. Explain this phenomenon in the context of cellular respiration and fermentation.

20. The evolution of photosynthesizing organisms on Earth and the development of an oxygen-rich environment led to a rapid diversification of life. Explain why there is an evolutionary advantage to an organism that requires oxygen to live compared to one that does not require oxygen.

21. Under laboratory conditions muscle cells were broken up and separated into fractions of mitochondria and cytoplasm in an attempt to learn more about cellular respiration. Each fraction was incubated with glucose or pyruvate. Tests were carried out during incubation for the presence of either carbon dioxide or lactic acid. The results are shown below:

Cell Fraction	**CO_2**	**Lactic Acid**
Mitochondria incubated with glucose	Absent	Absent
Mitochondria incubated with pyruvate	Present	Absent
Cytoplasm incubated with glucose	Absent	Present
Cytoplasm incubated with pyruvate	Absent	Present

a. What does the presence of lactic acid in a sample indicate about what process is occurring in each cell fraction?

b. Explain why lactic acid was produced by the cytoplasm fraction incubated with glucose, but not the mitochondrial fraction.

c. Why was no carbon dioxide produced by either fraction incubated with glucose?

d. Why did the cytoplasm fraction produce lactic acid in the presence of both glucose and pyruvate?

e. Why did the mitochondria produce carbon dioxide in the presence of pyruvate but not in the presence of glucose?