Cellular Respiration

Although plants can absorb the energy of light and convert it into chemical bond energy through the process of photosynthesis, they do **NOT** have the ability to use light directly to get their energy for life processes. **Like all living organisms, plants must carry on *CELLULAR RESPIRATION.***

What is Cellular Respiration?

1. ***Cellular respiration is an enzyme controlled process that involves the transfer of chemical bond energy of organic food molecules such as glucose to a more available form of energy for the cell.***
2. Once the energy is released from the bonds of the food molecules, the energy is transferred and stored on the bonds of the energy carrier molecule **ATP (adenosine triphosphate)**
3. ATP is made by ***dehydration synthesis*** from ADP (adenosine diphosphate) and P (phosphate) molecules.
4. The energy released from the glucose or other food molecules is stored in the bond that is made between ADP and P.
5. ATP-ase is the enzyme that helps (catalyzes) the metabolic reaction to make ATP

Formation of ATP:

$$ADP + P + \text{chemical bond energy} \xrightleftharpoons{\text{ATP-ase}} ATP + H_2O$$

6. When ATP is formed, water, a metabolic waste is released.
7. When energy is needed, ATP is **hydrolyzed** (broken down) with the addition of water into ADP, P, and the release of chemical bond energy.
8. ADP and P can be used over and over to form ATP from the chemical bond energy released during cellular respiration.

Check your Understanding:

1. Do plants carry on cellular respiration? Explain.
2. Describe the function of ATP in all living organisms.
4. Where does the energy stored on the bonds of the ATP come from?
5. Describe the function of ATP-ase.
6. Is the water from this chemical process excreted or egested? Explain your answer.
7. Is the chemical equation to make ATP reversible? How do you know?
8. By what process is ATP made?
9. By what process is ATP broken down?

Starting Point of Cell Respiration… GLYCOLYSIS

Points:

1. Cellular respiration begins in the **cytoplasm** of the cell.
2. **No oxygen is required**
3. **Glucose is broken down into 2 molecules of pyruvic acid.**
4. For each molecule of glucose broken down, 2 ATP are formed from this process

Anarobic Phase (glycolysis)

Glucose $\xrightarrow{\text{enzymes}}$ 2 three carbon compounds (2 pyruvic acid) + 2 ATP

Check your Understanding:

1. Where does cellular respiration start?
2. Describe what happens to one molecule of glucose during the glycolysis.
3. What is the net number of ATP formed during the process of glycolysis?
4. Why is pyruvic acid considered to be a metabolic waste?

Once glycolysis occurs, cell respiration takes one of two metabolic pathways:

1. **Anaerobic Pathway: *requires NO oxygen***, takes place in the cytoplasm
2. **Aerobic Pathway: *requires the use of oxygen***, takes place in the mitochondria

Glycolysis

Anaerobic Respiration (does NOT use oxygen) **Aerobic Respiration (uses oxygen)**

Anaerobic Respiration:

Points

1. Follows glycolysis, **<u>when there is *NO* oxygen</u>**
2. Often referred to as **FERMENTATION**
3. Also takes place in the cytoplasm of the cell
4. Fermentation further breaks down pyruvic acid **WITHOUT** making any additional ATP
5. ***There are two main types of fermentation:*** **<u>lactic acid fermentation and alcoholic fermentation.</u>**

General Equation for Glycolysis and Fermentation:

$C_6H_{12}O_6$ $\longrightarrow$ 2 pyruvic acid (3 carbon compound) + 2 ATP

2 lactic acid 2 alcohol + 2 CO_2

Lactic Acid Fermentation

- In some cells, like bacteria, **pyruvic acid is converted to lactic acid.**
- **No additional ATP is made** during this process.

- **So, there is only a net of 2 ATP per molecule of glucose** made during lactic acid fermentation.

Lactic Acid Fermentation and Bacteria

1. Some bacteria use lactic acid fermentation to obtain their energy.
2. The dairy industry uses the lactic acid produced by bacteria during fermentation to make yogurt, buttermilk, and cheeses (this gives these foods their familiar "sour" taste).

Muscle Fatigue (Oxygen Debt)

1. Lactic acid is produced in your muscle cells during rapid exercise when the body cannot supply enough oxygen to all the tissues.
2. When you exercise vigorously, the large muscles of your arms and legs run out of oxygen quickly.
3. Without oxygen, your muscle cells continue to produce ATP through lactic acid fermentation, resulting in an excess build-up of lactic acid, quickly tiring the muscles and causing a painful, burning sensation.
4. If you continue to push your muscles, they will eventually give out and you will have to stop because the pain is too great.
5. Once our muscles form lactic acid, it is gradually released to the bloodstream to be excreted

Check your Understanding:

1. What is another name for anaerobic respiration?
2. What is the net production of ATP during lactic acid fermentation?
3. Trace the pathway of a molecule of glucose that enters a cell that performs lactic acid fermentation.
4. Why does the dairy industry use bacteria to make such products as yogurt, buttermilk and cheeses?
5. What is the relationship between anaerobic respiration and muscle fatigue?

Alcohol Fermentation

1. Yeast and a few other microorganisms use a different pathway to break down pyruvic acid.
2. These cells break pyruvic acid ***into alcohol and CO_2 (metabolic wastes) with no further production of ATP.***
3. The baking industry takes advantage of the fact that ***yeast, although it is an aerobic organism, can revert to fermentation if oxygen is not present.***
   --When the yeast in the dough runs out of oxygen, it begins to ferment the glucose, producing CO_2 bubbles which pop, forming the air spaces you see in bread and muffins.
   --The small amount of alcohol that is made during this process evaporates when the bread is baked.
   --That is why people love the smell of baking bread – it is the alcohol burning off when the bread is in the oven!
4. The beer and wine-making industries also use yeast to obtain the alcohol content of their

drinks and bubbly or fizz, which come from the bubbles of CO_2 .

Some more questions to see you how you are doing!

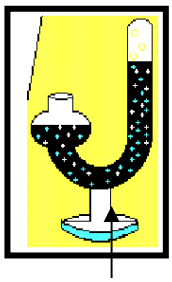
1. What is another name for alcohol fermentation?
2. If a cell uses alcohol fermentation, what is pyruvic acid broken down into?
3. Why are these end products considered to be metabolic wastes?
4. What is the overall net production of ATP during alcohol fermentation?
5. Yeast is a single celled fungus that is used in the baking industry. What is special about yeast with respect to cellular respiration?
6. Why don't people get drunk if they eat a great deal of bread at a meal?
7. How does alcohol fermentation enable a glass of beer to have a "foamy head"?

Try this question to check your understanding!

Your family bakery is famous for their cakes and pies. Although your customers like the taste of your breads, they complain they are just too heavy to eat. After a discussion with your accountant, you realize you are losing lots of business because your bread sales are sluggish. How can you make your bread lighter so you can improve your sales?

Fermentation Experimentation in the Lab

A fermentation tube is often used to observe the process of alcohol fermentation by various organisms such as yeast. In such an experiment, the fermentation tube would be loaded with a mixture of water, glucose (usually brown sugar or molasses), and yeast. After stoppering the tube and mixing the contents for a few minutes, the tube is tilted so that the mixture moves into the blind end of the apparatus. A vacuum is created that will initially hold the mixture up in the blind end of the tube. Eventually the yeast cells begin to "burn" the sugar and produce a gas which pushes the mixture back down the tube into the bulb. As fermentation continues, the gas collects in the blind part of the tube



Fermentation Tube

1. Identify the gas you believe collects in the blind part of the tube. Justify your answer.
2. If we did this experiment in class, what do you think the room would smell like after a period or two?

Aerobic Respiration

Pyruvic Acid ….Chock full of Potential Energy!

1. At the end of glycolysis, pyruvic acid still has about 90% available unused energy locked in its high energy electrons that bond this molecule together.
2. To unleash this energy, the cell uses oxygen, one of the most powerful electron acceptors in order to release as much energy as possible from the bonds of the pyruvic acid.
3. Once glycolysis is completed, **pyruvic acid and oxygen move into the mitochondria where aerobic respiration takes place.**

Overall Summary Equation of Aerobic Respiration:

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{enzymes}} 36\ ATP + 6\ CO2 + 6\ H_2O$$

Points of Aerobic Respiration:

1. Starts with glycolysis in the cytoplasm of the cell
2. Glucose is cut in half to make 2 molecules of pyruvic acid (3 carbon compound) and **2 ATP.**
3. If oxygen is present, pyruvic acid and oxygen enter the mitochondria.
4. Through a series of enzyme controlled reactions, the high energy electrons of pyruvic acid release their energy to form an additional **34 ATP.**
5. **Oxygen is the final acceptor of these electrons and their hydrogens, forming the metabolic waste, water.**
6. **Carbon dioxide,** another metabolic waste, is also formed.
7. ***The overall net yield of ATP from 1 molecule of glucose during aerobic respiration is 2 ATP from glycolysis and 34 ATP from the breakdown of pyruvic acid in the mitochondria to yield a total of 36 ATP.***

Comparison of Anaerobic and Aerobic Respiration

1. **Anaerobic Respiration** is quick, but not very efficient – it provides only 2 ATP per molecule of glucose. **That means that its end products, pyruvic acid, are chock full of untapped potential energy!**
2. When cells evolved to use oxygen and mitochondria, cellular respiration became very efficient. **Aerobic respiration** removes 34 additional ATP from pyruvic acid, **so its end metabolic products, CO2 + H_2O have little potential energy left in their bonds.**

Final Set of Questions to Check your Understanding

1. Where does aerobic respiration take place?
2. Write out the overall reaction of aerobic respiration. Identify the raw materials, the product, and the metabolic wastes.
3. If 34 ATP are formed by aerobic respiration in the mitochondria, where do the additional 2 ATP come from?
4. How do we know that the metabolic waste products of glycolysis have more potential energy than the waste products of aerobic respiration?

Challenge:

Carbon monoxide (CO) is an odorless, colorless gas produced when fuels such as gas, oil, or wood is burned. If carbon monoxide is inhaled, it competes with oxygen binding sites on the oxygen-carrying molecule known as hemoglobin found in your red blood cells. This is called carbon monoxide poisoning.

1. How would CO poisoning affect a person's ability to produce ATP. Explain.
2. What impact would this have on this person?