Standard: Students will derive the relationship between single-celled and multi-celled organisms and the increasing complexity of systems.

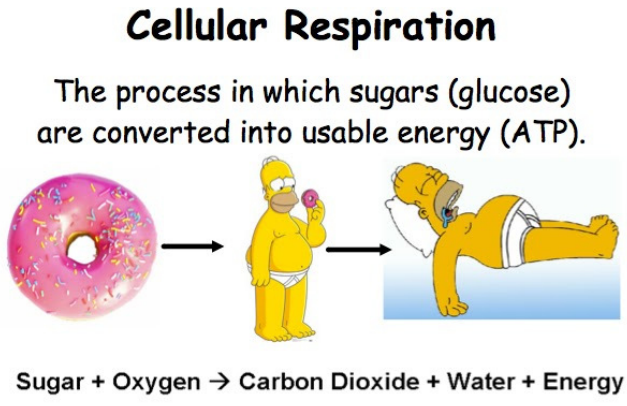
Element: Explain the cycling of energy through the processes of photosynthesis and respiration.

EQ: What is cellular respiration?

I) The Reaction:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy (ATP)

In words: Glucose is broken down in the presence of oxygen to produce ATP, releasing carbon dioxide and water as waste products.



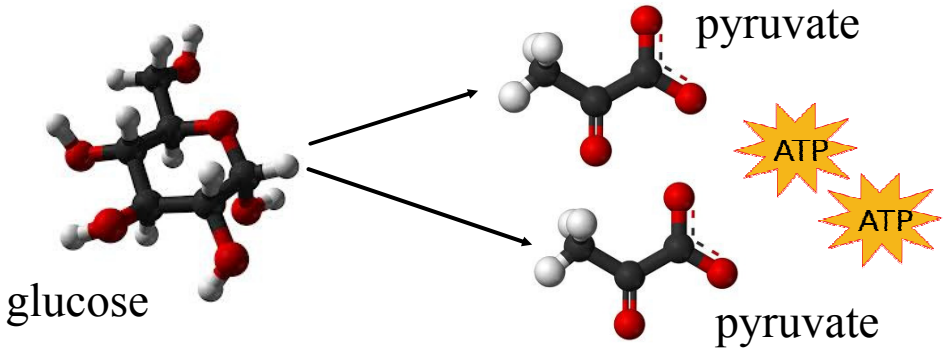
A) First stage of cellular respiration: Glycolysis

1) Does not require oxygen (O_2)

2) Occurs in the cytoplasm of the cell

3) One molecule of glucose is broken into two 3-carbon molecules called *pyruvate*

4) Generates two molecules of ATP

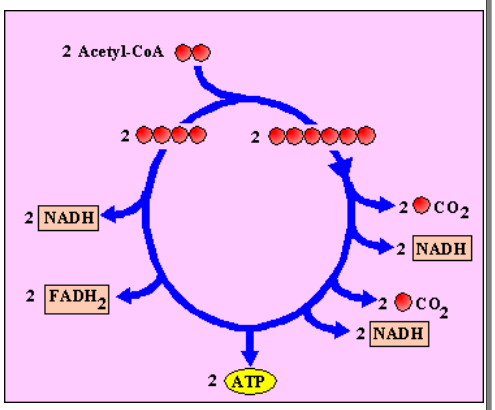


B) Second stage of cellular respiration: Krebs Cycle

1) Only possible if oxygen (O_2) is present

2) Occurs in the mitochondrial matrix of eukaryotic cells (in prokaryotic cells it can occur in the cytoplasm)

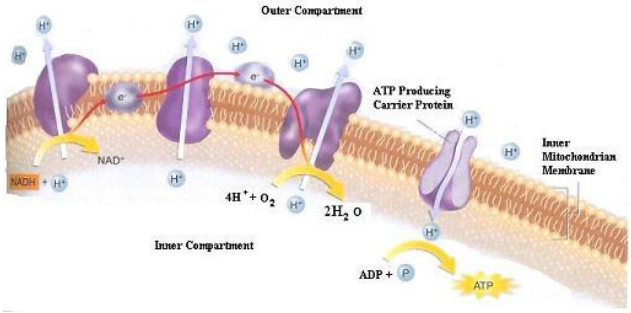
3) Generates two molecules of ATP for every molecule of glucose



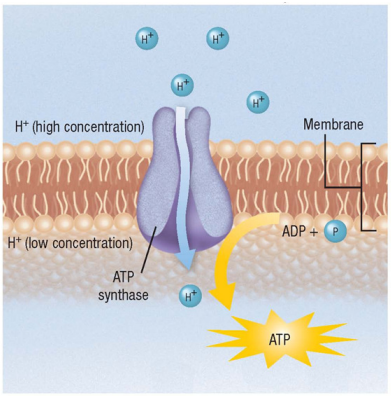
C) Final stage of cellular respiration: Electron Transport Chain (ETC)

1) Only possible if oxygen (O_2) is present; molecules are constantly cycled between the Krebs cycle and the electron transport chain. If one process is stopped, the other cannot occur.

2) The ETC causes hydrogen ions (H^+) to be pumped out of the inner compartment of mitochondria.

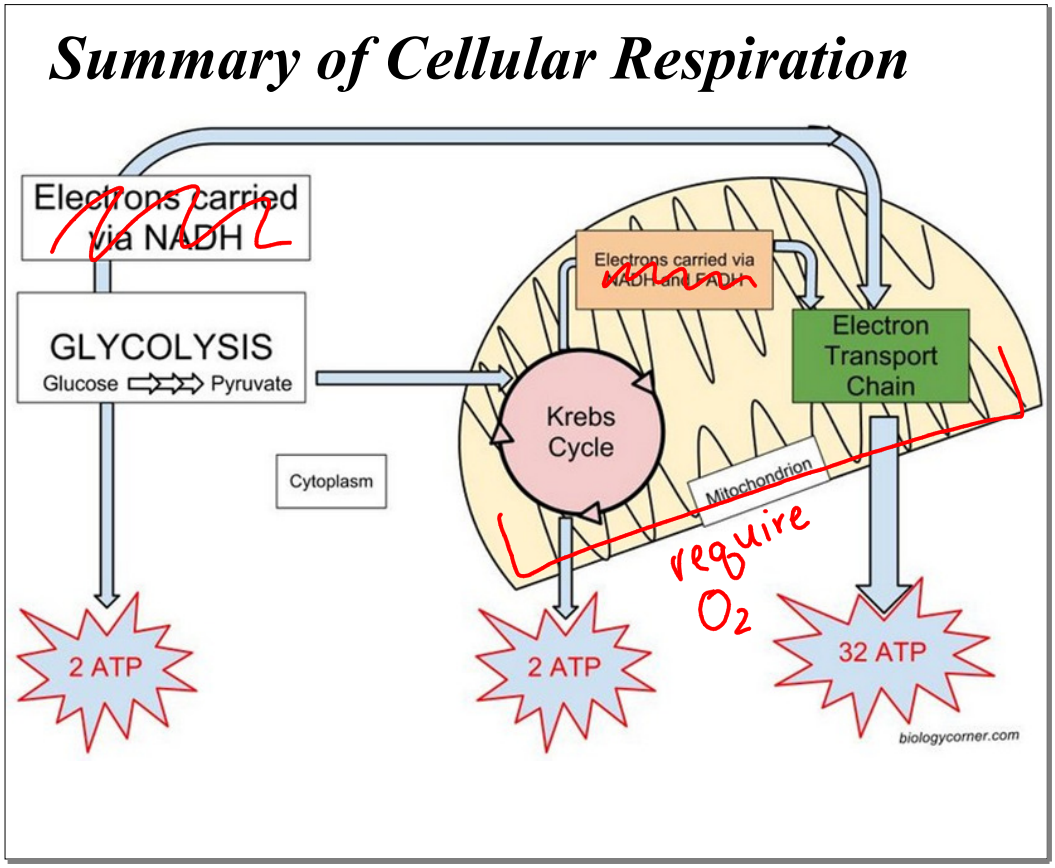


3) A membrane protein called **ATP synthase** allows hydrogen ions to flow back into the inner compartment, which produces ATP



(a) ATP = adenosine ***tri*** phosphate, a molecule that is high in potential energy that is released when one phosphate group is broken off

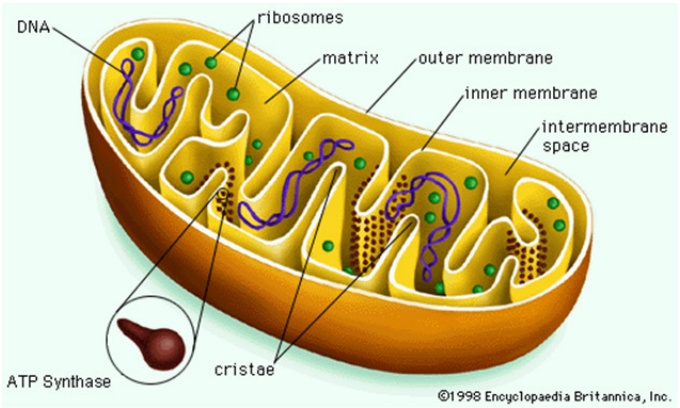
(b) ADP = adenosine ***di*** phosphate, a molecule that is low in potential energy but can be converted back to ATP if a phosphate group (P_i) is added



II) Mitochondria (singular, *mitochondrion*):

A) Double membrane-bound organelle that is the site of cellular respiration in eukaryotes

B) Contains ribosomes, DNA separate from nucleus, and can replicate on its own



C) Interior structure of a mitochondrion

1) Cristae: folds in the inner membrane

(a) Inner membrane is larger than outer membrane in order to maximize surface area

(b) Electron Transport Chain, including ATP Synthase, is located within the membrane of the cristae

2) Intermembrane space: space between the outer and inner membranes

3) Matrix: fluid inside the inner membrane where the Krebs cycle takes place

III) Anaerobic Respiration

A) In some circumstances, cellular respiration can take place in the absence of oxygen (O_2)

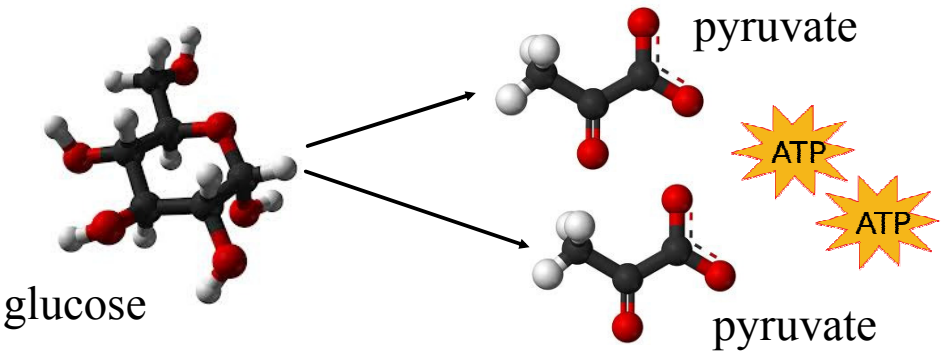
1) Aerobic refers to oxygen

2) Anaerobic refers to the lack of oxygen

B) First stage of anaerobic respiration: Glycolysis

1) This happens in all organisms whether oxygen is present or not

2) Remember, this produces two molecules of ATP for every molecule of glucose



C) Second stage of anaerobic respiration: Fermentation

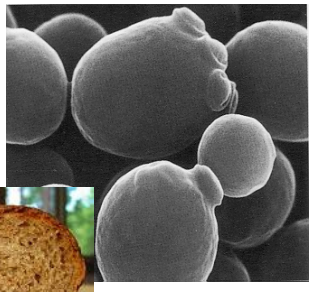
1) After glycolysis, there are two different fermentation pathways

(a) Lactic Acid fermentation produces lactic acid as a byproduct

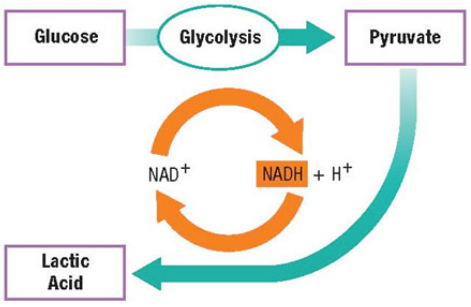
Example: This happens in our muscles when we exercise. If your body needs more energy (ATP) but is running out of oxygen, this type of fermentation happens in muscle cells. The buildup of lactic acid causes the burning sensation we feel during a hard workout.

(b) Alcoholic Fermentation produces ethanol as a byproduct

Example: Yeast are capable of alcoholic fermentation and humans have learned how to use this knowledge to produce beer and other alcoholic beverages.

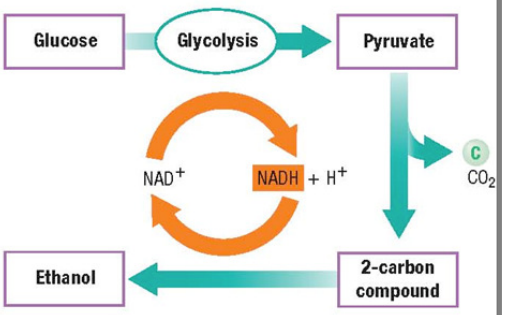


2) Neither type of fermentation produce any more ATP, they are simply necessary for recycling the carbon compounds so that glycolysis can continue.



Lactic acid fermentation

In lactic acid fermentation, pyruvate is converted to lactic acid.



Alcoholic fermentation

In alcoholic fermentation, pyruvate is broken down to ethanol, releasing carbon dioxide.