PDF File

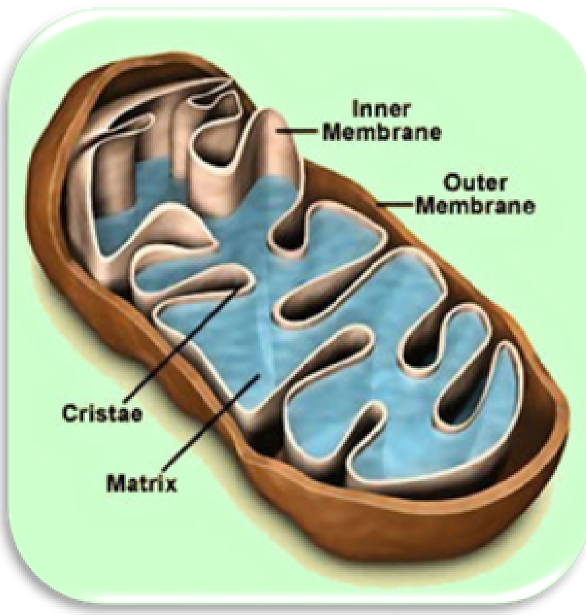
CELLULAR RESPIRATION

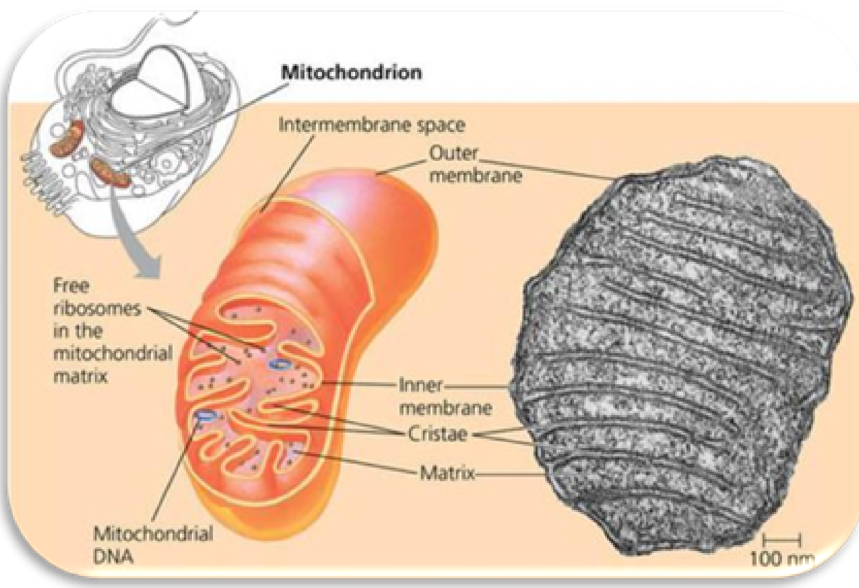
In the last unit you learned of the two processes (photosynthesis and chemosynthesis) which some cells carry out in order to produce food or chemical energy for other organisms. In this unit we will look at the process which all cells utilize in order to convert the energy that is produced by photosynthesis or chemosynthesis into a usable energy form for cells. In this process, known as cellular respiration, energy is released from the chemical bonds of the food (biomolecules) consumed and then transferred to ATP. Cellular respiration does not only involve the carbohydrates made from photosynthesis or chemosynthesis but also proteins and lipids. Remember from previous units about the structure and importance of ATP and how a cell needs this molecule in order to have a usable form of energy. In other words, a cell can have all the sugar it wants, but if the energy in the sugar is not converted to ATP (process of cellular respiration) then that energy is useless to the cell.

Mitochondria

The process of cellular respiration occurs in the organelle know as a mitochondrion (singular) or mitochondria (plural). Mitochondria were mentioned in Unit 6 - Cell. Here we will examine the mitochondrion in a little more detail. **The mitochondria are nicknamed the "powerhouse" of the cell,** because this is where cellular respiration occurs which produces all of the ATP (usable energy) for the cell. Cells which require a great amount of energy will contain more mitochondria than other cells which may not require as much energy. Muscle cells and liver cells are examples of cells within us that require more energy (ATP) and therefore more mitochondria than other cells such as skin cells. In eukaryotes, you will find mitochondria for the process of cellular respirations. In prokaryotes, remember they have no membrane-bound organelles, cellular respiration occurs in their plasma membrane.

Mitochondria are double membrane organelles. The **outer membrane** is smooth while the **inner membrane** has many folds so to increase surface area. Having more of this inner membrane allows for more cellular respiration reactions. Just as we mentioned how different cells can have greater or lesser amounts of mitochondria in their cells, the mitochondria themselves may have more inner membrane folds than others. These inner membrane folds are called **cristae**. These two membranes also create two spaces within the organelle. The space between the inner membrane and outer membrane is called the **intermembrane space**. The space totally enclosed by the inner membrane is called the **matrix**. It is on this inner membrane and matrix where many of the ATP-producing enzymes are found.



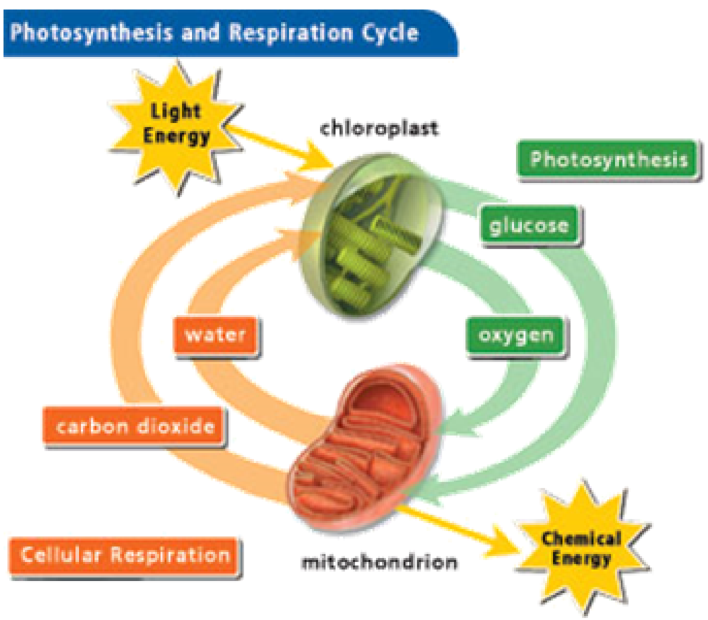


Cellular Respiration Overview

Cellular respiration is a process that involves a set of metabolic reactions by which the cell produces energy from carbohydrates. The overall cellular respiration reaction involves using glucose ($C_6H_{12}O_6$) and oxygen gas (O_2) to produce water (H_2O), carbon dioxide gas (CO_2) and most importantly ATP.

$$6\,O_2 + C_6H_{12}O_6 \longrightarrow 6\,CO_2 + 6\,H_2O + ATP$$

Carbon Cycle



The reaction of cellular respiration in conjunction with the reaction of photosynthesis are the major parts of the carbon cycle. *Metabolism* involves using energy to either build organic molecules or break down organic molecules. When breaking down organic molecules, chemical bonds are broken and that is when energy is released. Organic molecules are molecules made with carbon. The fact that photosynthesis produces the organic molecule and cellular respiration uses that organic molecule makes these two reactions major players in the carbon cycle. Not only are they cycling carbon through the environment, but they are also cycling chemical energy.

Recall that photosynthesis is the process which uses sunlight to produce organic molecules, more specifically carbohydrates (sugars). Cellular respiration is the process that will release the energy from that carbohydrate and produce ATP for the cell to use. From the cellular respiration reaction above, you see that carbon dioxide is produced when the glucose (sugar) is broken down. That carbon dioxide will be used by photosynthesis to produce carbohydrates again.

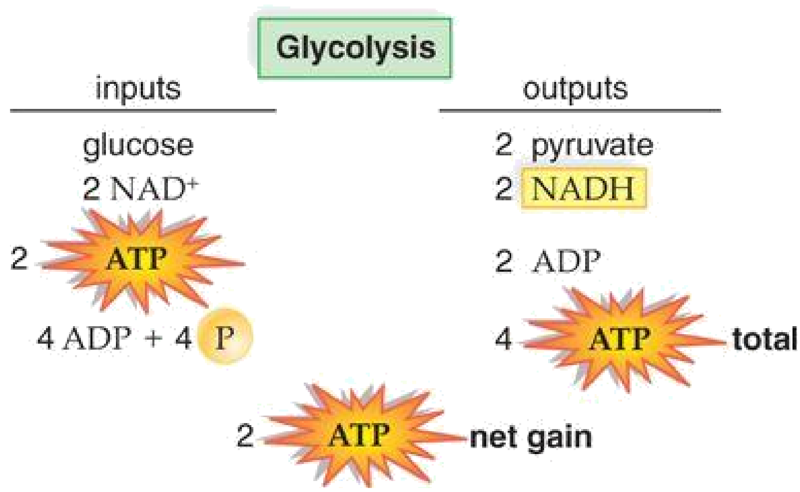
The following video segment defines glycolysis, citric acid cycle (Krebs cycle), and the electron transport chain.

Cellular Respiration Stages

Cellular respiration occurs in a series of stages. The three main stages of cellular respiration are **glycolysis, the citric acid cycle, and the electron transport chain**.

The first stage of cellular respiration is **glycolysis which translated means "splitting sugars".** In glycolysis, glucose ($C_6H_{12}O_6$), which is a six-carbon sugar, is broken down with the help of enzymes into two three-carbon sugars called pyruvate molecules.

The process begins using two ATP molecules and in the end of glycolysis four ATP molecules are produced, so it is said that there is a net gain of 2 ATP molecules in glycolysis.

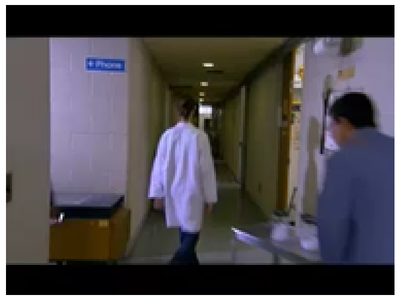


Aerobic Respiration

Any cellular process that requires oxygen is described as **aerobic**. Any cellular process that does not require oxygen is described as **anaerobic**. Stage 1 – Glycolysis is an anaerobic process. Aerobic Respiration continues after glycolysis with the two pyruvate molecules that were produced, if oxygen is present. Essentially the two pyruvates are converted into many ATP molecules. Aerobic Respiration is the most efficient method of producing ATP. Aerobic Cellular Respiration involves two steps: **Citric Acid Cycle and Electron Transport Chain**.

2. Citric Acid Cycle

The Citric Acid Cycle is also known as the Krebs Cycle. The cycle is named after the German biochemist Hans Adolf Krebs. Hans Adolf Krebs identified the citric acid cycle in 1937. To learn more watch the following video.

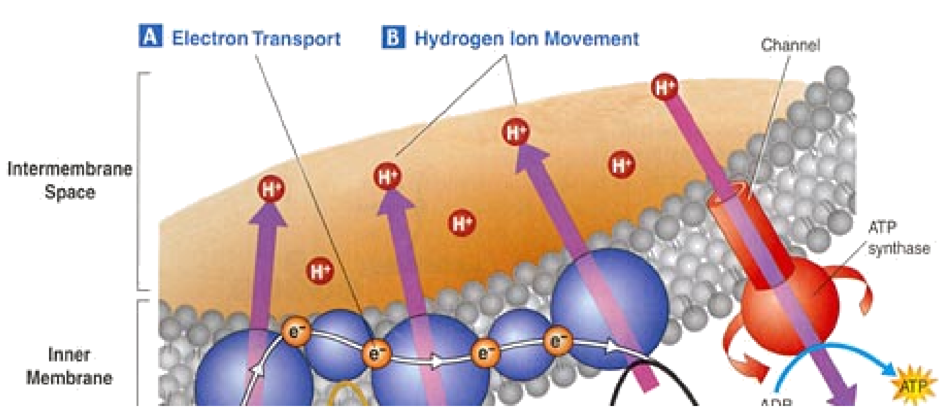


The **Citric Acid Cycle** involves a series of biochemical reactions that convert the pyruvate from glycolysis into carbon dioxide, water, and more importantly ATP, NADH (electron carrier), and $FADH_2$ (electron carrier).

$$6\,O_2 + C_6H_{12}O_6 \longrightarrow 6\,CO_2 + 6\,H_2O + ATP$$

3. Electron Transport Chain

The electron transport chain occurs on the inner membrane of the mitochondrion. The more cristae present within the mitochondrion, the more electron transport chains possible, therefore the more ATP that will be made. In photosynthesis, you learned about an electron transport chain. This electron transport chain is similar in terms of the process.



The electron carriers (NADH and $FADH_2$) that were produced in the Krebs cycle will now pass through this electron transport chain. The electrons that NADH

and $FADH_2$ bring to the electron transport chain will be released and pass through this chain releasing their energy to molecules within the membrane. Hydrogen ion pumps are some of the membrane molecules that energy from the electrons is pass to.

The energy from the electrons have the hydrogen ion pumps move hydrogen ions outside of the matrix. As hydrogen ions accumulate outside the inner membrane of the mitochondria a higher concentration of hydrogen ions is created outside the inner membrane.

> *To review Active Transport and Passive Transport go back to Unit 8 – Cell Transport.*

> *To review "ATP Synthase" go back to Unit 9 – Photosynthesis-Chemosynthesis under "Synthesis of ATP".*

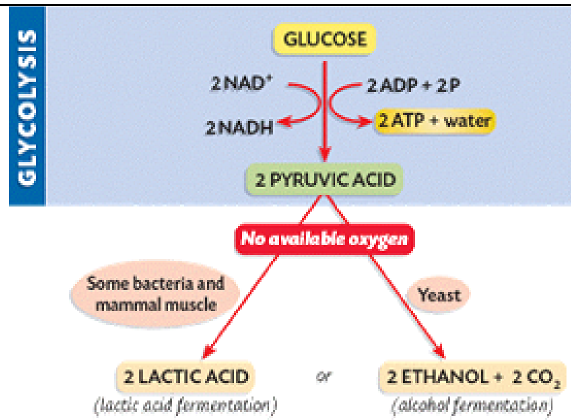
Now that there is a higher concentration of hydrogen ions outside the inner membrane, hydrogen ions will begin to diffuse naturally (passive transport) back through the inner membrane. The hydrogen ions use the membrane protein/enzyme "ATP Synthase" to diffuse back into the matrix. **As the hydrogen ions diffuse through the ATP Synthase the energy created is used to produce up to 34 ATP molecules.**

$$6\ O_2 + C_6H_{12}O_6 \longrightarrow 6\ CO_2 + 6\ H_2O + ATP$$

If no oxygen is present or available then the electron transport chain stops, no electron carriers can be recycled, and the only ATP produced is as a result of *Stage 1 Glycolysis*. As you can see it is very important to keep a supply of oxygen available to keep aerobic cellular respiration working in order to produce the most ATP molecules possible.

Anaerobic Respiration

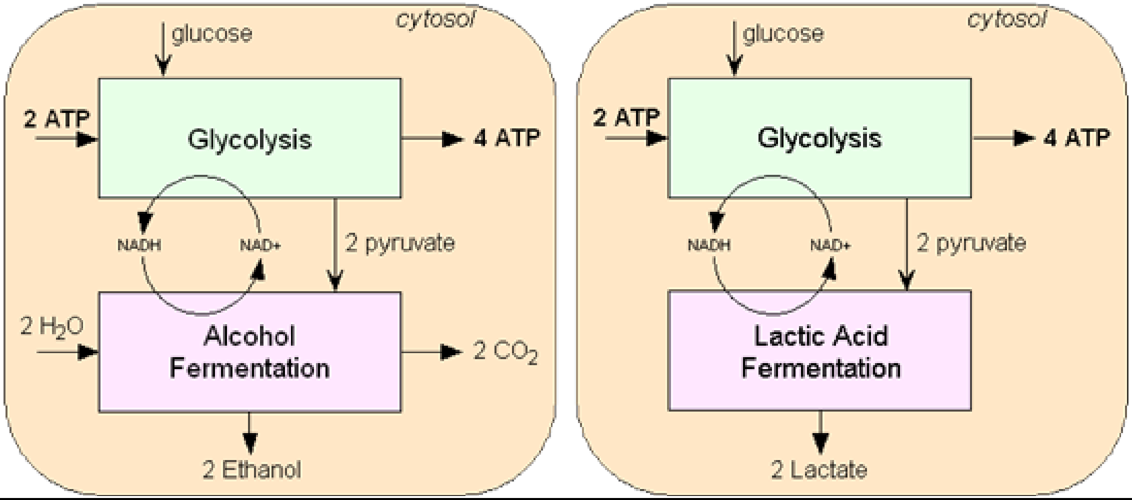
At the end of Stage 1 Glycolysis, sometimes oxygen is not available. If no oxygen is available the cell then undergoes anaerobic respiration.



Instead of the Krebs cycle and electron transport chain that is used in aerobic respiration, anaerobic respiration will use the process of **fermentation** to recycle NAD^+ which is needed to continue making ATP in Stage 1 Glycolysis. In other words, fermentation is necessary to keep glycolysis working when no oxygen is present so ATP is still being produced. There are two types of fermentation: **Lactic Acid Fermentation** and **Alcoholic Fermentation**.

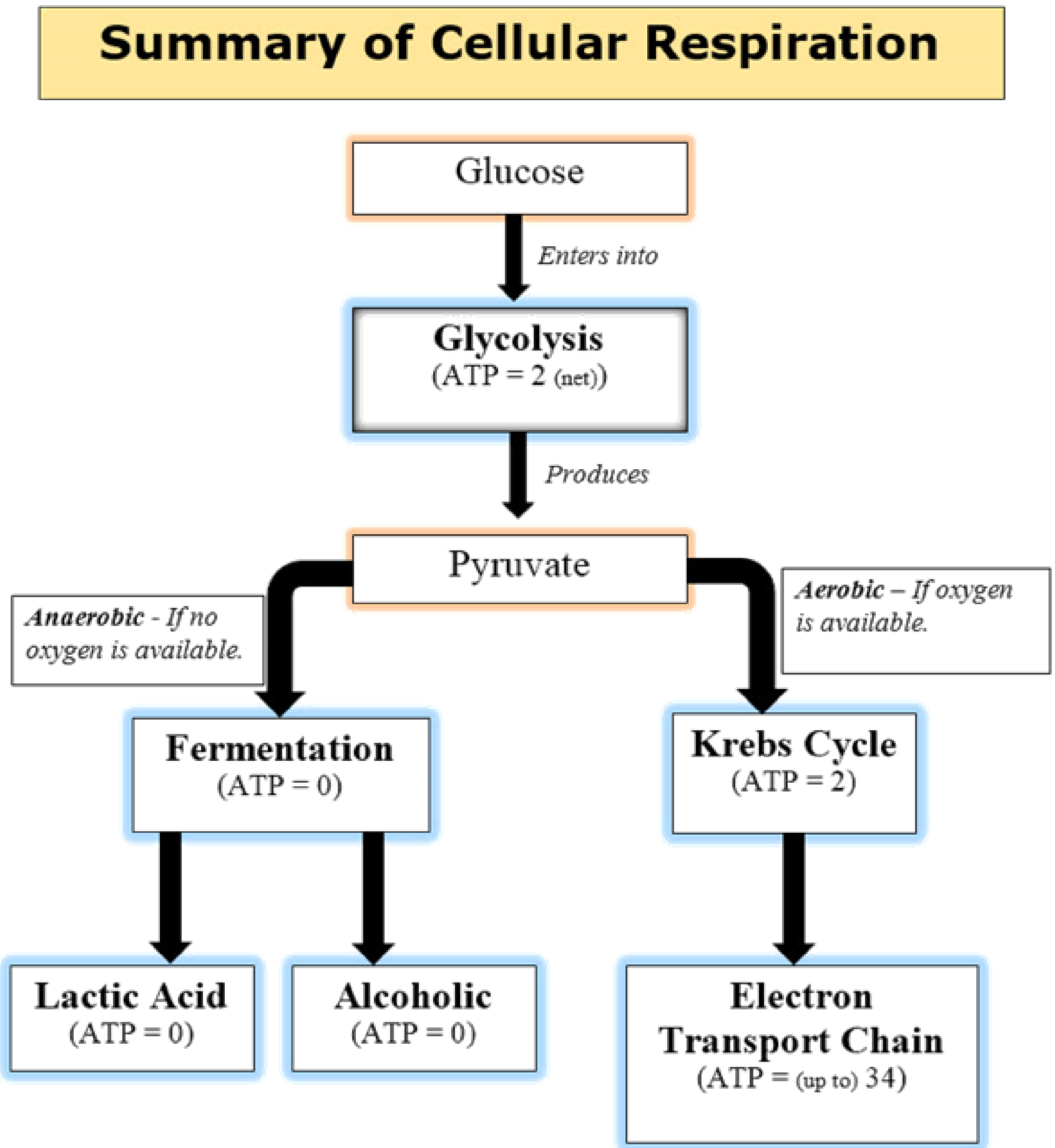
Lactic Acid Fermentation

Lactic acid fermentation involves converting the pyruvates from the end of stage1 glycolysis into lactic acid while using the electrons and hydrogen ions from NADH. Using NADH will keep glycolysis going so to recycle NADH and to keep producing ATP. Lactic acid fermentation occurs in animal cells, more specifically muscle cells, and some bacteria. As muscle cells go through vigorous exercise or intense work, they must continue to operate even though there may not be enough oxygen for aerobic respiration. When these muscle cells do not have enough oxygen they will work under anaerobic respiration (lactic acid fermentation). Lactic acid fermentation will at least produce some ATP, by recycling NADH in glycolysis, to supply the muscle cells with some energy. The product of lactic acid fermentation is lactic acid. Lactic acid will build up in a muscle causing the muscle to become tired and sore at that moment, soreness found later involves something else. Keep in mind, no ATP is made in lactic acid fermentation, it is only made in glycolysis when no oxygen is present.



Alcoholic Fermentation

Alcoholic fermentation involves converting the pyruvates, from the end of stage 1 glycolysis, into ethanol (ethyl alcohol), while releasing carbon dioxide (CO_2) and using the electrons and hydrogen ions from NADH. Using NADH will keep glycolysis going so to recycle NADH and to keep producing ATP. Alcoholic fermentation occurs in some bacteria and fungi. If you have ever watched bread dough rise, you are watching the yeast (fungi) eat the sugar in the dough and undergo alcoholic fermentation producing carbon dioxide and ethanol. The bread rises as a result of the carbon dioxide bubbles inside the dough while ethanol is produced in the process. However, through the bread baking process the ethyl alcohol will evaporate out of the bread.



Unit 10 Worksheet

UNIT VOCABULARY REVIEW

The first stage of cellular respiration

View this study set

Choose a Study Mode