CELLULAR RESPIRATION AND ENERGY

CHEMOSYNTHESIS

Reduction of CO_2 benefitting from chemical energy instead of solar energy is called **chemosynthesis**. Some primitive plants obtain energy by oxidizing chemical compounds. During this process they reduce CO_2 and make their own food.

Via chemosynthesis, toxic substances that are found in nature are detoxified. And some unsolved compounds are also solved and take the form that can be used by complex organisms. For example, nitrogen is accumulated in the form of NH_3. Plants can consume nitrogen in the form of nitrite and nitrate, not NH_3.

Chemosynthetic organisms:

1) **Nitrification bacteria**:

Nitrite bacteria found in the soil oxidize NH_3 into nitrite. Then, nitrobacteria (nitrate bacteria) nitrite turn it into nitrate. Meanwhile, the released energy is used in the reduction of CO_2 and they make their own food.

2) **Sulphur bacteria**:

H_2S is poisonous and oxidized and thus detoxified by sulphur bacteria.

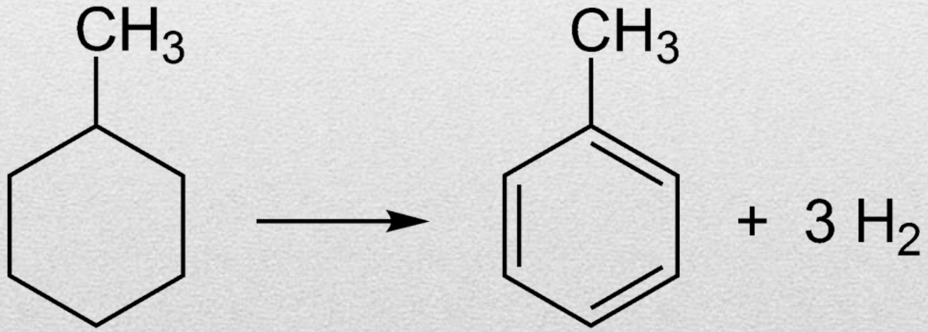
3) **Ferrous bacteria**:

These bacteria convert (Fe^{+2}) ions into (Fe^{+3}) and make their own food with the energy released during this process.

All metabolic events within a living cell requires energy and ATP is the energy source that can be used by the cell. After ATP is being used by the cells, in turns into ADP. **ATP has to be formed again** from ADP for the cell to continue its vital activities. And energy is needed for this conversion. Organisms obtain this energy from the chemical bond energy that is found in the C-H bonds of glucose and other organic compounds. Obtaining energy by oxidizing the foodstuff within the cell is called **CELLULAR RESPIRATION**.

During cellular respiration, the cell uses carbohydrates first to produce energy; and the uses lipids and lastly proteins. Carbohydrates are broken down into monosaccharides; lipids into fatty acids and proteins into amino acids and consequently into **CO_2** and **H_2O**. During this process, their chemical bond energies are released. These reactions occur in the cytoplasm and in the mitochondria of the cells in the form of consecutive oxidation and reduction reactions.

Each **oxidation reaction** is followed by a reduction reaction in which electrons are taken by another molecules. During the reaction hydrogen is removed (dehydrogenation).



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Cellular respiration in a living cell can be divided into 2 types:

a) "**Aerobic Respiration**" if oxygen is used; and

b) "**Anaerobic Respiration (Fermentation)**" if oxygen is not used.

Anaerobic respiration is a kind of "**Alcoholic Fermentation**".

Since oxygen is not stored in the body, organisms that are dependent on **Aerobic respiration** die in the absence of oxygen.

The oxygen that will enter the body is provided by external respiration with the help of the lungs.

1. Aerobic Respiration (= Oxidation):

Aerobic respiration center of the cell is **mitochondrion** (pl. mitochondria). The substance that would be used in the cell as fuel (precursor) goes into the mitochondria and there the form of energy that can be used in the cell is obtained. All organic compounds that have breakable carbon bonds can be used as the raw material in aerobic respiration. Big molecules are first separated into smaller molecules in the lysosomes with the help of enzymes, and then enter the mitochondria.

General formula for aerobic respiration is as follows:

$C_6H_{12}O_6$ + 6 O_2 ↔ 6 CO_2 + 6 H_2O + Energy (36-38 ATP)

Aerobic Respiration occurs in 3 stages:

I. Glycolysis
II. Citric acid Cycle (= Krebs Cycle)
III. Electron Transfer System

I. Glycolysis:

Hans Buchner (bacteriologist) and Eduard Buchner (chemist, awarded Nobel Prize in 1907 for his studies on fermentation in the field of Chemistry) observed that the extract that they had obtained from yeast cells turned sugar into alcohol in 1897. Then, Arthur Harden (biochemist, awarded Nobel Prize in 1929 for his studies on the fermentation of sugar and fermentative enzymes in the field of Chemistry) and William John Young (biochemist) showed in 1905 that glucose turns into alcohol with yeast extract and also determined the stages and conditions of this reaction. In the coming years, similar reactions were found to take place with the muscle cell extracts in sophisticated animals and **the reactions resulting in the breaking of glucose into pyruvate is called glycolysis**.

Glycolysis takes place in the cytoplasm of the cell. Here, hexose with 6 C atoms are broken down into pyruvic acid containing 3 C atoms. In order for glucose to enter into the reaction, it has to be **activated** first. Because enzymes are not sufficient to break the bonds between carbon atoms, and the energy required for activation is obtained from the ATP that is present in the system and glucose-6-phosphate is formed. The ATP energy used during this stage is called **activation energy**.

2 Pyruvic acid molecules loses 1 C each and then enters into the liquid phase of the mitochondria as substances with 2 C atoms and the reaction continues.

As a result: In glycolysis a total of:

2 H_2O

2 NADH + H^+

4 ATP

2 Pyruvic Acid are formed

II. **Citric Acid Cycle:** (Krebs Cycle)

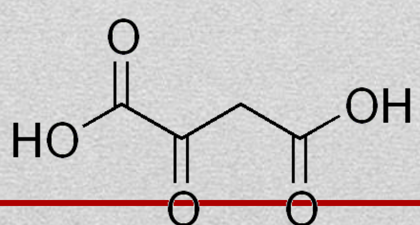
Occurs in the liquid phase of the mitochondria with the help pf many enzymes related to respiration.

Citric acid is used in these reactions within mitochondria and then it is formed again by the sequence of these reactions to complete the cycle. Since citric acid reactions were elucidate by a German originated British biochemist Hans Adolf KREBS in 1937, this stage is called **Krebs Cycle** in his honor. And he had been awarded with Nobel Prize in the field of medicine in 1953.

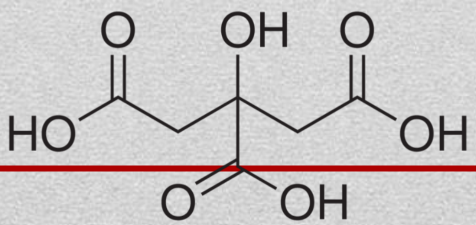
Krebs Cycle forms an important sequence of metabolic chemical reactions that forms energy in the cells.

Important issues in Citric Acid Cycle are:

- Formation of **acetic** acid from pyruvic acid.
- Combination of acetic acid having 2 carbons with **Coenzyme-A** that is found in the system and the formation of **Acetyl-CoA** (C_2H_3O-CoA). This is the activated acetic acid molecule. Acetyl-CoA is the key for every molecule to enter into Krebs Cycle.
- Acetyl-CoA combines with the **oxaloacetic acid** (with 4 C) in the system and **citric acid** (having 6 C) is formed. Therefore this reaction is also called **Citric Acid Cycle**.



oxaloacetic acid



citric acid

This stage occurs in the liquid inner membrane of the mitochondrion and ends in the liquid phase (matrix). Some phosphorylation enzymes are present in the inner membrane and crista of mitochondrion.

III. Electron Transfer System (ET Chain)

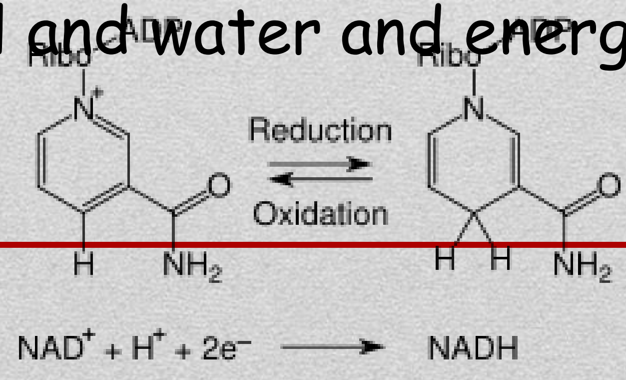
ETC is made of a series of molecules that have the ability to synthesize ATP and are arranged according to their redox potentials. **ATP** is synthesized with phosphorylation.

For these reactions to continue, O_2 has to be present and CO_2 has to be exhaled and this is provided by internal and external respiration.

Importance of NADH

NADH is the biological form of hydrogen. Pure hydrogen is very reactive. For example, if you put metallic sodium into water, hydrogen is formed within a 1/10 sec. However too much energy is formed during this reaction and thus hydrogen ignited immediately. If hydrogen results in this reaction in living cells, than the cells would burst. However, when hydrogen is bound to NAD, it will not demonstrate an explosive behavior and NADH is formed.

Hydrogen is also reactive in this compound, but does not burn immediately. In addition, it reacts with the oxygen found in the cell and water and energy is formed.



This reaction occurs in all living cells. Therefore, hydrogen and oxygen are the most important elements that are found in our cells for the production of energy. The amount of NADH found in a cells is determined by the energy requirement of that cell. Our heart and brain are the organs that need the most amount of energy within our bodies.

NADH can also be taken with foods or in the form of a food supplement.

Metabolic Control

Glycolysis and citric acid reactions are under the control of enzymes at various staged (feedback inhibition). These reactions continue or stop according to the ATP requirement of the cell. Hexokinase, phosphofructokinase and pyruvate kinase enzymes have roles in this control mechanism. For example, hexokinase is the enzyme that catalyzes the phosphorylation of glucose (to glucose-6-phosphate).