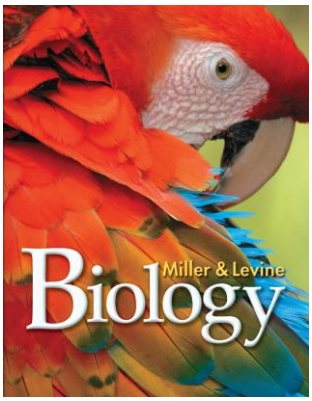


Lesson Overview

9.2 The Process of Cellular Respiration

THINK ABOUT IT

Food burns! How does a living cell extract the energy stored in food without setting a fire or blowing things up?

Glycolysis

- What happens during the process of **glycolysis**?

Glycolysis

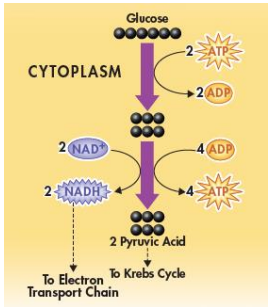
- What happens during the process of glycolysis?
- During glycolysis, 1 molecule of glucose, a 6-carbon compound, is transformed into 2 molecules of pyruvic acid, a 3-carbon compound.

Glycolysis

Glycolysis is the first stage of cellular respiration.

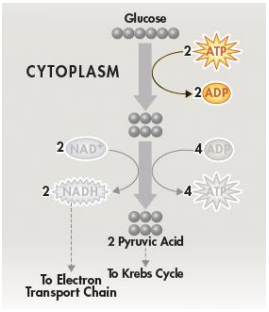
During glycolysis, glucose is broken down into 2 molecules of the 3-carbon molecule pyruvic acid. Pyruvic acid is a reactant in the **Krebs cycle**.

ATP and NADH are produced as part of the process.



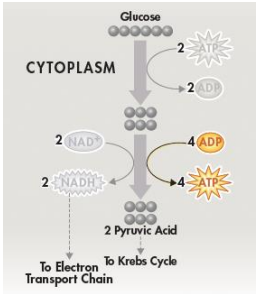
ATP Production

The cell "deposits" 2 ATP molecules into its "account" to get glycolysis going.



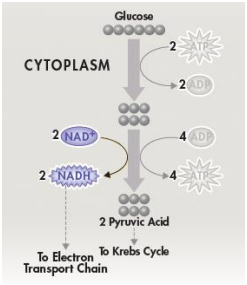
ATP Production

Glycolysis then produces 4 ATP molecules, giving the cell a net gain of 2 ATP molecules for each molecule of glucose that enters glycolysis.



NADH Production

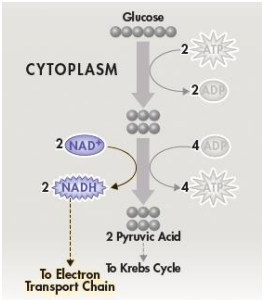
During glycolysis, the electron carrier **NAD⁺** (nicotinamide adenine dinucleotide) accepts a pair of high-energy electrons and becomes NADH.



NADH Production

NADH carries the high-energy electrons to the electron transport chain, where they can be used to produce more ATP.

2 NADH molecules are produced for every molecule of glucose that enters glycolysis.

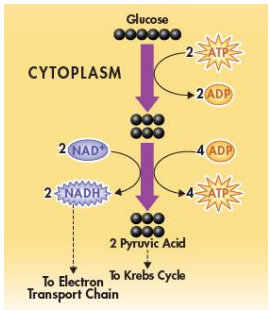


The Advantages of Glycolysis

Glycolysis produces ATP very fast, which is an advantage when the energy demands of the cell suddenly increase.

Glycolysis does not require oxygen, so it can quickly supply energy to cells when oxygen is unavailable.

Glycolysis



The Krebs Cycle

- What happens during the Krebs cycle?
- Where does the Krebs cycle occur?

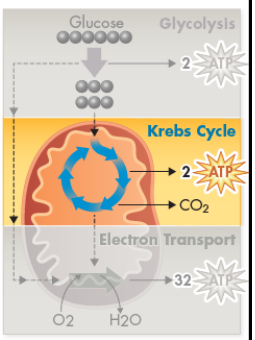
The Krebs Cycle

- What happens during the Krebs cycle?

During the Krebs cycle, pyruvic acid is broken down into carbon dioxide in a series of energy-extracting reactions.

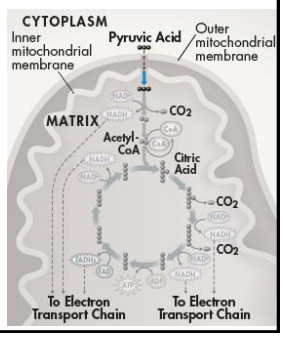
The Krebs Cycle

The Krebs cycle is also known as the citric acid cycle because citric acid is the first compound formed in this series of reactions.



Citric Acid Production

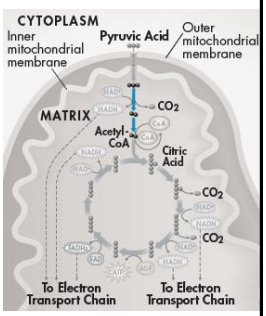
Pyruvic acid from glycolysis enters the **matrix**, the innermost compartment of the mitochondrion.



Citric Acid Production

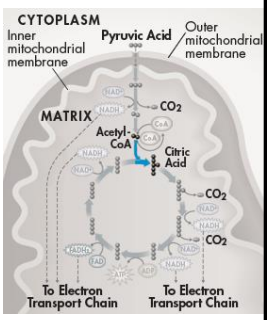
Once pyruvic acid is in the mitochondrial matrix, NAD^+ accepts 2 high-energy electrons to form NADH. One molecule of CO_2 is also produced.

The remaining 2 carbon atoms react to form acetyl-CoA.



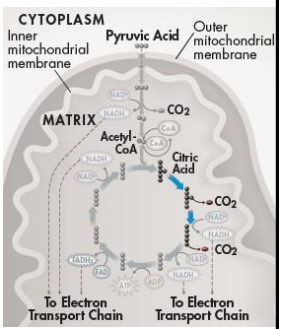
Citric Acid Production

Acetyl-CoA combines with a 4-carbon molecule to produce **citric acid**.



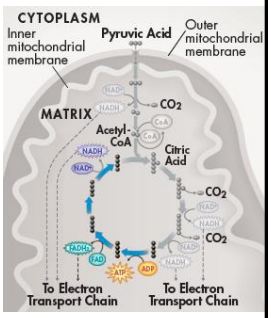
Energy Extraction

Citric acid is broken down into a 5-carbon compound and then a 4-carbon compound. Two molecules of CO_2 are released. The 4-carbon compound can then start the cycle again by combining with acetyl-CoA.



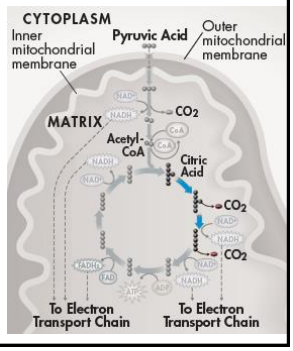
Energy Extraction

Energy released by the breaking and rearranging of carbon bonds is captured in the forms of ATP, NADH, and $FADH_2$.



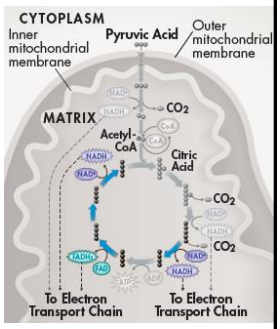
Energy Extraction

For each turn of the cycle, one ADP molecule is converted into ATP. ATP can directly power the cell's activities.



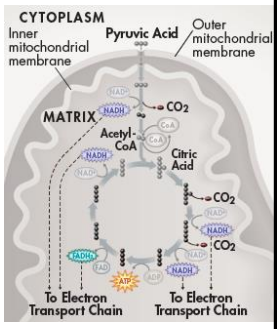
Energy Extraction

The electron carriers NAD^+ and FAD each accept pairs of high-energy electrons to form NADH and $FADH_2$. NADH and $FADH_2$ are used in the electron transport chain to generate ATP.



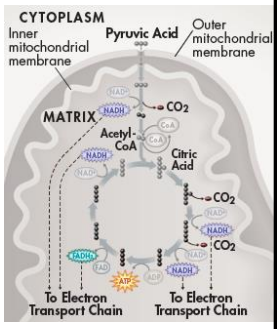
Energy Extraction

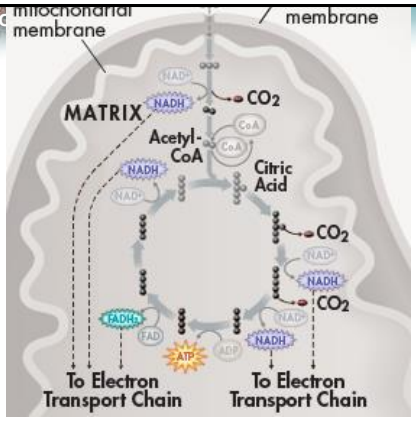
Remember! Each molecule of glucose results in 2 molecules of pyruvic acid, which enter the Krebs cycle. So each molecule of glucose results in two complete "turns" of the Krebs cycle.



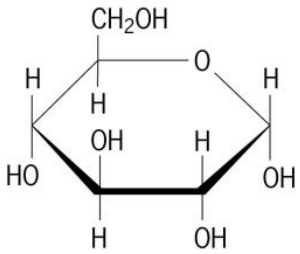
Energy Extraction

Therefore, for each glucose molecule, 6 CO_2 molecules, 2 ATP molecules, 8 NADH molecules, and 2 $FADH_2$ molecules are produced.

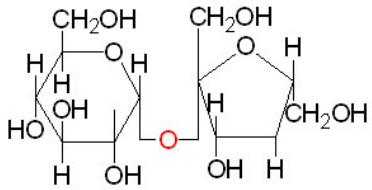




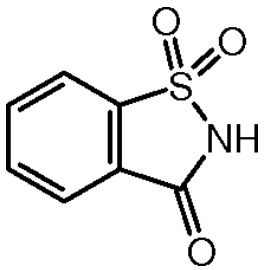
Glucose $C_6H_{12}O_6$

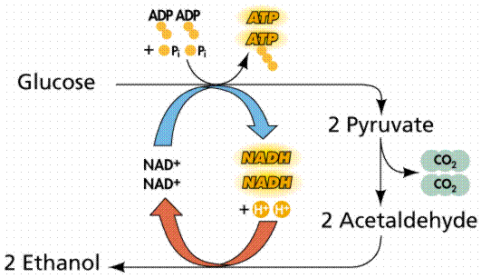


Sucrose $C_{12}H_{22}O_{11}$



Saccharin $C_7H_5NO_3S$





Electron Transport and ATP Synthesis

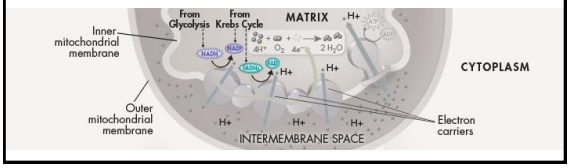
How does the electron transport chain use high-energy electrons from glycolysis and the Krebs cycle?

Electron Transport and ATP Synthesis

- How does the electron transport chain use high-energy electrons from glycolysis and the Krebs cycle?
- The electron transport chain uses the high-energy electrons from glycolysis and the Krebs cycle to convert ADP into ATP.

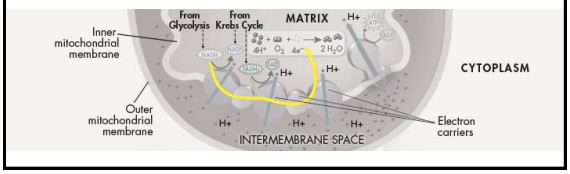
Electron Transport

NADH and $FADH_2$ pass their high-energy electrons to electron carrier proteins in the electron transport chain.



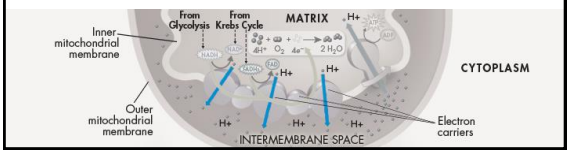
Electron Transport

At the end of the electron transport chain, the electrons combine with H^+ ions and oxygen to form water.



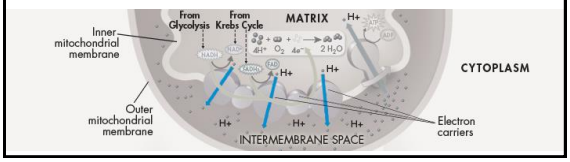
Electron Transport

Energy generated by the electron transport chain is used to move H+ ions against a concentration gradient across the inner mitochondrial membrane and into the **intermembrane space**.



ATP Production

H+ ions pass back across the mitochondrial membrane through the **ATP synthase**, causing the ATP synthase molecule to spin. With each rotation, the ATP synthase attaches a phosphate to ADP to produce ATP.



The Totals

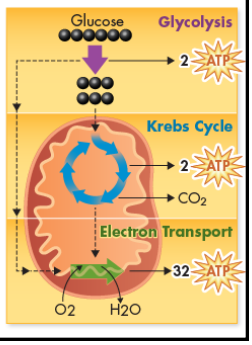
- How much energy does cellular respiration generate?

The Totals

- How much energy does cellular respiration generate?
- Together, glycolysis, the Krebs cycle, and the electron transport chain release about 36 molecules of ATP per molecule of glucose.

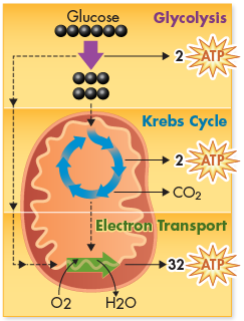
Energy Totals

In the presence of oxygen, the complete breakdown of glucose through cellular respiration results in the production of 36 ATP molecules.



Energy Totals

This represents about 36 percent of the total energy of glucose. The remaining 64 percent is released as heat.



Energy Totals

The cell can generate ATP from just about any source, even though we've modeled it using only glucose. Complex carbohydrates are broken down into simple sugars like glucose. Lipids and proteins can be broken down into molecules that enter the Krebs cycle or glycolysis at one of several places.