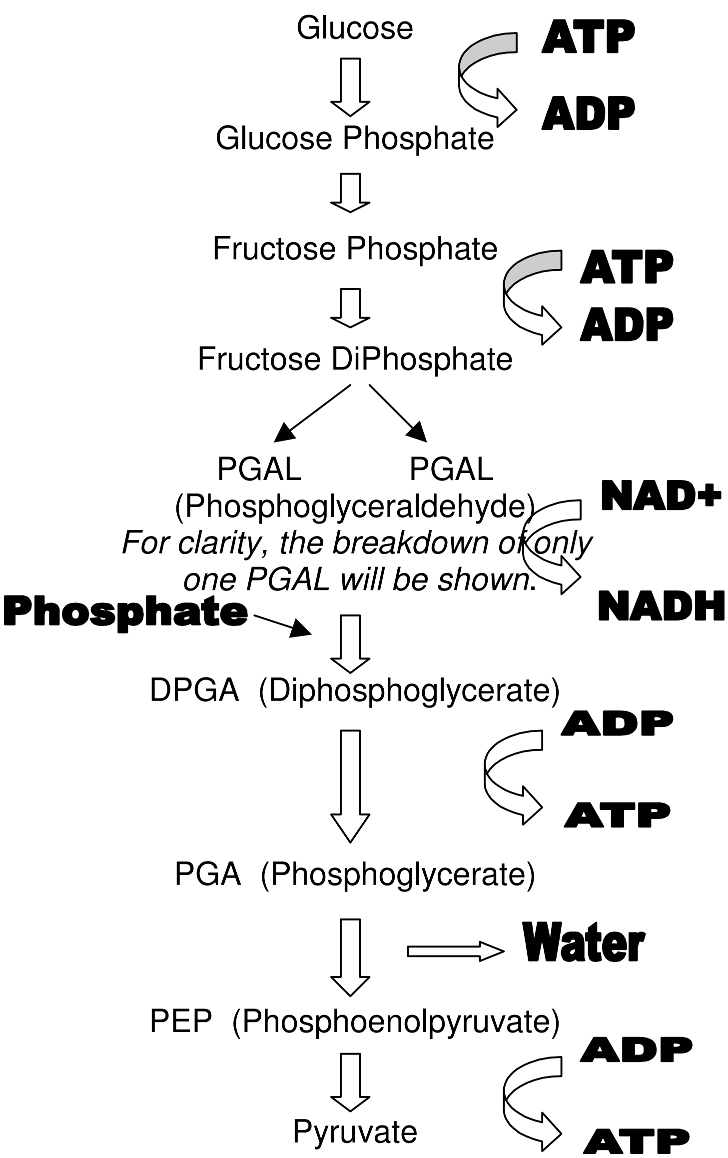
Cellular Respiration

GLYCOLYSIS



Glucose in the cytoplasm of the cell is broken down by the process of cellular respiration. The equation for this process is:
$C_6H_{12}O_6 + 6O_2$ ◊ $6CO_2 + 6H_2O + 36$ ATP

An ATP molecule transfers it's third phosphate group (and corresponding high energy electrons) to glucose to form glucose phosphate and ADP. Then the glucose phosphate is transformed into fructose phospate. Next, another ATP is used to transfer a phosphate group to fructose phosphate and change it into fructose diphosphate. This is then split in half by enzymes to form two molecules of PGAL. In the next step PGAL is oxidized by NAD+.

NAD+ is an electron deficient molecule that removes a pair of electrons and a hydrogen proton from the two PGAL' s. This changes NAD+ into NADH. At the same time a free phosphate from the cytoplasm is joined to PGAL' s to form 2 molecules of DPGA.

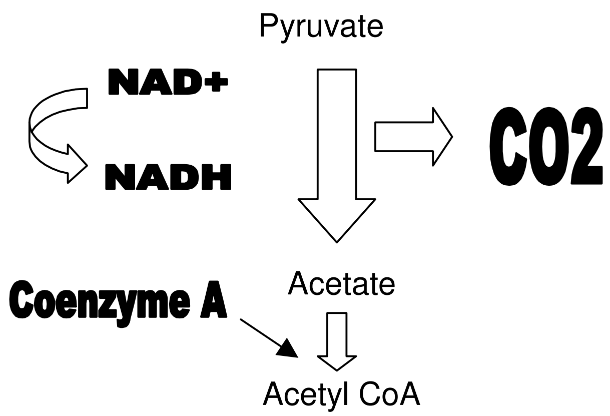
A phosphate is removed from each DPGA and added to ADP to form 2 ATP' s. This changes the DPGA into PGA.

Next, a water molecule is removed from each PGA changing them into PEP.

In the final step of glycolysis, another phosphate is removed from each PEP, changing them into 2 molecules of pyruvate. The phosphates are added to ADP forming 2 more ATP' s.

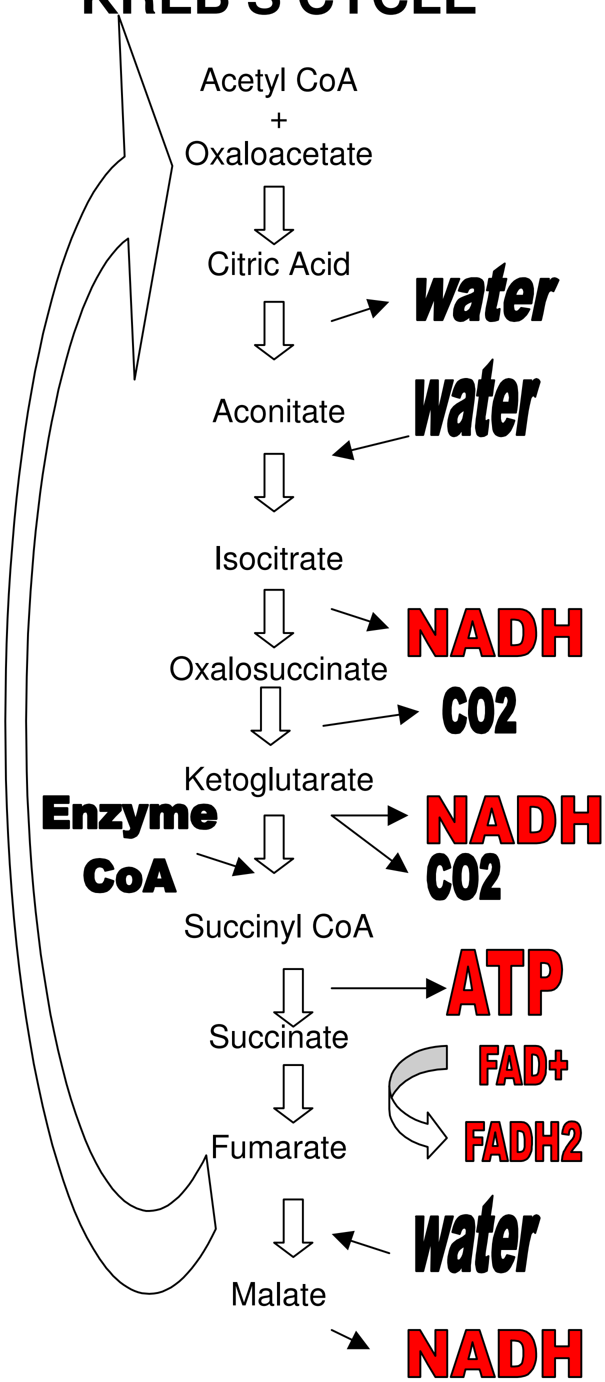
So the final products of glycolysis are 2 pyruvate molecules, 2 NADH molecules, and a net gain of 2 ATP molecules.

OXIDATIVE DECARBOXYLATION



Oxidative decarboxylation is a transition stage between glycolysis and the Kreb' s cycle, In this stage pyruvate is oxidized by NAD+ and has a CO_2 molecule removed, forming acetate which joins with coenzyme A to form Acetyl CoA.

KREB'S CYCLE



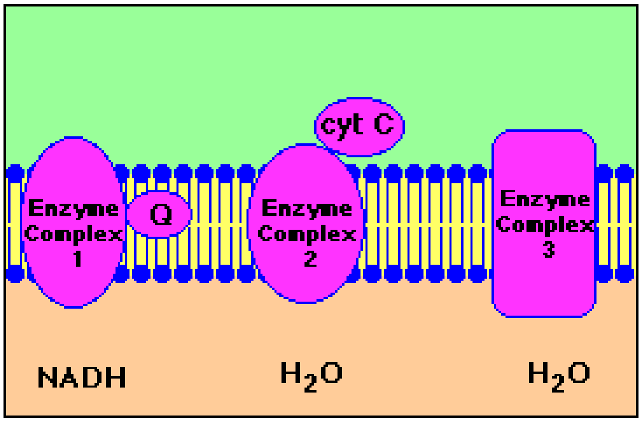
During the Kreb' s cycle acetyl CoA joins with oxaloacetate to form citric acid. The rest of the Kreb' s cycle is dedicated to breaking down citric acid by removing carbon dioxide molecules and hydrogen atoms. As this process occurs a number of intermediate products are formed as the 6-carbon citric acid is broken down into the 4-carbon oxaloacetate which joins with more acetyl CoA to start the cycle again.

Citric acid is broken down into aconitate by removing a molecule of water. Then, enzymes make a slight rearrangement of the atoms of aconitate and add back the molecule of water to form isocitrate.

Isocitrate, is oxidized by NAD+ to form another NADH. This changes it into Oxalosuccinate. A molecule of CO2 is removed from it and converts it to ketoglutarate. Another CO2 is removed and another NADH formed as ketoglutarate is changed into succinyl CoA with the addition of the enzyme CoA.
An ATP is formed as succinyl CoA is changed to succinate.
A molecule of FAD+ oxidzes succinate and produces a molecule of FADH2, changing succinate into fumarate.
A molecule of water is added to fumarate to convert it into malate. And finally, another NAD+ oxidizes malate into oxaloacetate which joins with more acetyl CoA to enter the cycle again.

The final products of oxidative decarboxylation and the Kreb's cycle are:
8 NADH, 2 FADH2, 6 CO2, and 2 ATP's.

OXIDATIVE PHOSPHORYLATION



The electron transport chain takes place in the inner mitochondrion membrane. The first step is the transfer of high-energy electrons from $NADH+H^+$ to FMN, the first carrier in the chain. In this transfer, a hydride ion H^- passes to FMN, which then picks up an additional H^+ from the surrounding aqueous medium. As a result, $NADH+H^+$ is oxidized to NAD^+, and FMN is reduced to $FMNH_2$.
In the second step in the electron transport chain, $FMNH_2$ passes electrons to several iron-sulfur centers and then to coenzyme Q, which picks up an additional H^+ from the surrounding aqueous medium. As a result, $FMNH_2$ is oxidized to FMN.

The next sequence in the transport chain involves cytochromes, iron-sulfur clusters, and copper atoms located between coenzyme Q and molecular oxygen. Electrons are passed successively from coenzyme Q to cytochrome b, to Fe-S, to cytochrome c_1, to cytochrome c, to Cu, to cytochrome a, and finnally to cytochrome a_3. Each carrier in the chain is reduced as it picks up electrons and is oxidized as it gives up electrons. The last cytochrome, cytochrome a_3, passes its electrons to one-half of a molecule of oxygen, which becomes negatively charged and then picks up $2H^+$ from the surrounding medium to form H_2O. This is the only point in aerobic cellular respiration where O_2 is consumed.

Note that $FADH_2$, derived from the citric acid cycle, is another source of electrons. However, $FADH_2$ adds its electrons to the electron transport chain at a lower energy level than does $NADH+H^+$. Because of this, the electron transport chain produces about one-third less energy for ATP generation when $FADH_2$ donates electrons as compared with $NADH+H^+$.

Each NADH from the Kreb's cycle generates 3 ATP, while the 2 NADH from glycolysis and the FADH2 from the Kreb's cycle generate 2 ATP's each. This makes a total of
36 ATP's generated from one glucose molecule.

<u>Energy summary:</u>

Glycolysis – 2 ATP
2 NADH = 4 ATP

Kreb's Cycle – 2 ATP
8 NADH = 24 ATP
2 FADH2 = 4 ATP

For more information go to:
http://hem2.passagen.se/hazard1/projekt/summary.htm