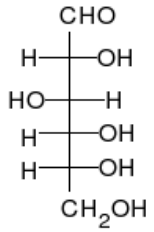


Glucose is the preferred carbohydrate of cells. In solution, it can change from a linear chain to a ring.

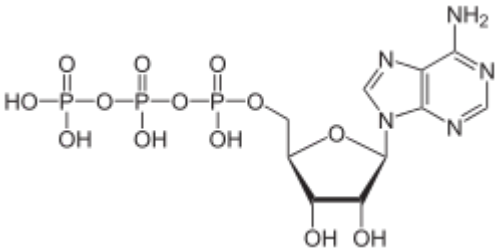
Energy is stored in the bonds of the carbohydrates. Breaking these bonds releases that energy. Crushing sugar crystals creates tiny electrical fields that give off invisible ultraviolet light. The wintergreen chemical (methyl salicylate) gets excited by these excited electrons and fluoresces in a visible blue wavelength. This phenomenon is called triboluminescence.

Contents

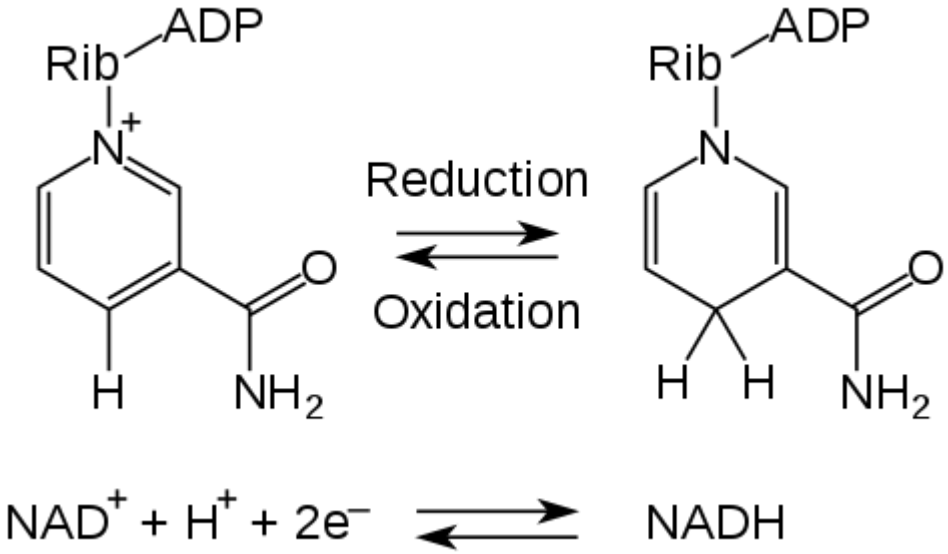
Glycolysis

Glucose is the preferred carbohydrate of cells. **Glycolysis** (***glyco*** – sugar; ***lysis*** – splitting) is a universal process of all cells that occurs in the cytosol whereby the glucose (a 6-carbon sugar) is split into two pyruvate (a 3-carbon molecule) molecules to generate ATP and reduced NADH. **ATP** (adenosine triphosphate) is the energy currency of the cell that stores chemical energy in 3 high energy phosphate bonds. **NADH** (reduced nicotinamide adenine dinucleotide) is a high energy electron carrier that acts as a coenzyme in reactions and as a rechargeable battery of sorts. The uncharged state that is not carrying high energy electrons is called **NAD^+**.

Glycolysis is the splitting of glucose into 2 pyruvate molecules to generate 2 NADH and 2ATP molecules.



ATP contains 3 high energy phosphates and acts as cellular energy currency.

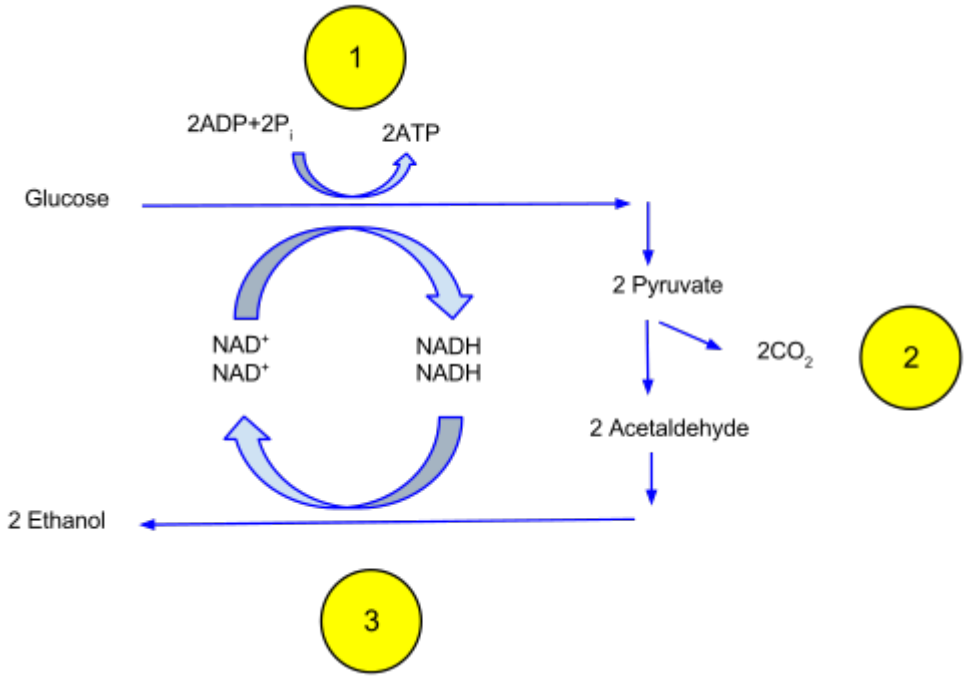


NADH is the reduced form of NAD+. The High energy electrons associated with the reduced form come with a H atom.

Fermentation

In the absence of oxygen, cells may decide to utilize the pyruvate from glycolysis to rapidly generate additional ATP molecules in a process called fermentation. **Fermentation** is the anaerobic process of reducing pyruvate to generate ATP. This process uses the NADH generated from glycolysis as the reducing agents. Fermentation is a familiar process that occurs in yeast to generate ethanol. In other organisms, like humans, fermentation results in the production of lactic acid. Both lactic acid and ethanol are toxic, but this aids the cells

in generating ATP when energy is required rapidly. Fermentation also generates CO_2 as a waste molecule as pyruvate is broken down into a 2-carbon compound.



Fermentation in yeast generates ATP in the absence of oxygen but yields little ATP at the cost of the reduced NADH. Credit: Davidcarmack (CC-BY-SA)

The Preparatory Reaction

In the presence of O_2, aerobic organisms will use a reaction of pyruvate decarboxylation in the cytosol. This reaction generates a molecule of **Acetyl-CoA** from the Coenzyme A which can enter the mitochondria.

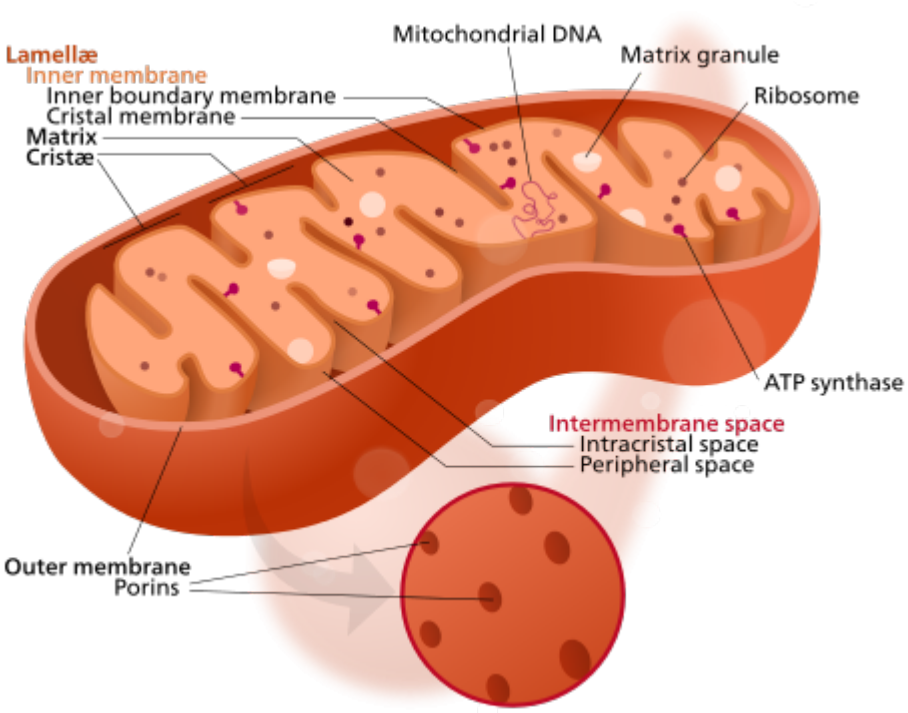
Coenzyme A (CoA) is charged with an Acetyl group (2 carbon compound) to generate Acetyl-CoA and a CO_2.

When there is an excess of carbohydrates, the Acetyl-CoA is used as a starting point for long-term energy storage in lipid synthesis.

Mitochondria

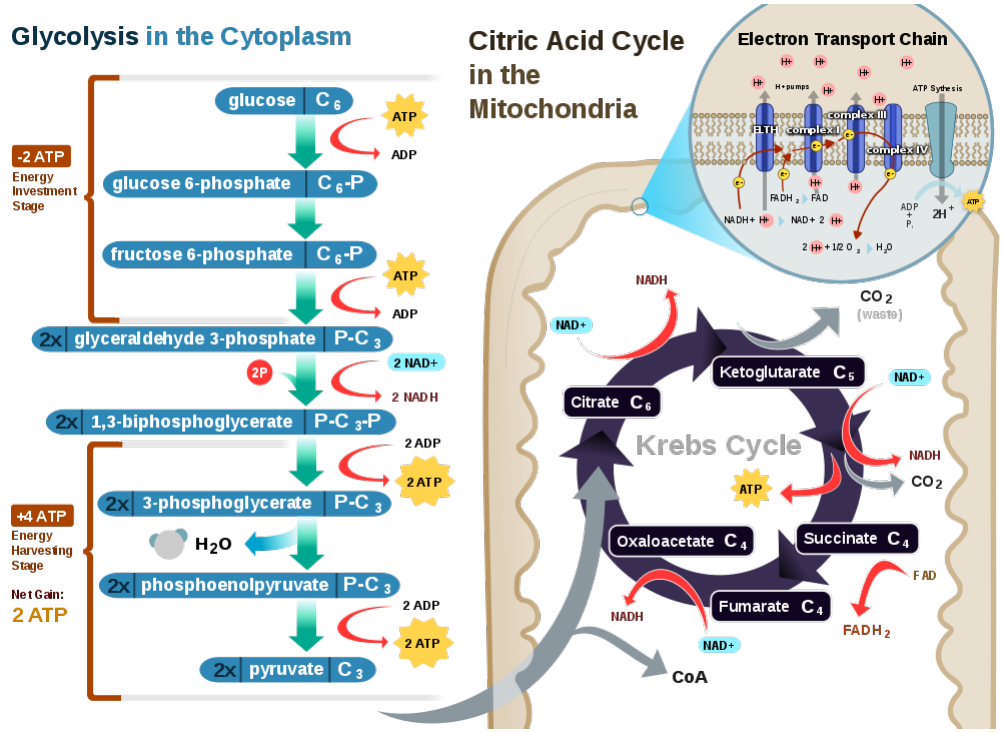
Mitochondria are the power station of eukaryotic cells. They are derived from a process described by the **endosymbiotic theory** whereby aerobic prokaryotes were engulfed by a

protoeukaryote. In this mutualistic arrangement, the prokaryote detoxified the deadly O_2 gas in the environment and used it to fully break down glucose to yield many ATP molecules. Evidence for this theory comes from the independent replication of the mitochondria, the bacterial-like mitochondrial DNA, the bacterial-like mitochondrial ribosomes, the bacterial lipids found in the inner membrane and the eukaryotic nature of the outer membrane. Mitochondria are genomically similar to bacteria of the order Rickettsiales. Some bacteria of this order are still free-living and some are intracellular pathogens.



Credit: *Kelvinsong* (*CC-BY*-SA 3.0)

Aerobic Respiration



Cellular Respiration. Left side is glycolysis (anaerobic). The Right side is what occurs in the presence of oxygen in eukaryotes. The aerobic reactions occur inside the mitochondria after being fed Acetyl-CoA molecules from the cytoplasmic preparatory reaction. *Credit: RegisFrey (CC-BY-SA 3.0)*

Acetyl-CoA enters the mitochondrial matrix where it is used in the **Krebs Cycle** (aka Tricarboxylic acid cycle (TCA), aka Citric acid cycle). For each pyruvate, there are 2 turns of the cycle where additional NADH and another high energy electron carrier **$FADH_2$** (flavin adenine dinucleotide) are generated. The electrons stored by NADH and $FADH_2$ are transferred to proteins called **cytochromes** that have metal centers for conducting these electrons. In the process of moving these electrons, the cytochromes in this **Electron Transport Chains** (ETC) power the movement of protons into the intermembrane space. The terminus of these electrons is an O_2 molecule that is reduced into 1/2 H_2O molecules. This apparent movement of water molecules from the chemical synthesis is termed **chemiosmosis**. A channel in the membrane called **ATP synthase** acts as a gateway for the H^+ back into the matrix, but use this motion to convert ADP into ATP.

Closeup of the **Electron Transport Chain** (ETC) that takes place on the inner membrane of mitochondria. This is where oxygen is utilized as the final electron acceptor. Reduction of 1/2 O_2 results in the generation of a water molecule (**chemiosmosis**). *Credit: Jeremy Seto (CC-BY-NC-SA 3.0)*

Metabolic Pool

The catabolic pathways involved in the glycolysis and the Krebs cycle constitute the **metabolic pool** that supplies building blocks for other anabolic reactions in the cell. An excess of carbohydrates can result in an accumulation of Acetyl-CoA molecules. If there is a great excess of Acetyl-CoA, the acetyl groups can be committed to fatty acid synthesis for long-term energy storage. Glycolytic products can also be the starting point for amino acid synthesis. 3-phosphoglycerate can be used to synthesize glycine, cysteine and serine. Pyruvate can be used to generate alanine, valine and leucine. Oxaloacetate from the Krebs cycle can be used as a starting point for aspartate, lysine, asparagine, methionine, threonine and isoleucine. Glutamate and glutamine are synthesized from α-ketoglutarate formed during the Krebs cycle. While most of the 20 amino acids can be synthesized *de novo*, there are 9 **essential amino acids** in humans that can not be synthesized in sufficient quantity and therefore must be gained from the diet. These essential amino acids include: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine.