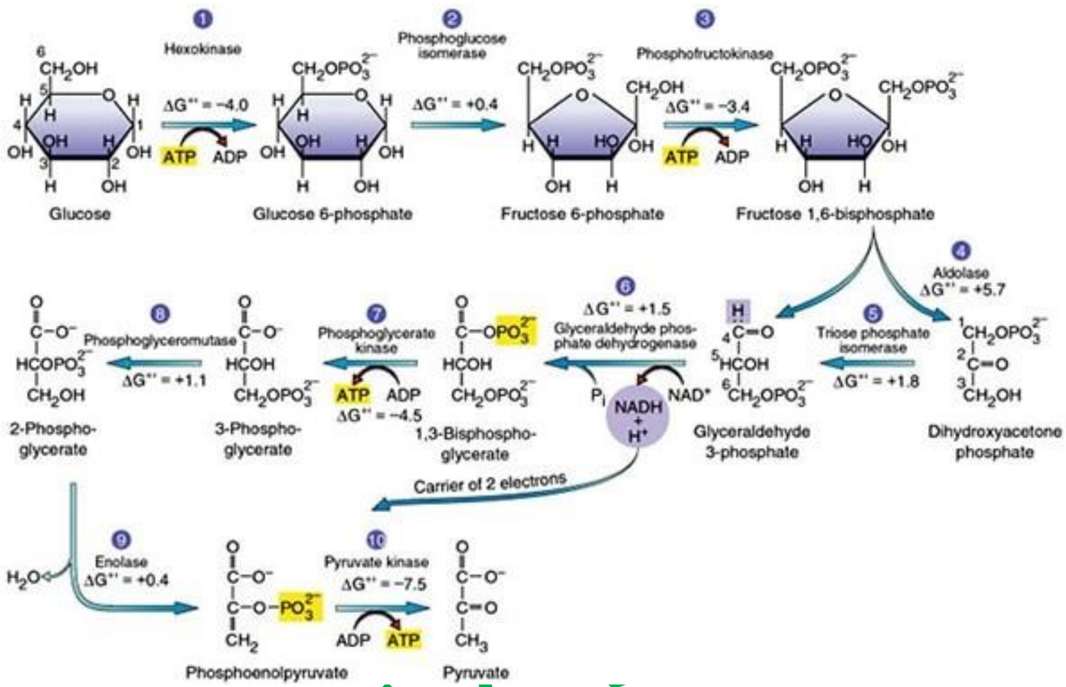
Glycolysis



Glycolysis Explained in 10 Easy Steps

Glycolysis is the metabolic process that serves as the foundation for both aerobic and anaerobic cellular respiration. In glycolysis, glucose is converted into pyruvate. Glucose is a six- memebered ring molecule found in the blood and is usually a result of the breakdown of carbohydrates into sugars. It enters cells through specific transporter proteins that move it from outside the cell into the cell's cytosol. All of the glycolytic enzymes are found in the cytosol.

The overall reaction of glycolysis which occurs in the cytoplasm is represented simply as:

$C_6H_{12}O_6$ + 2 NAD^+ + 2 ADP + 2 P ——> 2 pyruvic acid, ($CH_3(C=O)COOH$ + 2 ATP + 2 NADH + 2 H^+

Step 1: Hexokinase

The first step in glycolysis is the conversion of D-glucose into glucose-6-phosphate. The enzyme that catalyzes this reaction is hexokinase.

Details:

Here, the glucose ring is phosphorylated. Phosphorylation is the process of adding a phosphate group to a molecule derived from ATP. As a result, at this point in glycolysis, 1 molecule of ATP has been consumed.

The reaction occurs with the help of the enzyme hexokinase, an enzyme that catalyzes the phosphorylation of many six-membered glucose-like ring structures. Atomic magnesium (Mg) is also involved to help shield the negative charges from the phosphate groups on the ATP molecule. The result of this phosphorylation is a molecule called glucose-6-phosphate (G6P), thusly called because the 6′ carbon of the glucose acquires the phosphate group.

Step 2: Phosphoglucose Isomerase

The second reaction of glycolysis is the rearrangement of glucose 6-phosphate (G6P) into fructose 6-phosphate (F6P) by glucose phosphate isomerase (Phosphoglucose Isomerase).

Details:

The second step of glycolysis involves the conversion of glucose-6-phosphate to fructose-6- phosphate (F6P). This reaction occurs with the help of the enzyme phosphoglucose isomerase (PI). Asthe name of the enzyme suggests, this reaction involves an isomerization reaction.

The reaction involves the rearrangement of the carbon-oxygen bond to transform the six-membered ring into a five-membered ring. To rearrangement takes place when the six-membered ring opens and then closes in such a way that the first carbon becomes now external to the ring.

Step 3: Phosphofructokinase

Phosphofructokinase, with magnesium as a cofactor, changes fructose 6-phosphate into fructose 1,6-bisphosphate.

Details:

In the third step of glycolysis, fructose-6-phosphate is converted to fructose- 1,6-*bis*phosphate (FBP). Similar to the reaction that occurs in step 1 of glycolysis, a second molecule of ATP provides the phosphate group that is added on to the F6P molecule.

The enzyme that catalyzes this reaction is phosphofructokinase (PFK). As in step 1, a magnesium atom is involved to help shield negative charges.

Step 4: Aldolase

The enzyme Aldolase splits fructose 1, 6-bisphosphate into two sugars that are isomers of each other. These two sugars are dihydroxyacetone phosphate (DHAP) and glyceraldehyde 3-phosphate (GAP).

Details:

This step utilizes the enzyme aldolase, which catalyzes the cleavage of FBP to yield two 3-carbon molecules. One of these molecules is called glyceraldehyde-3-phosphate (GAP) and the other is called dihydroxyacetone phosphate (DHAP).

Step 5: Triosephosphate isomerase

The enzyme triosephosphate isomerase rapidly inter- converts the molecules dihydroxyacetone phosphate (DHAP) and glyceraldehyde 3-phosphate (GAP). Glyceraldehyde phosphate is removed / used in next step of Glycolysis.

Details:

GAP is the only molecule that continues in the glycolytic pathway. As a result, all of the DHAP molecules produced are further acted on by the enzyme Triosephosphate isomerase (TIM), which reorganizes the DHAP into GAP so it can continue in glycolysis. At this point in the glycolytic pathway, we have two 3-carbon molecules, but have not yet fully converted glucose into pyruvate.

Step 6: Glyceraldehyde-3-phosphate Dehydrogenase

Glyceraldehyde-3-phosphate dehydrogenase (GAPDH) dehydrogenates and adds an inorganic phosphate to glyceraldehyde 3-phosphate, producing 1,3-bisphosphoglycerate.

Details:

In this step, two main events take place: 1) glyceraldehyde-3-phosphate is oxidized by the coenzyme nicotinamide adenine dinucleotide (NAD); 2) the molecule is phosphorylated by the addition of a free phosphate group. The enzyme that catalyzes this reaction is glyceraldehyde-3-phosphate dehydrogenase (GAPDH).

The enzyme GAPDH contains appropriate structures and holds the molecule in a conformation such that it allows the NAD molecule to pull a hydrogen off the GAP, converting the NAD to NADH. The phosphate group then attacks the GAP molecule and releases it from the enzyme to yield 1,3 bisphoglycerate, NADH, and a hydrogen atom.

Step 7: Phosphoglycerate Kinase

Phosphoglycerate kinase transfers a phosphate group from 1,3-bisphosphoglycerate to ADP to form ATP and 3-phosphoglycerate.

Details:

In this step, 1,3 bisphoglycerate is converted to 3-phosphoglycerate by the enzyme phosphoglycerate kinase (PGK). This reaction involves the loss of a phosphate group from the starting material. The phosphate is transferred to a molecule of ADP that yields our first molecule of ATP. Since we actually have two molecules of 1,3 bisphoglycerate (because there were two 3-carbon products from stage 1 of glycolysis), we actually synthesize two molecules of ATP at this step. With this synthesis of ATP, we have cancelled the first two molecules of ATP that we used, leaving us with a net of 0 ATP molecules up to this stage of glycolysis.

Again, we see that an atom of magnesium is involved to shield the negative charges on the phosphate groups of the ATP molecule.

Step 8: Phosphoglycerate Mutase

The enzyme phosphoglycero mutase relocates the P from 3- phosphoglycerate from the 3rd carbon tothe nd carbon to form 2-phosphoglycerate.

Details:

This step involves a simple rearrangement of the position of the phosphate group on the 3 phosphoglycerate molecule, making it 2 phosphoglycerate. The molecule responsible for catalyzing this reaction is called phosphoglycerate mutase (PGM). A *mutase* is an enzyme that catalyzes the transfer of a functional group from one position on a molecule to another.

The reaction mechanism proceeds by first adding an additional phosphate group to the 2′ position of the 3 phosphoglycerate. The enzyme then removes the phosphate from the 3′ position leaving just the 2′ phosphate, and thus yielding 2 phsophoglycerate. In this way, the enzyme is also restored to its original, phosphorylated state.

Step 9: Enolase

he enzyme enolase removes a molecule of water from 2-phosphoglycerate to formphosphoenolpyruvic cid (PEP).

Details:

This step involves the conversion of 2 phosphoglycerate to phosphoenolpyruvate (PEP). The reaction is catalyzed by the enzyme enolase. Enolase works by removing a water group, or *dehydrating* the 2 phosphoglycerate. The specificity of the enzyme pocket allows for the reaction to occur through a series of steps too complicated to cover here.

Step 10: Pyruvate Kinase

he enzyme pyruvate kinase transfers a P from phosphoenolpyruvate (PEP) to ADP to form pyruvicacid nd ATP Result in step 10.

Details:

The final step of glycolysis converts phosphoenolpyruvate into pyruvate with the help of the enzyme pyruvate kinase. As the enzyme’s name suggests, this reaction involves the transfer of a phosphate group. The phosphate group attached to the 2′ carbon of the PEP is transferred to a molecule of ADP, yielding ATP. Again, since there are two molecules of PEP, here we actually generate 2 ATP molecules.

Steps 1 and 3 = – 2ATP
Steps 7 and 10 = + 4 ATP
Net "visible" ATP produced = 2.

Immediately upon finishing glycolysis, the cell must continue respiration in either an aerobic or anaerobic direction; this choice is made based on the circumstances of the particular cell. A cell that can perform aerobic respiration and which finds itself in the presence of oxygen will continue on to the aerobic citric acid cycle in the mitochondria. If a cell able to perform aerobic respiration is in a situation where there is no oxygen (such as muscles under extreme exertion), it will move into a type of anaerobic respiration called homolactic fermentation. Some cells such as yeast are unable to carry out aerobic respiration and will automatically move into a type of anaerobic respiration called alcoholic fermentation.

Net ATPs produced are 2 but 2 NADH are also produced which in Electron Transport Chain each produces 3 ATPs so according to this idea $3 \times 2 = 6$ ATPs and overall ATPs produced are $2+6=8$ ATP.