Tutorial 28: Carbohydrate Metabolism and Glycolysis

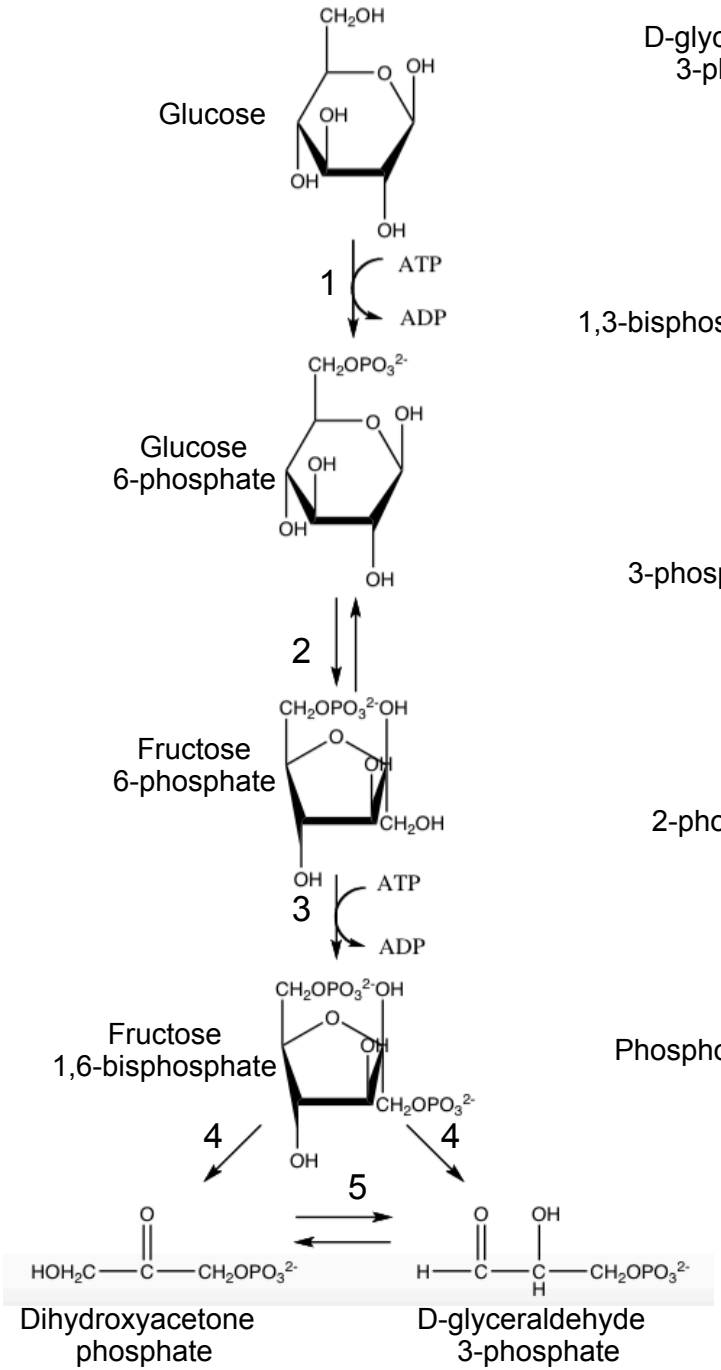
Goals:

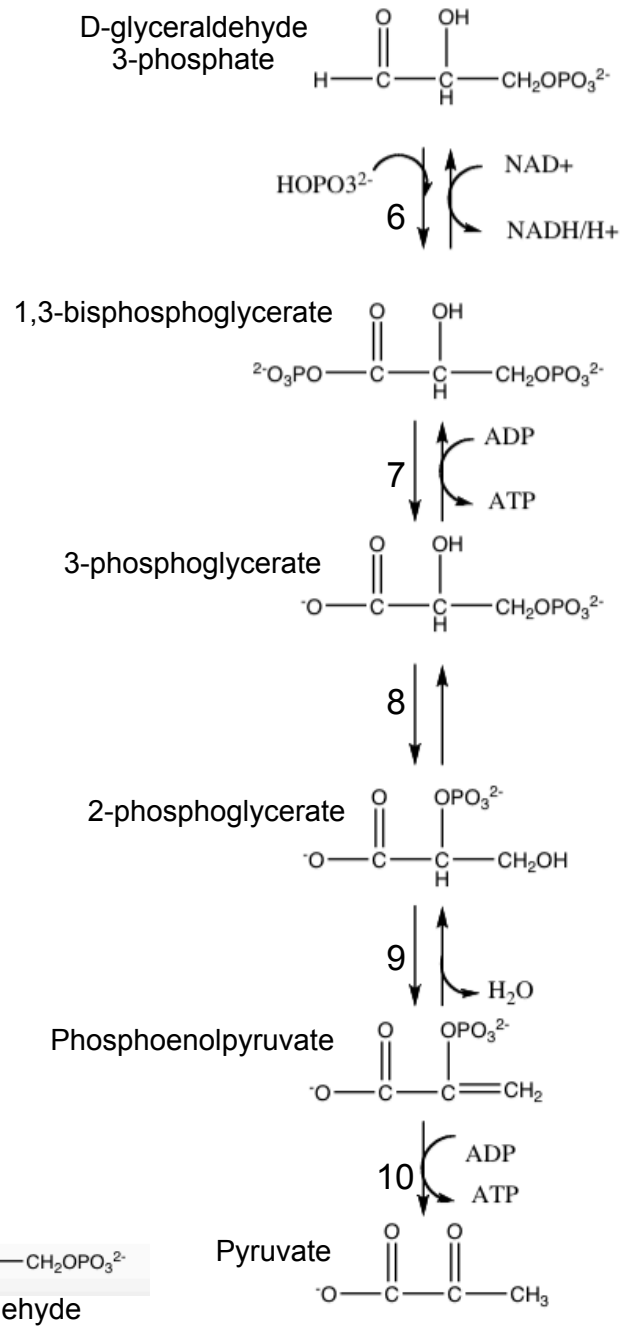
- ✓ To be able to give an overview of glycolysis, and to understand the 10 steps of glycolysis.
- ✓ To understand the fate of pyruvate under aerobic and anaerobic conditions.
- ✓ To be able to calculate the ATP yield from complete catabolism of glucose.

Glycolysis

- **Overview of Glycolysis:** Glycolysis is a ten step process that converts the six carbon molecule glucose into two three carbon pyruvate molecules. In the first four steps, two ATP are used, but in the last six steps four ATP are synthesized along with two reduced coenzymes of NADH/H+. Other sugars enter glycolysis at various steps and are also converted into 2 pyruvates.
- **Details of Glycolysis:**
  - In step 1, glucose is phosphorylated to glucose-6-phosphate. The phosphate comes from ATP.
  - In step 2, glucose-6-phosphate is isomerized into fructose-6-phosphate.
  - In step 3, another phosphorylation makes the more symmetrical fructose 1,6-bisphosphate. The phosphate comes from another ATP.
  - In step 4, fructose 1,6-bisphosphate is cleaved into two three carbon molecules, dihydroxyacetone phosphate and D-glyceraldehyde 3-phosphate.
  - Only dihydroxyacetone phosphate undergoes step 5 as it isomerizes into D-glyceraldehyde 3-phosphate.
  - Both D-glyceraldehyde 3-phosphate molecules continue steps 6-10 separately. This means that for ONE glucose, steps 6-10 happen TWO times.
  - In step 6, D-glyceraldehyde 3-phosphate is oxidized and phosphorylated. NAD+ is reduced to NADH/H+. The phosphate comes from inorganic hydrogen phosphate ions.
  - In step 7, one phosphate is removed and used to phosphorylate ADP to ATP.
  - Step 8 is an isomerization.
  - Step 9 is a dehydration.
  - In step 10, the second phosphate is removed and used to phosphorylate another ADP to ATP. The product is pyruvate.

Glycolysis Continued

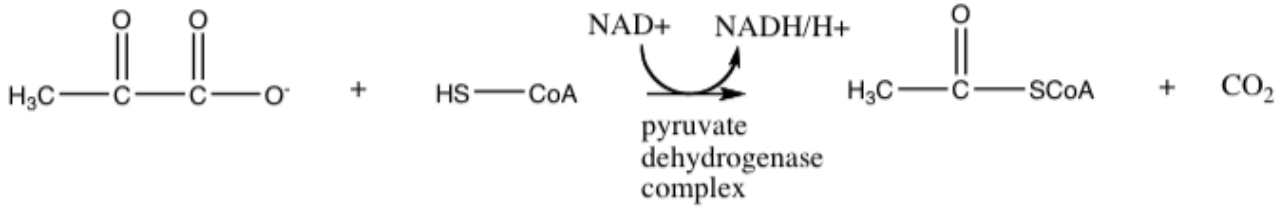




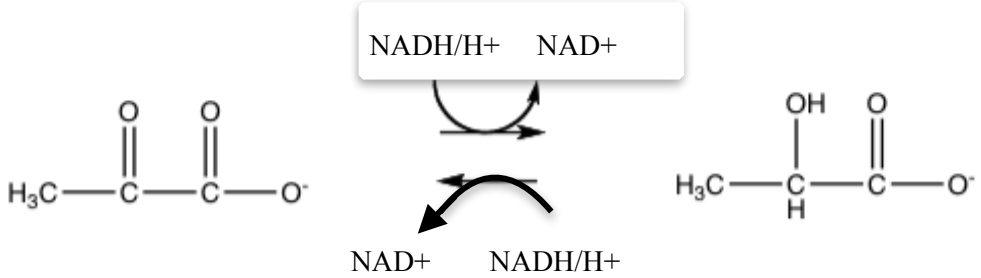
Step	***Enzyme***
1	Hexokinase
2	Glucose 6-phosphate isomerase
3	Phosphofructokinase
4	Alsolase
5	Triose phosphate isomerase
6	3-phosphate dehydrogenase
7	Phosphoglycerate kinase
8	Phosphoglycerate mutase
9	Enolase
10	Pyruvate kinase

Pyruvate Oxidation

- Under aerobic conditions pyruvate is decarboxylated and oxidized into acetyl-CoA. Acetyl-CoA enters into the Krebs cycle, followed by ETC and oxidative phosphorylation.



- Under anaerobic conditions NADH/H+ and $FADH_2$ cannot be reoxidized in the ETC. The lack of NAD+ means that pyruvate cannot be oxidized to acetyl-CoA for entry into the Krebs cycle. Pyruvate is reduced to lactate temporarily.



ATP Yield for Complete Catabolism of 1 mol of Glucose

Glycolysis:
-2 ATP to start
+4 ATP (2 ATP per unit of D-glyceraldehyde 3-phosphate)
+2 NADH/H+ which yields 6 ATP from ETC/Ox Phos

Pyruvate Oxidation:
+2 NADH/H+ (1 NADH/H+ per pyruvate) which yield 6 ATP from ETC/Ox Phos

Krebs Cycle:
Two turns in the Krebs Cycle yields 24 ATP total

Total Yield = 38 mol ATP