Course- B.Sc. (Honours), Part -3

Subject- Botany, Paper-V (Group-A)

Topic- Glycolysis (Respiration)

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Binod Kumar Pandey

Assistant Professor & HOD, Botany Department,

Ram Ratan Singh College, Mokama, Patna.

E.mail- binodkp14@gmail.com

Glycolysis

Glycolysis (Gk. glykys = sweet, lysis = splitting), also called glycolytic pathway or Embden-Meyerhof-Parnas (EMP) pathway, is the sequence of reactions that metabolises one molecule of glucose to two molecules of pyruvate with the concomitant net production of two molecules of ATP.

Glycolysis is almost an universal central pathway of glucose catabolism, and the complete pathway of glycolysis was elucidated by 1940, largely through the pioneering contributions of G. Embden, O. Meyerhof, J. Parnas, C. Neuberg, O. Warburg, G. Cori, and C. Cori. However, glycolysis occurs in all major groups of microorganisms and functions in the presence or absence of oxygen. It is located in the cytoplasmic matrix of the cells of an organism.

The whole process of glycolysis (i.e., the breakdown of the 6-carbon glucose molecule into two molecules of the 3-carbon pyruvate) occurs in ten steps (Fig. 24.1). The first five-steps constitute the preparatory phase while the rest live-steps represent the payoff phase (oxidation phase).

In preparatory phase there is phosphorylation of glucose and its conversion to glyceraldehyde 3-phosphate at the expense of two molecules of ATP. Oxidative conversion of glyceraldehyde 3-phosphate to pyruvate and the coupled formation of ATP and NADH is the feature of payoff phase.

The step-wise concise account of glycolysis is the following:

1. Glucose (hexose sugar) is activated for subsequent reactions by its phosphorylation to yield glucose 6-phosphate, with ATP as the phosphoryl donor. This reaction, which is irreversible under intracellular conditions, is catalyzed by enzyme hexokinase, which requires Mg^{2+} for its activity.

2. Enzyme phosphohexose isomerase (phosphoglucose isomerase) catalyzes the reversible isomerization of glucose 6-phosphate (an aldose) to fructose 6- phosphate (a ketose). Phosphohexose isomerase requires Mg^{2+} and is specific for glucose 6-phosphate and fructose 6-phosphate.

3. Enzyme phosphofructokinase catalyses the transfer of a phosphoryl group from ATP to fructose 6-phosphate to yield fructose 1, 6-bisphosphate. This reaction is essentially irreversible under cellular conditions. Phosphofructokinase also requires Mg^{2+} for its activity.

4. The enzyme fructose 1, 6-bisphosphate aldolase, often called simply aldolase catalyses the cleavage of fructose 1,6-bisphosphate to yield two different triose sugar phosphates, glyceraldehyde 3-phosphate (an aldose) and dihydroxyacetone phosphate (a ketose).

5. Glyceraldehyde 3-phosphate and dihydroxyacetone phosphate are inter-convertible. Only glyceraldehyde 3-phosphate is directly degraded in the subsequent steps and, therefore, dihydorxyacetone phosphate is rapidly and reversibly converted to glyceraldehyde 3-phosphate by the enzyme triose phosphate isomerase. This reaction completes the preparatory phase of glycolysis.

6. This step is the first step of payoff phase of glycolysis, Glyceraldehyde 3-phosphate oxidises to 1, 3- bisphosphoglycerate with the involvement of enzyme glyceraldehyde 3-phosphate dehydrogenase. During this reaction NAD^+ is reduced yielding NADH (oxidative phosphorylation).

7. 1, 3-bisphosphoglyceratc is converted to 3-phosphoglycerate. In this reaction the enzyme phosphoglycerokina.se transfers the high-energy phosphoryl group from 1,3-bisphosphoglycerate to ADP yielding ATP and 3-phosphoglycerate. The formation of ATP by phosphoryl group transfer from a substrate (1,3-bisphosphoglycerate) is called substrate level phosphorylation.

8. 3-phosphoglycerate is now converted to 2-phosphoglycerate. In this reaction the enzyme phosphoglycerate mutase catalyses a reversible shift of the phosphoryl group between C-2 and C-3 of glycerate; Mg^{2+} is essential for this reaction.

9. In this step the enzyme enalase promotes reversible removal of a molecule of water from 2-phosphoglycerate to yield phosphoenolpyruvate.

10. This is the last step in glycolysis. Phosphoryl group from phosphoenolpyruvate is transferred to ADP by enzyme pyruvate kinase to yield ATP and pyruvate via substrate level phosphorylation. The enzyme pyruvate kinase requires K and cither Mg^{2+} or Mn^{2+} for its activity.

The whole of glycolysis can be represented by the following simple equation:

$$\textbf{Glucose + 2ADP + 2Pi + 2NAD}^{+} \textbf{ = 2 pyruvate + 2ATP + 2NADH + 2H}^{+}$$

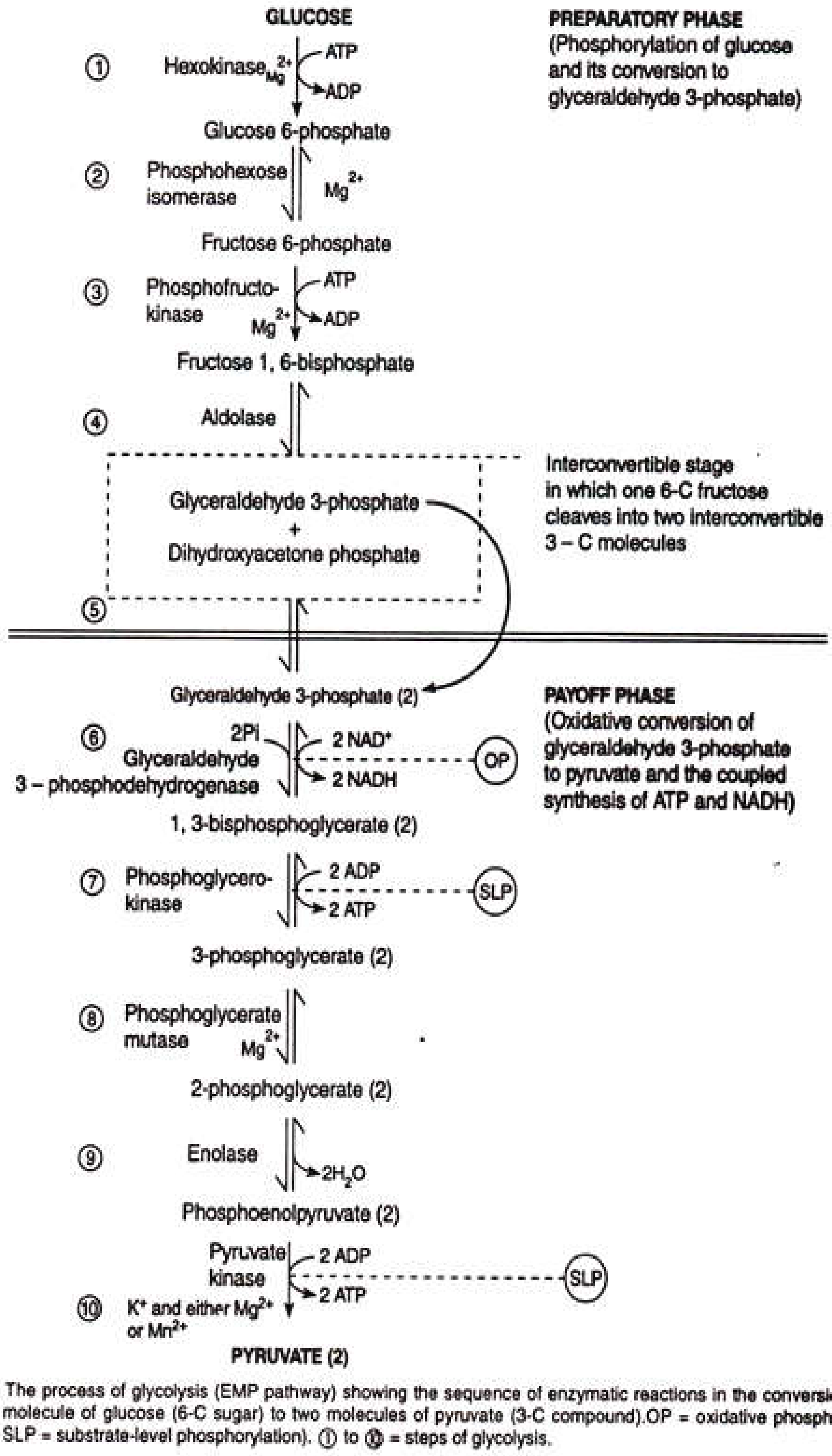

FIG. 24.1. The process of glycolysis (EMP pathway) showing the sequence of enzymatic reactions in the conversion of one molecule of glucose (6-C sugar) to two molecules of pyruvate (3-C compound).OP = oxidative phosphorylation; SLP = substrate-level phosphorylation). ① to ⑩ = steps of glycolysis.