VIVEKANANDA COLLEGE THAKURPUKUR KOLKATA-700063

NAAC ACCREDITED 'A' GRADE

- Topic: RESPIRATION
- Course Title: PLANT PHYSIOLOGY AND METABOLISM
- Paper: BOT-G-CC-4-4-TH
- Unit: 5.1
- Semester: IV
- Name of the Teacher: ISHITA ROY
- Name of the Department: BOTANY

GLYCOLYSIS

Glycolysis (glycos=sugar (sweet); lysis=dissolution) is the sequence of 10 enzyme catalysed reactions that converts one molecule glucose into two molecules of three-carbon compound pyruvate with the simultaneous production of ATP. Moreover, glycolysis also includes the formation of lactate from pyruvate.

In aerobic organisms, glycolysis is the prelude to the citric acid cycle and the electron transport chain which together harvest most of the energy contained in glucose. In fact, is the central pathway of glucose catabolism.

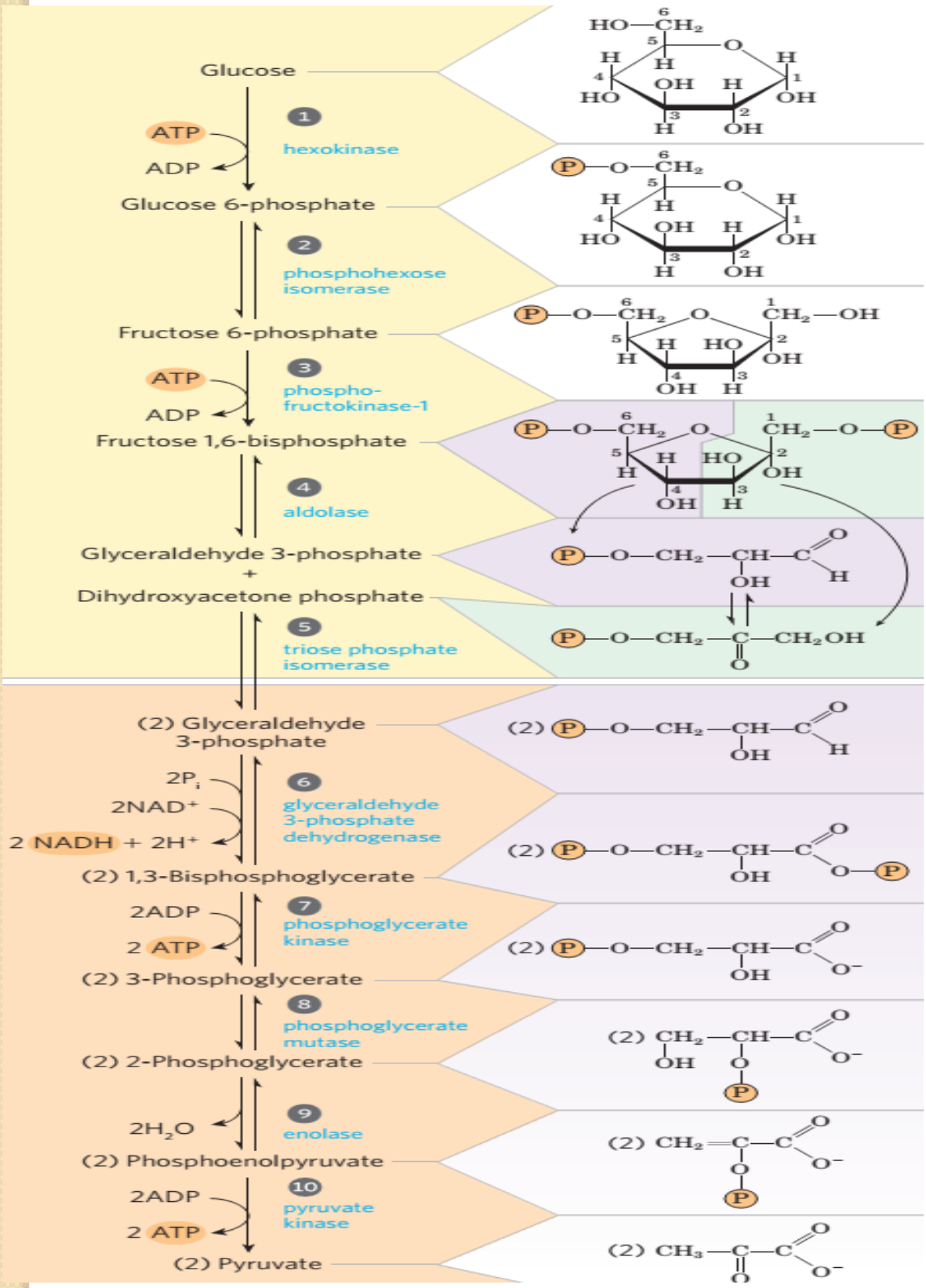
Location: Glycolysis takes place in the extra-mitochondrial part of the cell (or the soluble cytoplasm). It is frequently referred to as **Embden-Meyerhof-Parnas** or **EMP pathway**.

Two phases of Glycolysis:- During glycolysis, the 6-carbon glucose is broken down into two molecules of 3-carbon pyruvate via 10 enzyme catalysed sequential reactions. These reactions are grouped under two phases, phase I and phase II.

- **Phase I** or **Preparatory Phase:-** It consists of the first 5 steps. In these reactions, glucose is enzymatically phosphorylated by ATP (first at **carbon-6** and later at **carbon-1**) to yield fructose 1,6-bisphosphate which is then split in half to yield 2 molecules of the 3-carbon compound, **glyceraldehyde 3-phosphate**. The first phase of glycolysis, thus, results in cleavage of the hexose chain. This phase requires an investment of 2 molecules of ATP to activate the glucose molecule and prepare it for its cleavage into two 3-carbon pieces. Besides glucose, other hexose such as D-fructose, D-galactose and D-mannose may also convert into glyceraldehyde 3-phosphate.
- **Phase II** or **Payoff Phase:-** The last 5 reactions of glycolysis constitute this phase. This phase represents the payoff of glycolysis, in which the energy liberated during conversion of 3 molecules of glyceraldehyde 3-phosphate to **2 molecules of pyruvate** is converted by the coupled phosphorylation of **4 molecules of ADP to ATP**. Although 4 per molecule of glucose oxidised, since 2 molecules of ATP are invested in phase I. the phase II is thus, energy conserving. Energy is also conserved in the payoff phase in the **formation of two molecules of NADH per molecule of glucose**.

In the sequential reactions of glycolysis, three types of chemical transformations are particularly noteworthy: (1) degradation of the carbon skeleton of glucose to yield pyruvate, (2) phosphorylation of ADP to ATP by high-energy phosphate compounds formed during glycolysis, and (3) transfer of a hydride ion to NAD^+, by forming NADH.

10 steps of glycolysis as shown in the next slide-


Glucose
ATP
ADP
1
hexokinase
Glucose 6-phosphate
2
phosphohexose isomerase
Fructose 6-phosphate
ATP
ADP
3
phospho-fructokinase-1
Fructose 1,6-bisphosphate
4
aldolase
Glyceraldehyde 3-phosphate
+
Dihydroxyacetone phosphate
5
triose phosphate isomerase
(2) Glyceraldehyde 3-phosphate
2Pi
2NAD+
2 NADH + 2H+
6
glyceraldehyde 3-phosphate dehydrogenase
(2) 1,3-Bisphosphoglycerate
2ADP
2 ATP
7
phosphoglycerate kinase
(2) 3-Phosphoglycerate
8
phosphoglycerate mutase
(2) 2-Phosphoglycerate
2H2O
9
enolase
(2) Phosphoenolpyruvate
2ADP
2 ATP
10
pyruvate kinase
(2) Pyruvate

REACTION STEPS OF GLYCOLYSIS

Step 1: Phosphorylation of Glucose

In the first step, glucose is activated for subsequent reactions by its phosphorylation at C_6 to yield glucose 6-phosphate, using ATP as phosphate donor, by the enzyme *hexokinase*.

Glucose→Glucose 6-phosphate

Step 2: Isomerization of Glucose 6-phosphate

Glucose 6-phosphate reversibly isomerized to fructose 6-phosphate by *phosphohexoisomerase*. Thus, the 6-membered pyranose ring of glucose 6-phosphate is converted into 5-membered furanose ring of fructose 6-phosphate.

Glucose 6-phosphate↔Fructose 6-phosphate

Step 3: Phosphorylation of Fructose 6-phosphate

This is the second of the two activating reactions of glycolysis (the first one being Step 1). Fructose 6-phosphate is phosphorylated by ATP to produce fructose 1,6-bisphosphate in the presence of enzyme *phosphofructokinase*. This reaction is essentially irreversible and an important control point of glycolysis.

Fructose 6-phosphate→Fructose 1,6-bisphosphate

Step 4: Cleavage of Fructose 1,6-bisphosphate

This is a unique C-C bond scission reaction. Since, fructose 1,6-bisphosphate is a molecule with phosphate group on both ends, it splits in the middle into two different triose phosphates, glyceraldehyde 3-phosphate(GAP) and dihydroxyacetone phosphate(DHAP). This reaction is catalysed by the enzyme *aldolase*

Fructose 1,6-bisphosphate↔Dihydroxyacetone phosphate + Glyceraldehyde 3-phosphate

Step 5: Isomerization of Dihydroxyacetone phosphate

Dihydroxyacetone phosphate can be readily and reversibly converted into glyceraldehyde 3-phosphateby the enzyme *triose phosphate isomerase*.

Dihydroxyacetone phosphate↔Glyceraldehyde 3-phosphate

Step 6: Oxidative phosphorylation of Glyceraldehyde 3-phosphate

The first step of the payoff phase is the oxidation of glyceraldehyde 3-phosphate to 1,3-bisphosphoglycerate, catalysed by the enzyme *glyceraldehyde 3-phosphate dehydrogenase*, which is NAD dependent.

Glyceraldehyde 3-phosphate↔1,3-bisphosphoglycerate

Step 7: Transfer of phosphate from 1,3-bisphosphoglycerate to ADP

This is the first ATP generating reaction in glycolysis. It involves the transfer of high-energy phosphate group from the carboxylic group of 1,3-bisphosphoglycerate to ADP by the enzyme *phosphoglycerate kinase*, thus producing ATP and leaving 3-phosphoglycerate.

1,3-bisphosphoglycerate↔3-phosphoglycerate

Step 8: Isomerization of 3-phosphoglycerate

The 3-phosphoglycerate is converted into 2-phosphoglycerate due to intramolecular shift of phosphoryl group from $^{C}_{3}$ to $^{C}_{2}$ by the enzyme *phosphoglycerate mutase*.

3-phosphoglycerate↔2-phosphoglycerate

Step 9: Dehydration of 2-phosphoglycerate

This is the second reaction of glycolysis in which a high-energy phosphate compound is formed. The 2-phosphoglycerate is dehydrated by the action of *enolase* to phosphoenol pyruvate(PEP).

2-phosphoglycerate↔phosphoenol pyruvate

Step 10: Transfer of Phosphate from PEP to ADP

This is the second ATP generating reaction in glycolysis. Here phosphoenol pyruvate is converted into pyruvate in enol formby the enzyme *pyruvate kinase*.

Phosphoenol pyruvate→pyruvate