DEPARTMENT OF BIOTECHNOLOGY

METABOLISM OF CARBOHYDRATES

By-
Ms. Payal Talekar

DEFINATION OF METABOLISM

- Carbohydrate metabolism is the whole of the biochemical processes responsible for the metabolic formation, breakdown, and interconversion of carbohydrates in living organisms.
- Carbohydrates are central to many essential metabolic pathways.
- "The metabolism of an organism may be defined as the sum total of all the enzyme-catalyzed reactions that occur in an organism."

TERMINOLOGY OF METABOLISM

Metabolic Process

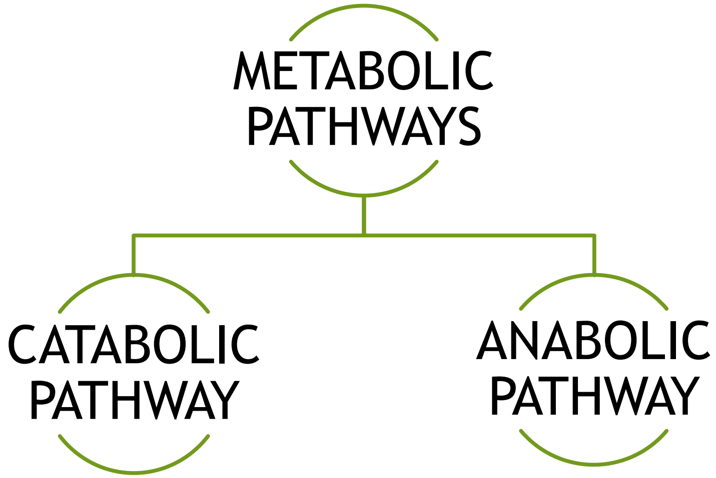
There are two types of metabolic process:

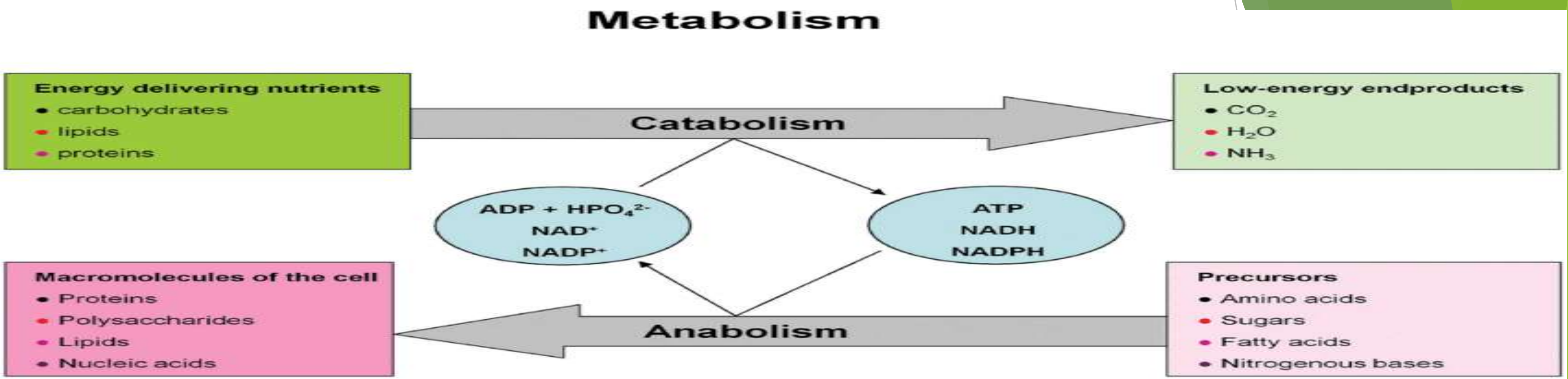
•Catabolism

•Anabolism

Catabolism – This process is mainly involved in breaking down larger organic molecules into smaller molecules. This metabolic process releases energy.

Anabolism – This process is mainly involved in building up or synthesizing compounds from simpler substances required by the cells. This metabolic process requires and stores energy.





Some processes can be either catabolic or anabolic, depending on the energy conditions in the cell. There are referred to as amphibolism.

Fuels (Carbohydrates, Fats) $\xrightarrow{\text{Catabolism}}$ CO_2 + H_2O + Useful energy

Useful energy + Small molecules $\xrightarrow{\text{Anabolism}}$ Complex molecules

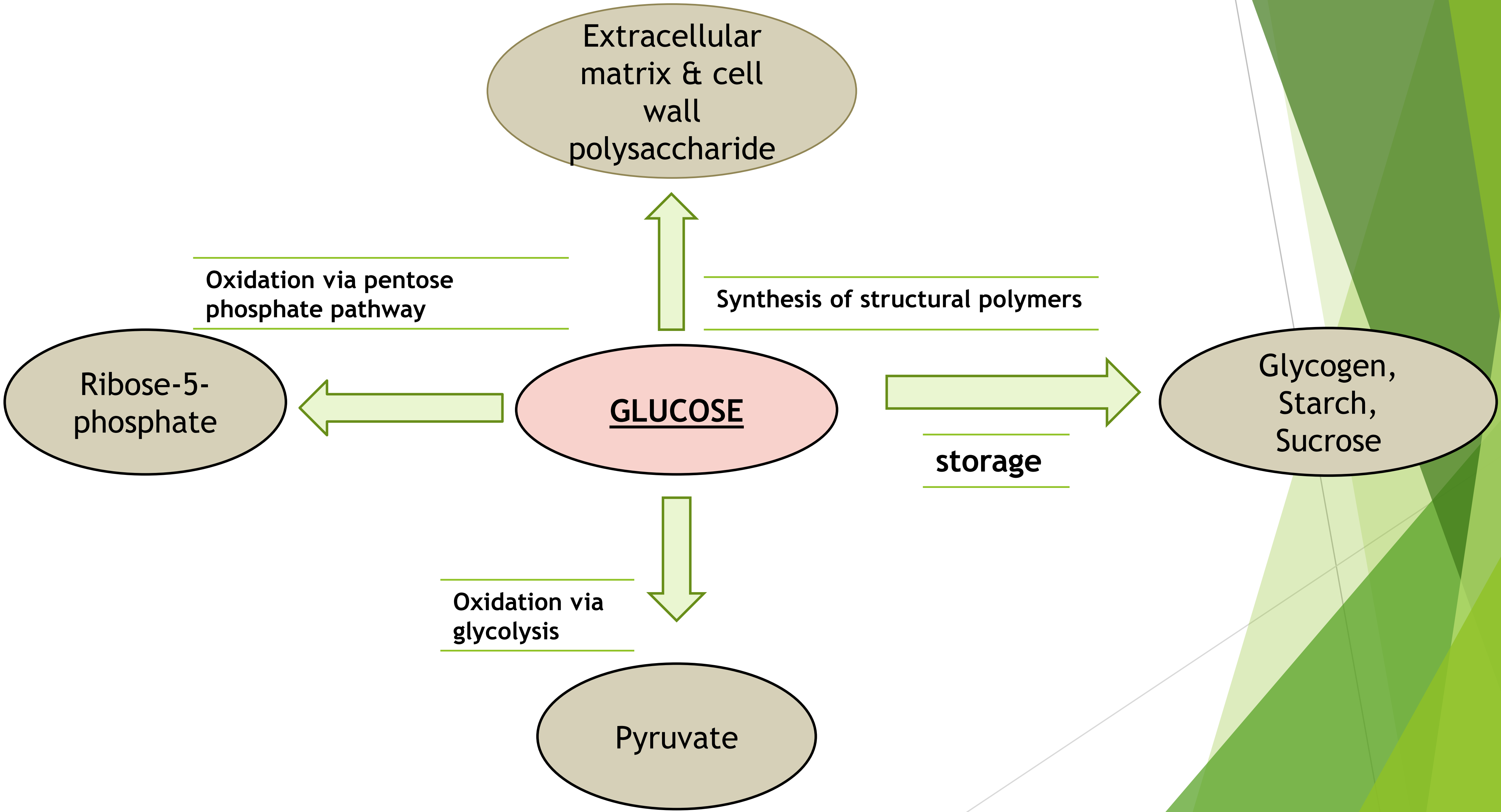
GLYCOLYSIS /EMP PATHWAY.

Glycolysis comes from a merger of two greek words:

- Glykys= sweet
- Lysis= Breakdown/ Splitting

Its is also known as Embden-Meyerhof-Parnas pathway or EMP pathway.

Major pathways of glucose utilization



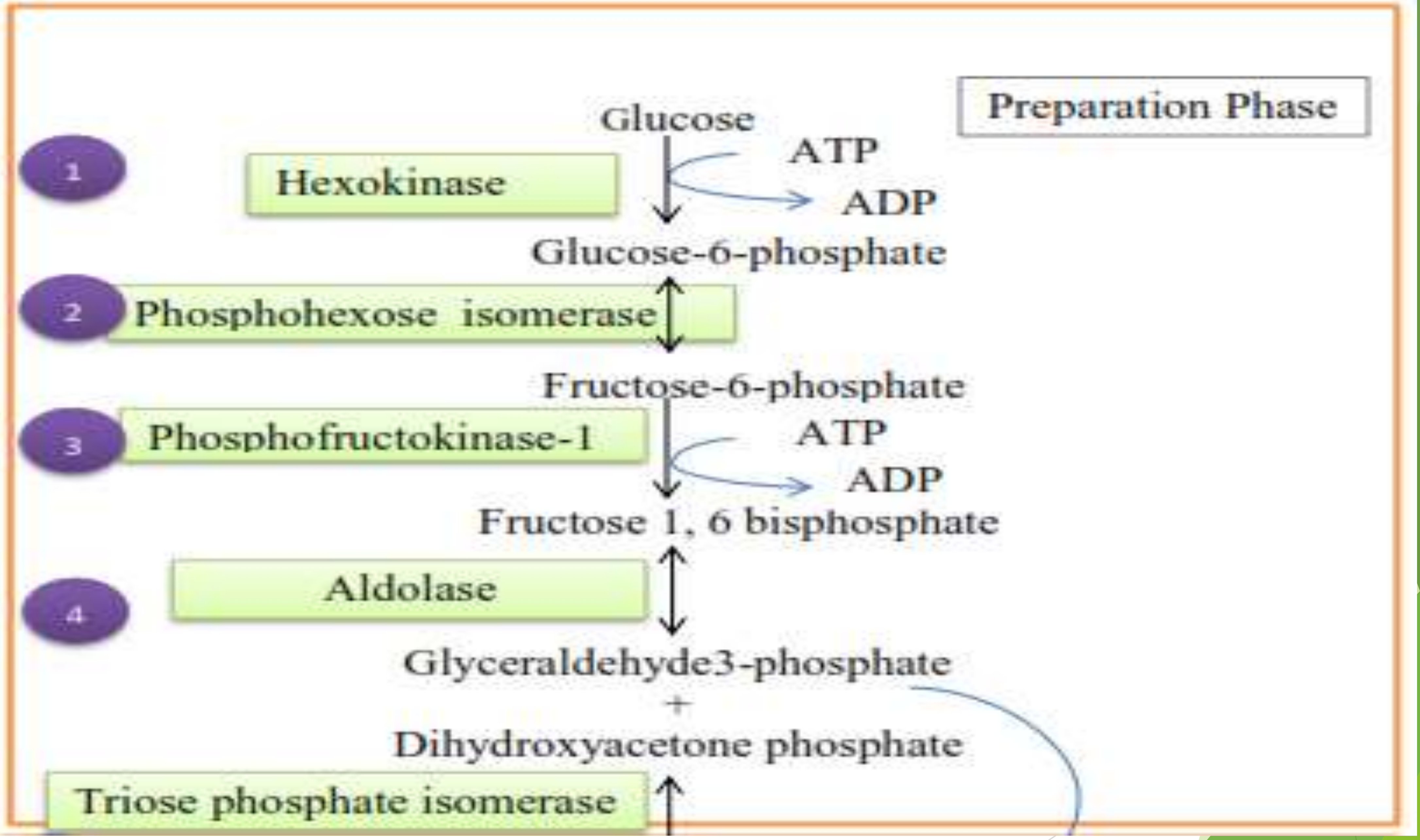
Two Phases of Glycolysis

Glycolysis leads to breakdown of 6-C glucose into two molecules of 3- C pyruvate with the enzyme catalysed reactions being bifurcated or catogorised into 2 phases:

Phase 1: preparatory phase
Phase 2: payoff phase

PREPARATORY PHASE

- It consists of the 1st 5 steps of glycolysis in which the glucose is enzymatically phosphorylated by ATP to yield Fructose-1,6-biphophated.
- This Fructose-1,6-biphophated is the split in half to yield 2 molecules of 3- carbon containing Glyceraldehhyde-3-phosphate/ dihydroxyacetone phosphate.
- Thus the 1st phase **results in cleavage of the hexose chain.**
- This cleavage requires an investment of 2 ATP molecules to activate the glucose mole and prepare it for its cleavage into 3-carbon compound.

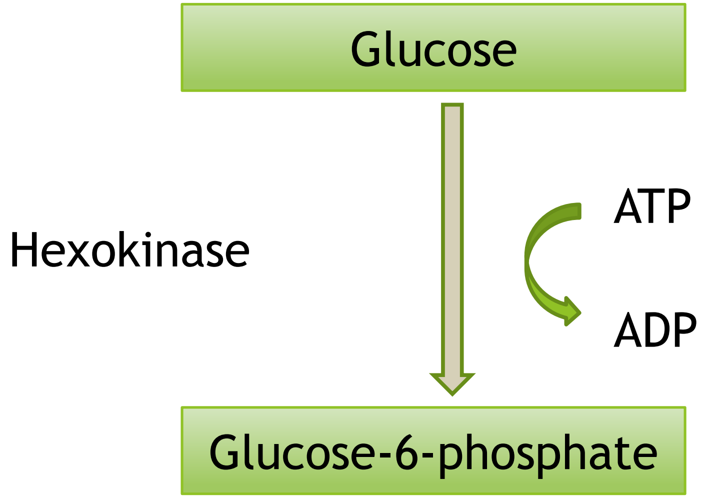

Preparation Phase
Glucose
1
Hexokinase
ATP
ADP
Glucose-6-phosphate
2
Phosphohexose isomerase
Fructose-6-phosphate
3
Phosphofructokinase-1
ATP
ADP
Fructose 1, 6 bisphosphate
4
Aldolase
Glyceraldehyde3-phosphate
+
Dihydroxyacetone phosphate
Triose phosphate isomerase

GLYCOLYSIS

"Glycolysis is the metabolic process that converts glucose into pyruvic acid."

Step 1: PHOSPHORYLATION

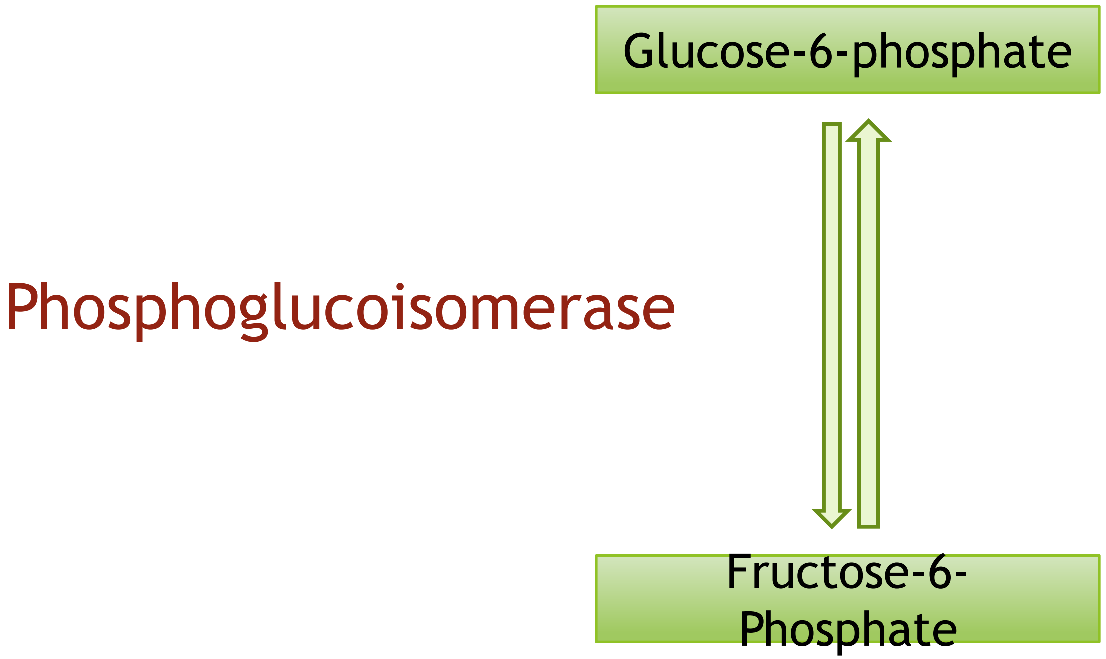
- Glucose is phosphorylated by ATP to form sugar phosphate.
- This is an irreversible reaction and is catalysed by hexokinase.
- Thus presented as



STEP 2: ISOMERIZATION

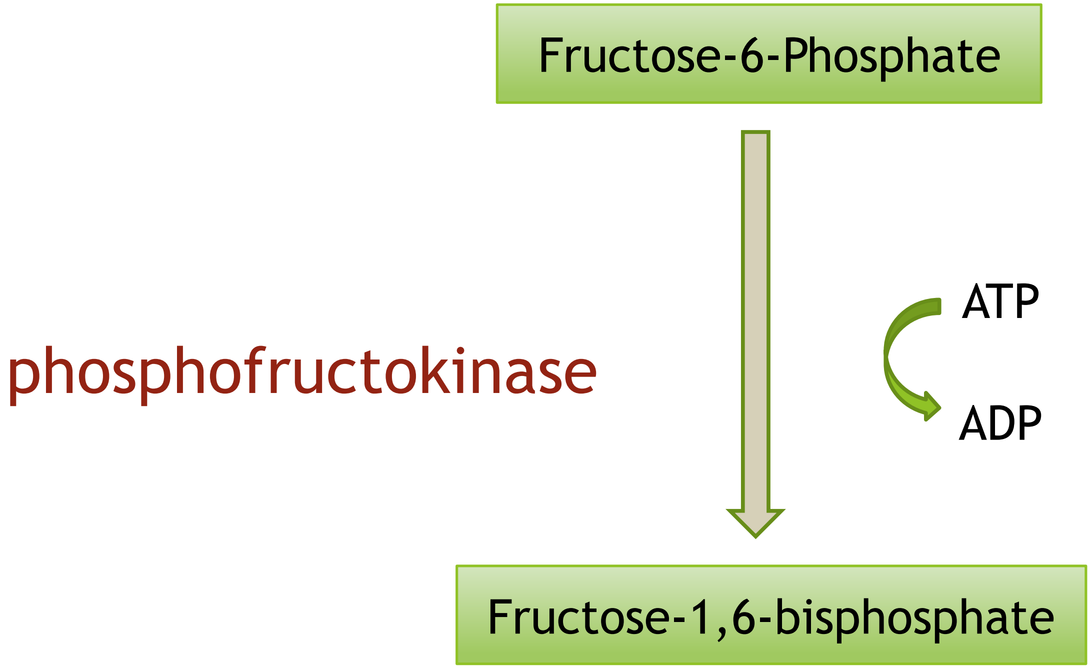
It is a reversible rearrangement of chemical structure of carbonyl oxygen from C1 to C2, forming a Ketose from the aldose.

Thus, isomerization of the aldose glucose-6-phosphate.



STEP 3: PHOPHORYLATION

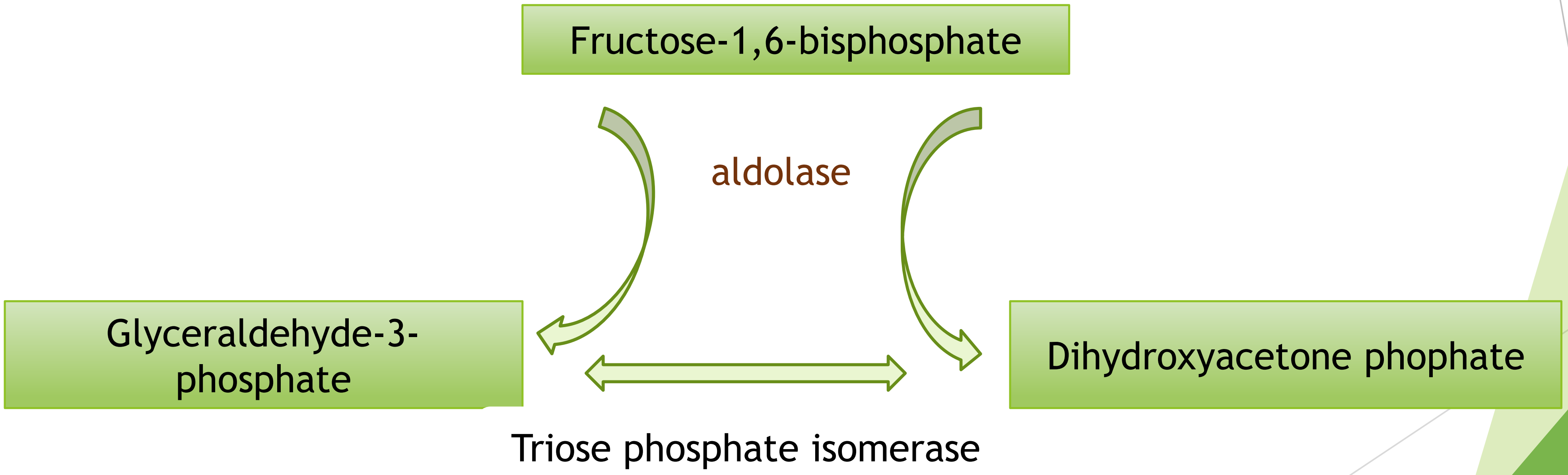
Here the Fructose-6- Phosphate is phosphorylated by ATP to fructose-1,6—bisphosphate.
This is an irreversible reaction and catalysed by phosphofructokinase enzyme.



STEP 4: BREAKDOWN

this six carbon sugar is cleaved to produce two 3-C molecules: glyceradldehyde-3-phosphate (GAP) & dihydroxyacetone phosphate (DHAP).

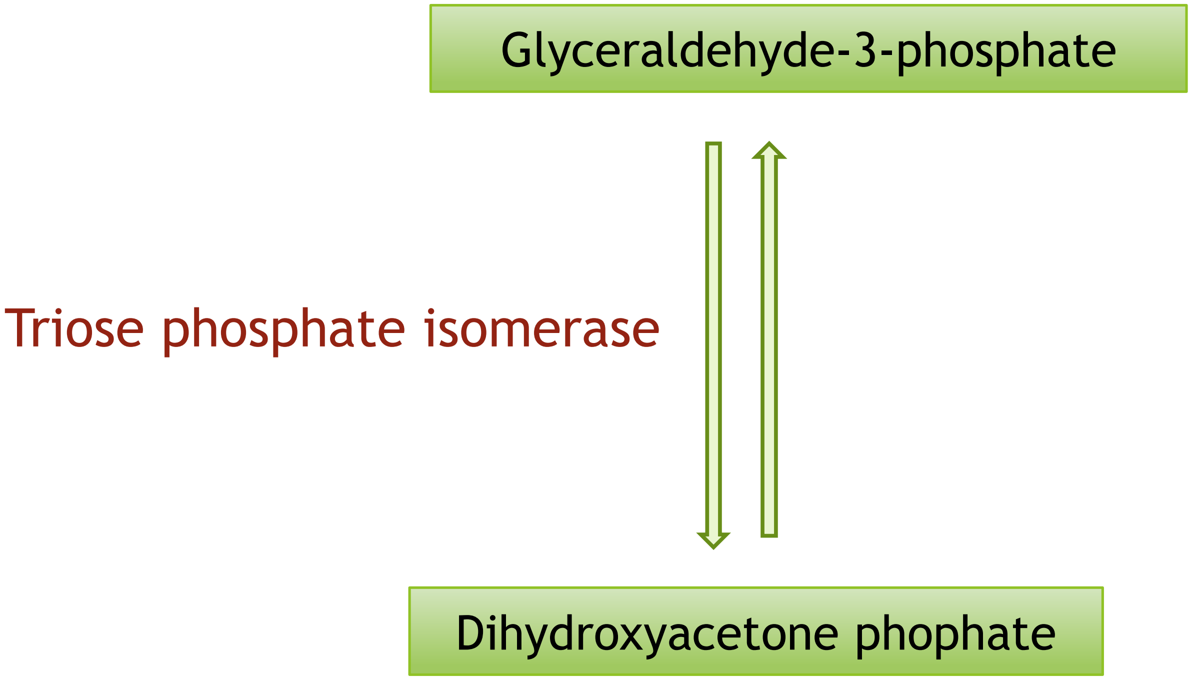
This reaction is catalysed by Aldolase.



STEP 5: ISOMERIZATION

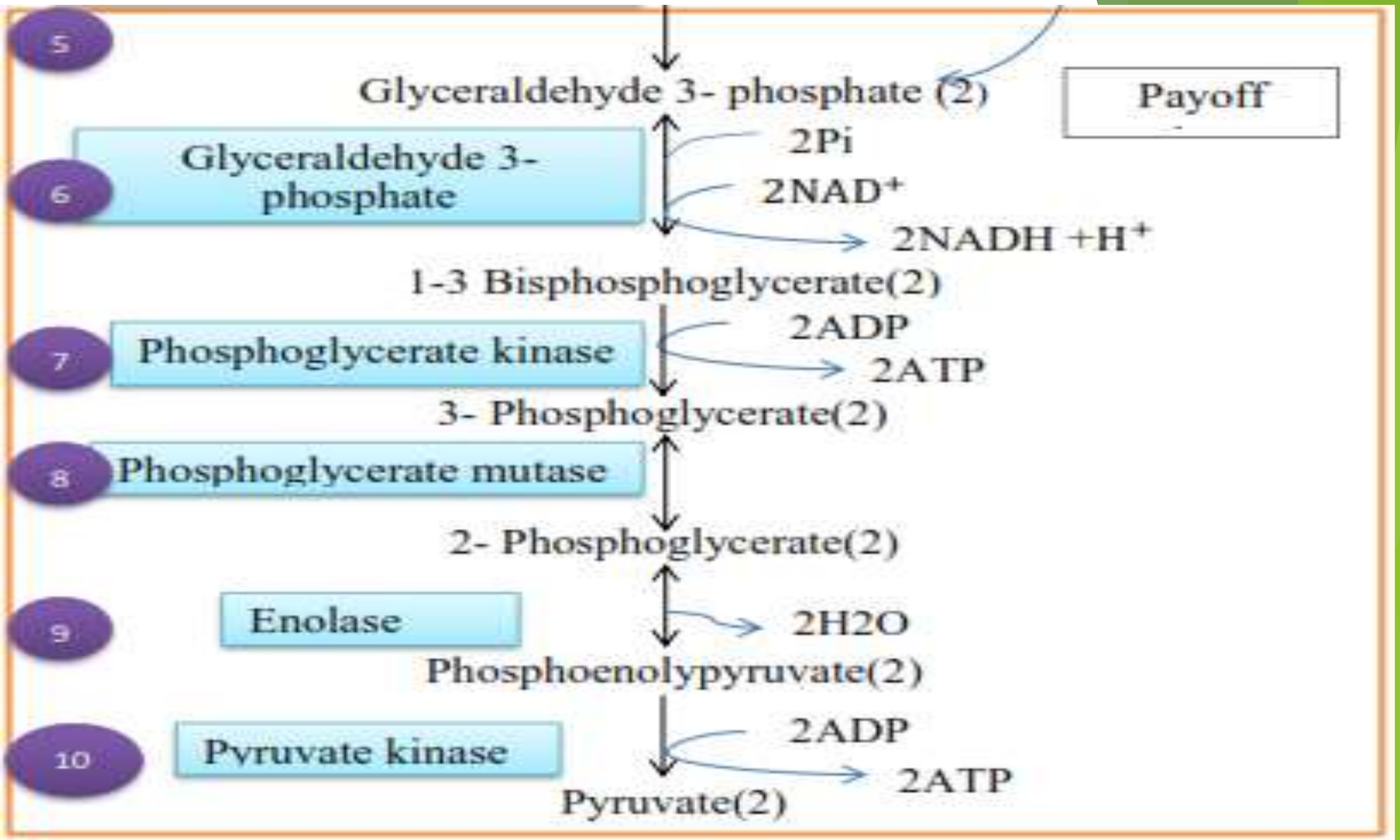
Dihydroxyacetone phosphate is oxidized to form Glyceraldehyde-3-phosphate.

This reaction is catalysed by triose phosphate isomerase enzyme.



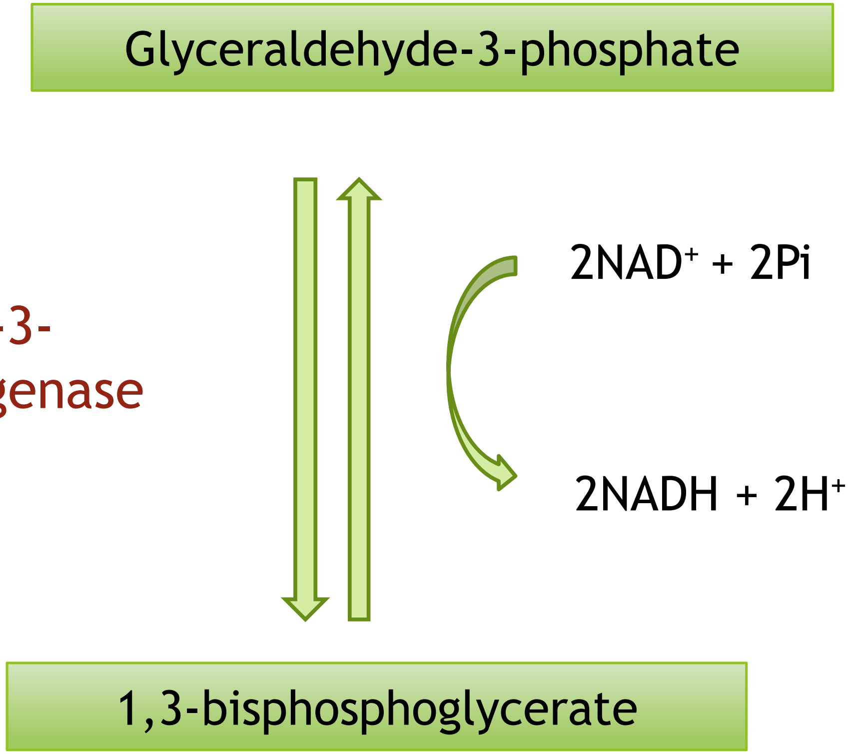
PAYOFF PHASE

- This phases constitutes the last 5 reactions of Glycolysis.
- This phase marks the release f ATP molecules during conversion of Glyceraldehyde-3-phosphate to 2 moles of Pyruvate.
- Here 4 moles of ADP are phosphorylated to ATP. Although 4 moles of ATP are formed , the next result is only 2 moles of ATP per mole of Glucose oxidised , since 3 moles of ATP are utilised in Phase 1.


5
Glyceraldehyde 3- phosphate (2)
Payoff
6
Glyceraldehyde 3-phosphate
2Pi
2NAD+
2NADH +H+
1-3 Bisphosphoglycerate(2)
7
Phosphoglycerate kinase
2ADP
2ATP
3- Phosphoglycerate(2)
8
Phosphoglycerate mutase
2- Phosphoglycerate(2)
9
Enolase
2H2O
Phosphoenolypyruvate(2)
10
Pyruvate kinase
2ADP
2ATP
Pyruvate(2)

STEP 6:

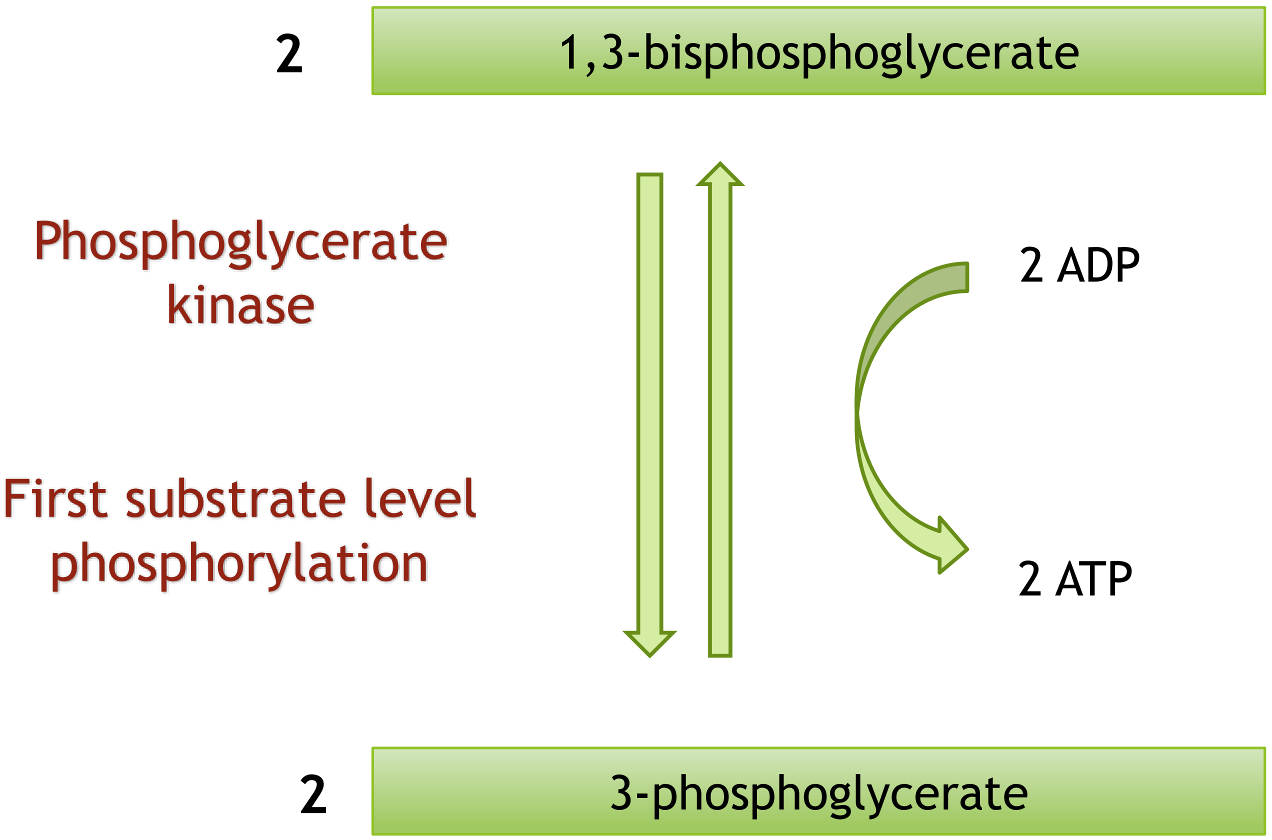
Glyceraldehyde-3-phosphate dehydrogenase



STEP 6:

2 molecules of glyceraldehyde-3-phosphate are oxidised. Glyceraldehyde-3-phosphate dehydrogenase catalysed the conversion of glyeraldehyde3- phosphate into 1,3-bisphosphoglycerate.

STEP 7:


2
1,3-bisphosphoglycerate
Phosphoglycerate kinase
First substrate level phosphorylation
2 ADP
2 ATP
2
3-phosphoglycerate

STEP 7:

the transfer of high energy phosphate group that was generated earlier to ADP, form ATP.

This phosphorylation i.e. addition of phosphate to ADP to give ATP is termed as Substrate level phosphorylation as the phosphate donor is the substrate 1,3-bisphospoglycerate (1,3-BPG).

The product of this reaction is 2 molecules of 3-phosphoglycerate.

STEP 8

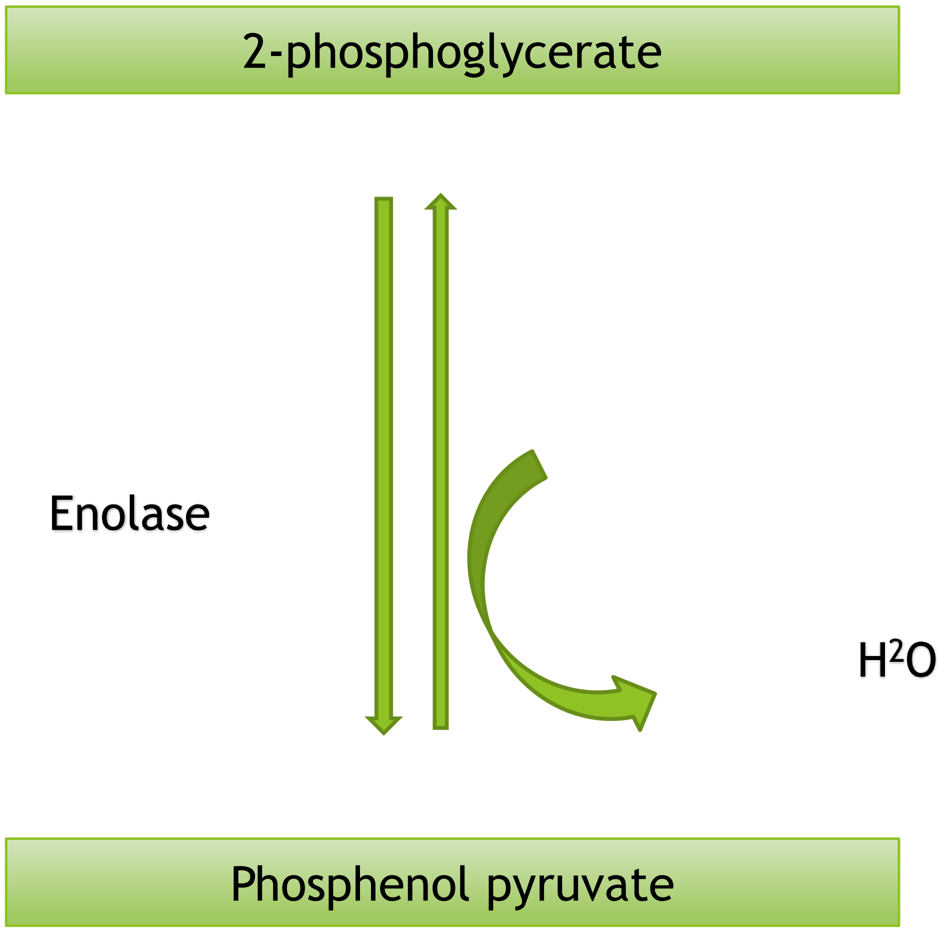
The remaining phosphate-ester linkage in 3-phosphoglycerate, is moved from carbon 3 to carbon 2, because of relatively low free energy of hydrolysis, to form 2-phosphoglycerate(2-PG).

2 3-phosphoglycerate

⇅ Phosphoglycerate mutase

2 2-phosphoglycerate

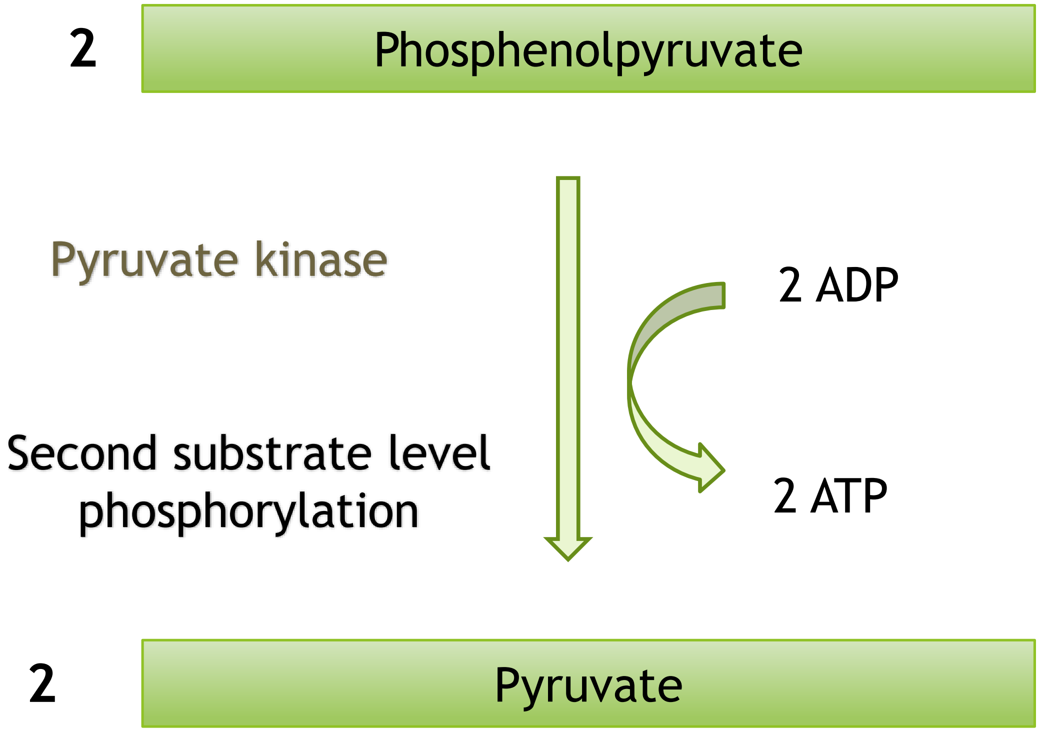
STEP 9: DEHYDRATION OF 2-PG



STEP 9: DEHYDRATION OF 2-PG

This is the second reaction in glycolysis where a high-enegy phosphate compound is formed.
The 2-phosphoglycerate is dehydrated by the action of enolase to phosphoenolpyruvate (PEP). This compound is the phosphate ester of the enol tautomer of pyruvate.
This is a reversible reaction.

STEP 10: TRANSFER OF PHOPHATE FROM PEP TO ADP



STEP 10: TRANSFER OF PHOPHATE FROM PEP TO ADP

This last step is the irreversible transfer of high energy phosphoryl group from phosphoenolpuruvate to ADP this reaction is catalysed by pyruvate kinase.

This is the second substrate level phosphorylation reaction in glycolysis which yields ATP.

This is a non-oxidative phosphorylation reaction.

OVERALL BALANCESHEET OF GLYCOLYSIS

EACH MOLECULE OF GLUCOE GIVS 2 MOLECULES OF Glyceraldehyde-3-phosphate. therefore, the tota; input of all 10 reactions can be summarized as:

$$\text{Glucose} + 2ATP + 2Pi + 2NAD^{+} + 2H^{+} + 4ADP$$

$$\downarrow$$

$$2\text{Pyruvate} + 2H^{+} + 4ATP + 2H_2O + 2NADH + 2ADP + 2H^{+}$$

On cancelling the common terms from the above equation, we get the net equation for Glycolysis:

$$\text{Glucose} + 2Pi + 2ADP + 2NAD^{+}$$

$$\downarrow$$

$$2\text{Pyruvate} + 2NADH + 2ATP + 2H^{+}\ 2H_2O$$

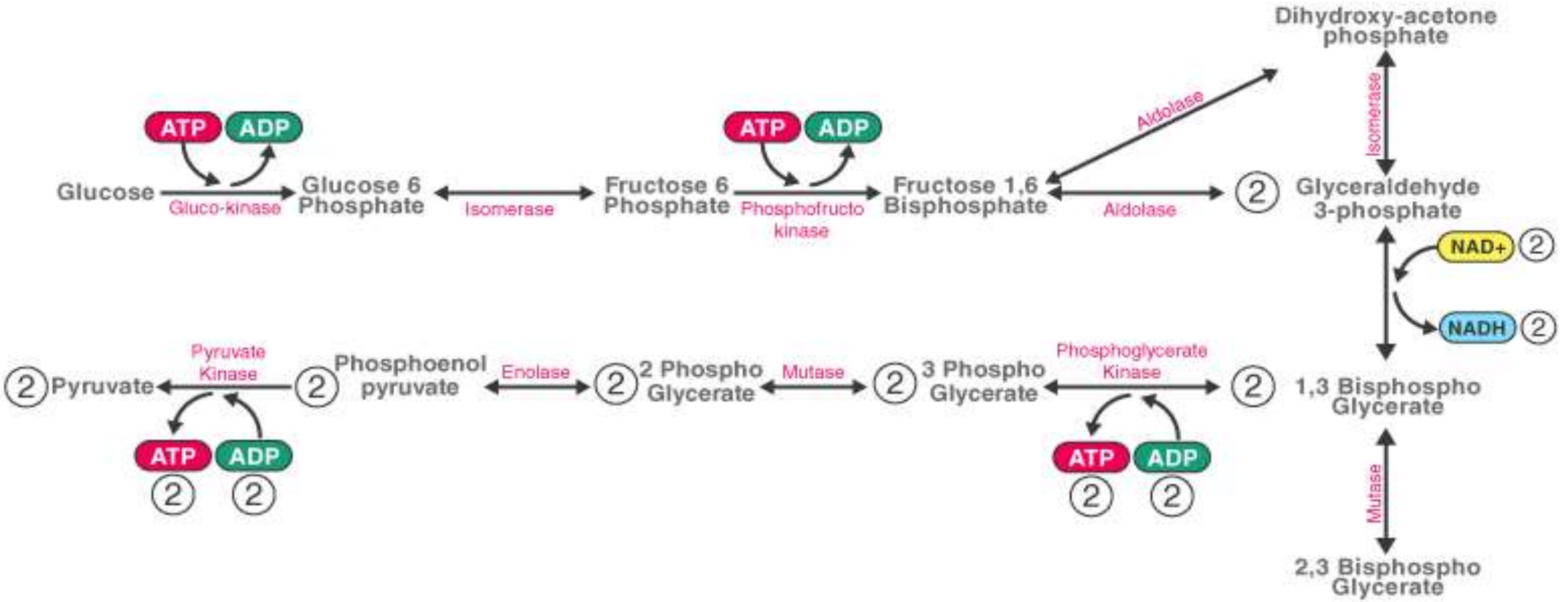
Thus the simultaneous reaction involved in glycolysis are:

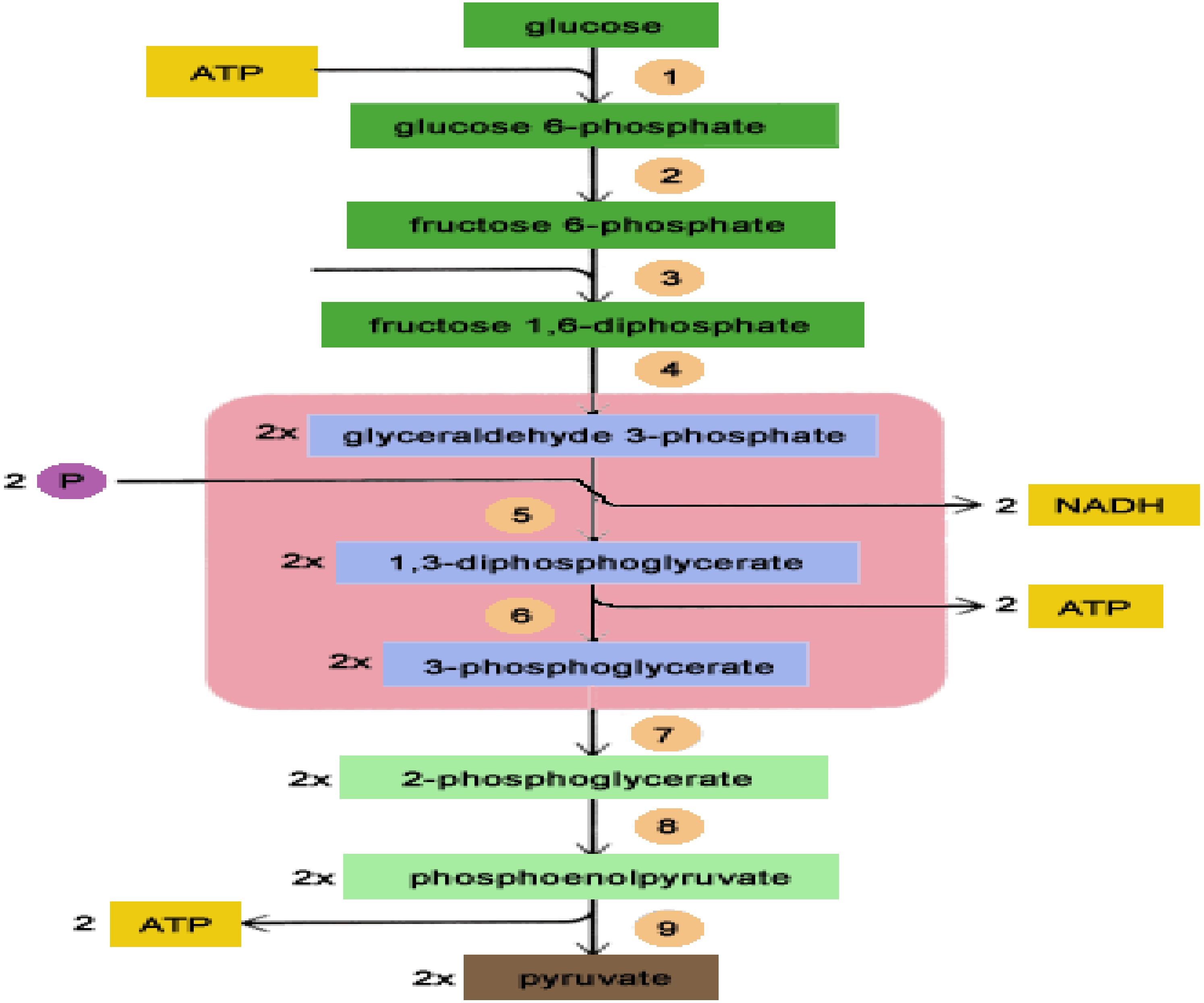
- Glycose is oxidized to Pyruvate
- $2NAD^+$ is reduced to NADH
- ADP is phosphorylated to ATP

Energy yield in Glycolysis:

Step No.	Reaction	Consumption of ATP	Gain of ATP
1	Glucose Glucose-6-phosphate	1	-
3	Fructose-6-phosphate fructose-1,6-biphosphate	1	-
7	1,3-diphophoglycerate 3-phosphoglycerate	-	1 * 2 = 2
10	Phosphoenolpyruvate pyruvate	-	1 * 2 = 2
		2	4

PATHWAY OF GLYCOLYSIS




glucose
ATP
1
glucose 6-phosphate
2
fructose 6-phosphate
3
fructose 1,6-diphosphate
4
2x glyceraldehyde 3-phosphate
2 P
2 NADH
5
2x 1,3-diphosphoglycerate
6
2 ATP
2x 3-phosphoglycerate
7
2x 2-phosphoglycerate
8
2x phosphoenolpyruvate
2 ATP
9
2x pyruvate

Thank you