

PLANT BIOCHEMISTRY AND PHILOSOPHY (SB 9402)

Course Outline:

1. Metabolism and synthesis of Carbohydrates.
2. Lipids.
3. Proteins and Amino acids.
4. Nitrogen cycle.
5. Assimilation of organic and inorganic Nitrogen in plants.
6. CAT 1
7. Nature and function of enzymes and vitamins.
8. Plant Organic Acids.
9. Respiration.
10. CAT 2.

1. Metabolism and Synthesis of Carbohydrates.

Metabolism - breakdown and synthesis.

- Glucose is the major form of sugar that is present in blood.
- The digestion of carbohydrate foods like starch, sucrose and lactose produces monosaccharides ^{are} glucose, fructose and galactose; these together pass into the bloodstream.
- The study of synthesis (anabolism) and degradation (catabolism) of biomolecules is referred to as metabolism; anabolism + catabolism = metabolism

NOTE:

Since Glucose is the most important carbohydrate present in physiological amounts in the body and is easily absorbed in the diet, carbohydrate metabolism ^{itself} result to the study of the metabolism of Glucose. Galactose and fructose are usually converted to Glucose in the liver and all monosaccharides are completely absorbed in the bloodstream. Glucose circulating in blood and other body

tissues are usually drawn by all the cells in the body to produce energy.

- Carbohydrates supply over half of the energy required in the body. eg the brain depends on carbohydrate metabolism as the source of energy and quickly stops to function when blood glucose level drops below normal.

Carbohydrates as a source of energy

the main function of

- Carbohydrates provide fuel and get oxidized to provide energy to serve as metabolic sources.
- Metabolic intermediates are used for other biosynthetic ^{reactions} and for this reason carbohydrates are used in form of glucose.
- A major part of glucose ^{directly} is converted to glycogen for storage.
- Glucose is degraded in the cell by a series of phosphorelated intermediates mainly due to metabolic pathways;

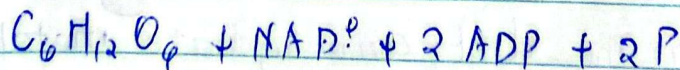
1. Glycolysis.

2. Tricarboxylic Acid Cycle.

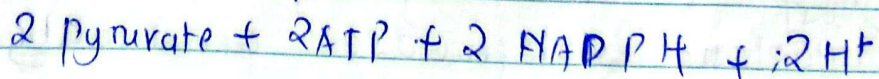
1. Glycolysis.

- Is the first step of breakdown of glucose.
- Glycolysis is a metabolic process that serves as both aerobic and anaerobic cellular respiration.

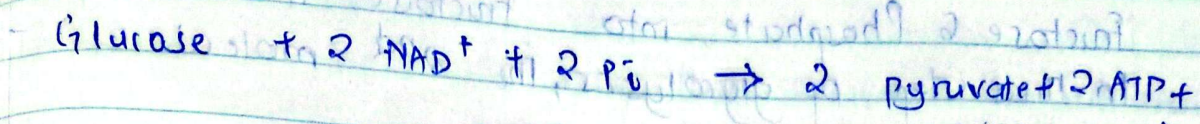
[In the process of glycolysis, glucose is converted to pyruvate through a ten step metabolic process through specific transporter proteins that enters the cells through cell's cytosomes.



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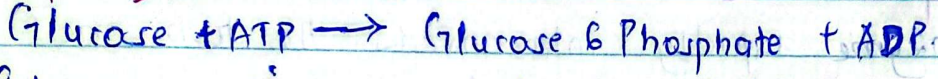
NOTE:



- In glycolysis Glucose molecule is split into two pyruvate molecules.
- 2 NAD⁺ are reduced to 2 NADH to capture high energy levels.
- 2 inorganic phosphates are incorporated during substrate level phosphorylation.
- 2 Hydrogen ions are released as ions during NAD⁺ reduction.
- Glycolysis is an anaerobic phase where energy is synthesized.

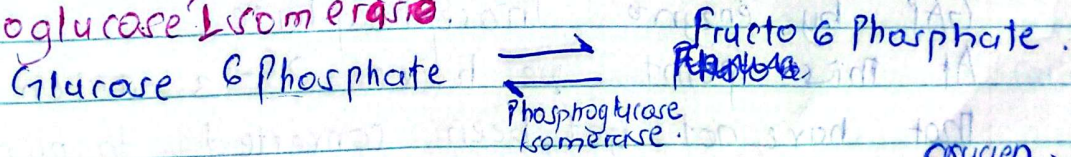
Steps of Glycolysis:

Step 1: Hexokinase.



- Glucose ring is phosphorylated.
- At this point in glycolysis, ATP is utilized to produce energy in the form of ADP.
- Atomic magnesium is also involved in this process. It helps to shield the negative charges from the phosphate group.

2. Phosphoglucose Isomerase.



- The reaction involves rearrangement of carbon ^{oxygen} ~~hydrogen~~ bond to transform the 6 membered ring to 5 membered ring.

3. Phosphofruktokinase.

- Kinases are enzymes that involve ATP and Mg²⁺.
- It functions with magnesium ions and charges.

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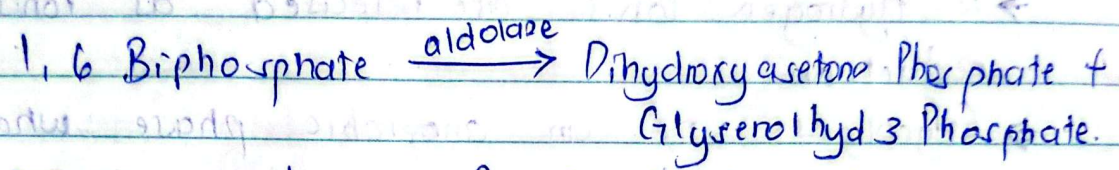
Fructose 6 Phosphate into Fructose 1, 6 Biphosphate.

In this step of glycolysis, the 2nd molecule of ATP is added providing a phosphate group

Aldolase

This enzyme splits 1, 6 Biphosphate into two sugars which are isomers of each other.

The two sugars are Dihydroxyacetone Phosphate (DHAP) and Glyceroldehyd 3 Phosphate (GAP)

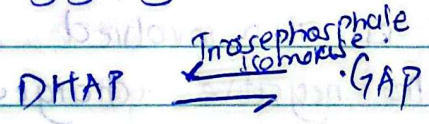


This enzyme produces 2-3 carbon molecule.

Triosephosphate Isomerase.

This enzyme rapidly interconverts the two molecules DHAP and GAP into each other.

GAP is rapidly removed and is used in the next step of glycolysis.



GAP is the only molecule that continues in the glycolytic path, this means that all DHAP are converted into GAP by enzyme Triosephosphate

At this point we have 2-3 carbon molecules that have not yet been converted to pyruvate in the glycolytic path.

GAP dehydrogenase

It converts GAP into 1-3 Bisphosphoglycerate.

It adds an inorganic phosphate to GAP

GAP is oxidized by the co-enzyme NAD⁺

The molecule is phosphorylated by addition of P

3 phosphate group.
The added phosphate group then attacks the GAP molecule and releases the enzyme to produce 1,3-bisphosphoglycerate and NADH and H^+ .

7. Phosphoglycerate kinase.

- 1,3-bisphosphoglycerate is converted by the enzyme to 3-phosphoglycerate molecule.



- The phosphate is transferred to a molecule of ATP.

NOTE: Since there are two molecules of 1,3-phosphoglycerate, two molecules of ATP are synthesized at this step.

- 2 molecules of ATP have already been utilized and therefore, at this point there is no ATP being produced.

8. Phosphoglycerate mutase

- The enzyme converts 3-phosphoglycerate to 2-phosphoglycerate.

- This enzyme relocates phosphate from the 3rd carbon to the 2nd carbon of the same molecule.

9. Enolase

- It converts 2-phosphoglycerate to Phosphoenolpyruvate (PEP) + water.

It also converts PEP into Pyruvate + ATP.

- PEP is converted to pyruvate with the help of pyruvate kinase.

→ Glycolysis produces 2 ATP molecules.

In this reaction, the phosphate group is transferred to 2 molecules of ADP to form ATP.

Since the two molecules of PEP, are involved two molecules of ATP are produced.

Gluconeogenesis

utilizes

Gluconeogenesis - process in which energy is produced during the absence of carbohydrates.

- It refers to the synthesis of glucose from non-carbohydrate sources/precursors.

- It takes place in the liver.

- It occurs when i) carbohydrate in the diet is insufficient.

ii) After taking a meal that is rich in protein.

iii) During starvation when the body breaks down proteins into amino acids.

2.1 - Gluconeogenesis and glycolysis are opposing metabolic pathways.

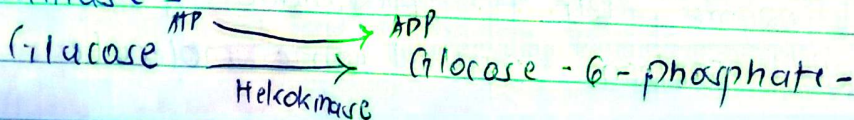
In glycolysis glucose is converted into pyruvate and in gluconeogenesis pyruvate is converted into glucose.

- Gluconeogenesis, is however, not the exact opposite of glycolysis.

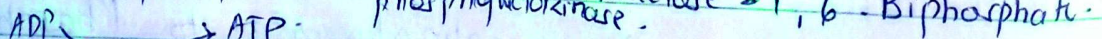
- There are 3 irreversible stages in gluconeogenesis passed from the glycolysis:

1. Hexokinase
2. Phosphofructokinase
3. Phosphoglycerate kinase.

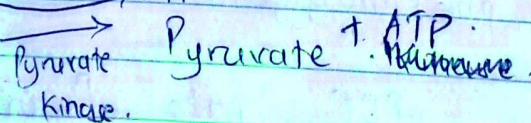
1. Hexokinase -



2. Fructose-6-phosphate



3. PEP



Step 1

Synthesized by gluco-6-phosphatase.

Step 2:

Catalysed by Fructose-1,6-Biphosphate.

Step 3

First pyruvate is converted to oxaloacetate AA by pyruvate carboxylase,
OAA is converted by PEP carboxylase to PEPi.

Importance of Gluconiogenesis:

- Helps in maintaining blood sugar levels e.g. fasting.
- Ensure constant supply of glucose to the brain, cells and other crucial body organs.

- The main substrates of Gluconiogenesis are:

Amino acids

Glycerol

Lactate.

- The substrates are converted to glucose by various pathways.

Enzymes involved in Gluconiogenesis.

1. Pyruvate Carboxylase.
2. Glucose-6-phosphatase.
3. Fructose-1,6-Biphosphate.
4. PEP.

→ Gluconiogenesis is highly regulated to prevent ^{water} high energy expenditure.

→ It only occurs when necessary.

The regulation of this pathway is regulated by glucagon, insulin.

→ It also takes place in the kidney but ^{mainly} the liver.

✓ Gluconiogenesis of amino acids:

Tri-Carboxylic Acid Cycle / Krebs's Cycle / C₃ Acid Cycle.

- It is a crucial metabolic pathway of aerobic respiration in eukaryotic cells.
- It is important in energy production, synthesis of biomolecules and metabolic integration.
- Site of reaction: mitochondrial matrix and all the enzymes of the TCA are located in the matrix except succinate dehydrogenase found within the inner membrane of the mitochondrion.

Substrates of TCA

1. Acetyl Co-enzyme A ^(1+carbon)

- It is obtained from pyruvate using the enzyme pyruvate dehydrogenase.
- It can also be obtained from β -oxidation of fatty acid.

2. Oxaloacetate ^(2-carbon)

Obtained from pyruvate, trans-amination from amino acids.

- The two substrate combine to form citrate (6-carbon substrate).

Step	Reaction	Enzyme	Explanation	Energy produced
1. Formation of citrate.	Acetyl Co-A + Oxaloacetate + H ₂ O → Citrate + CoASH	Citrate synthase	Combination of a 2 carbon oxaloacetate and 4 carbon Acetyl coenzyme.	No energy produced.
2. Isomerisation	Citrate → Isocitrate	Aconitase	Rearrangement of the OH ₂	No energy.
3. Oxidation to α -ketoglutarate	Isocitrate + NAD ⁺ → α -ketoglutarate + CO ₂ + NADH ² + H	Isocitrate dehydrogenase	Oxidative decarboxylation which releases CO ₂ and NADH is formed.	NADH
4. Oxidation to succinate	α -ketoglutarate + NAD ⁺ + CoASH → Succinate coenzyme A + CO ₂ + NADH ₂	α -ketoglutarate dehydrogenase.		NADH

Step	Reaction	Enzyme	Energy
5. Conversion to succinate	$\text{Succinate CoA} + \text{GDP} + \text{P}_i \rightarrow \text{Succinate} + \text{CoA} + \text{GTP}$	Succinyl Co-enzyme A synthetase.	GTP
6. Oxidation of succinate to fumarate	$\text{Succinate} + \text{FAD} \rightarrow \text{Fumarate} + \text{FADH}_2$	FADH₂ Succinate dehydrogenase (oxidises succinate)	FADH ₂
7. Hydration of fumarate to malate	$\text{Fumarate} + \text{H}_2\text{O} \rightarrow \text{malate}$	Fumarase	—
8. Oxidation of malate to oxaloacetate	$\text{Malate} + \text{NAD}^+ \rightarrow \text{Oxaloacetate} + \text{NADH} + \text{H}^+$	Malate dehydrogenase	NADH

Energy carrier	ATP
3 NADH	9 ATP molecules
FADH ₂	2
GTP	1

12 ATP molecule are produced in the TCA cycle.

Importance of TCA cycle

1. Production of energy in form of NADH, FADH and GTP.
2. It acts as a biosynthetic precursor. e.g. intermediates such as succinate CoA
3. It acts as a carbon skeleton, which offers a site for cell growth and repair.

Plays a critical role in metabolic integration. (regulation of biosynthetic pathways)