PLANT BIOCHEMISTRY AND PHILOSOPHY. SBB 9407

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 ie starch, sucrose and lactose produces monosaccharides which are; glucose, fructose and galactose; these together pass into the bloodstream.
- The study of synthesis (anabolism) and degradation (catabolism) of biomolecules is refered 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 result itself to the study of the metabolism of Glucose

Other monosaccharides: 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 biosynthesis reactions and for this reason carbohydrates are used in form of glucose.
- A major part of dietary glucose 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 cells cytosomes.

$$C_6H_{12}O_6 + NAD^+ + 2\ ADP + 2P$$
$$\downarrow$$
$$2\ Pyruvate + 2ATP + 2\ NADPH + 2H^+$$

NOTE:

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- Glucose + 2 NAD^+ + 2 Pi → 2 pyruvate + 2 ATP + 2 NADH + $2H^+$

→ 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 phosphorelation.

→ 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 + ATP ⟶ Glucose 6 Phosphate + ADP

- Glucose ring is phosphorelated.
- At this point in glycolysis, ATP is utilised 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

Glucose 6 Phosphate ⇌ (Phosphoglucose Isomerase) Fructo 6 Phosphate.

- The reaction involve rearrangement of Carbon oxygen bond to transform the 6 membered ring to 5 membered ring.

3. Phosphofructokinase.

- Kinases are enzymes that involve ATP and mg ions.

- 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 add
+ providing a phosphate group

4. Aldolase

- This enzyme splits 1, 6 Biphosphate into two sugars which are isomers of each other.
- The two sugars are; Dihydroxyacetone Phosphate. (DHAP. Glyceroldehyd 3 Phosphate (GAP)

1, 6 Biphosphate $\xrightarrow{\text{aldolase}}$ Dihydroxyacetone Phosphate + Glycerolhyd 3 Phosphate.

- This enzyme produces 2 - 3carbon molecule.

5. 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.

DHAP $\underset{\text{Triosephosphate isomerase}}{\rightleftarrows}$ GAP

- 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.

6. 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 phosphorelated by addition of a

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

7. Phosphoglyceratekinase.
- 1, 3 biphosphoglicerate is converted by the enzyme to 3 phosphoglicerate molecule.

1, 3 Phosphoglicerate + ADP → 3 phosphogleterate + ATP.

- The phosphate is transfered 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.
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8. Phosphoglliceratemutase
- The enzyme converts 3 phosphoglycerate to 2 phosphoglycerate.
- This enzyme relocate phosphate of phosphoglycerate from the 3rd carbon to the 2nd carbon of the same molecule.

9. Enolase
- It converts 2 phosphoglycerate to Phospho enol Pyruvate (PEP) + water.
It also converts PEP into Pyruvate + ATP.
- PEP is converted to pyruvate with the help of Pyruvatekinase.

⇒ 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.

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Gluconiogenesis

Gluconiogenesis - 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 reach in protein.
  iii) During starvation when the body breaks down proteins into amino acids.

1. Gluconiogenesis and glycolysis are opposing metabolic pathways
   b. In glycolysis glucose is converted into pyruvate and in gluconiogenesis pyruvate is converted into glucose.
- Gluconiogenesis, is however, not the exact opposite of glycolisis.
- There are 3 irreversable stages in gluconiogenesis passed from the glycolisis; 1. Hexokinase.
  2. Phosphofructokinase
  3. Phosphoglyserate kinase.

1. Hexokinase -

Glucose —(ATP → ADP, Hexokinase)→ Glucose - 6 - phosphate -

2. Fructose - 6 - phosphate —(phosphofructokinase)→ Fructose - 1, 6 - Biphosphate.

3. PEP —(ADP → ATP, Pyruvate Kinase)→ Pyruvate + ATP.

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 carboxydase,
OAA is converted by PEP carboxidase to PEP.

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

- Gluconiogenesis is highly regulated to prevent wasteful 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 majorly the liver.

- Gluconiogenesis of aminoacids,

Tri-Carboxylic Acid Cycle / Kreb's Cycle / CT 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 (4 carbon)
- It is obtained from pyruvate using the enzym pyruvate-dehydrogenase.
- It can also be obtained from bitter deoxidation 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.	Acetyle CO-A + Oxaloacetate + H_2O → Citrate + CoASH	Citrate synthase	Combination of a 2 carbon oxaloacetate and 4 carbon Acetyl coenzyme.	No energy produced.
2. Isomerization	Citrate → Isocitrate	Aconitase	Rearrangement of the OH O	No energy.
3. Oxidation to alphaketoglutarate	Isocitrate + NAD^+ → alphaketoglutarate + CO_2 + $NADH^2$ + H	Isocitrate dehydrogenase	Oxidative decarboxylation which releases CO_2 and NADH is formed	NADH
4. Oxidation to	Alphaketoglutarate + NAD^+ + CoASH → Succinate coenzyme A + CO_2 + $NADH_2$	Alphaketoglutarate dehydrogenase.		NADH

Step	Reaction	Enzyme	Energy
5. Conversion to succinate	Succinate CoA + GDP + (Pi) → Succinate + Co A SH + GTP	Succinyl Co-enzyme A synthatase.	GTP
6. Oxidation Fumerate	Succinate + FAD → Fumarate + $FADH_2$	Succinate dehydroginase (oxidises succinate)	$FADH_2$.
7. Hydration to malate	Fumarate + H_2O → malate	Fumarase	—
8. Oxidation to oxaloacetate	Malate + NAD^+ → Oxaloacetate $NADH_2$ + 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. eg intermediates such as succinate Co A
3. It acts as a carbon skeleton, which offers a site for cell growth and repair

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