Introduction to Carbohydrate metabolism
Some metabolic pathways of carbohydrates

- 1- Glycolysis
- 2- Krebs cycle
- 3- Glycogenesis
- 4- Glycogenolysis
- 5- Glyconeogenesis

- Pentose Phosphate Pathway (PPP)
- Curi cycle
- Biological oxidation
Metabolism

Metabolism involves:
- *Catabolic reactions* that break down large, complex molecules to provide energy and smaller molecules.
- *Anabolic reactions* that use ATP energy to build larger molecules.

**Stages of Carbohydrate Metabolism**

Stage 1: Digestion and hydrolysis - break down large molecules to smaller ones that enter the bloodstream.

Stage 2: Degradation - breaks down molecules to two- and three-carbon compounds.

Stage 3: Oxidation of small molecules in the citric acid cycle and electron transport provide ATP energy.
Stage 1: Digestion of Carbohydrates

The digestion of carbohydrates:

- Begins in the mouth where salivary amylase breaks down polysaccharides to smaller polysaccharides (dextrins), disaccharide (maltose), and some glucose.
- Continues in the small intestine where pancreatic amylase hydrolyzes dextrins to maltose and glucose.
- Hydrolyzes of disaccharides; maltose, lactose, and sucrose to monosaccharides, mostly glucose, which enter the bloodstream for transport to the cells.
Stage 2: Glycolysis

- Glycolysis is a metabolic pathway that degrades glucose (a six-carbon) to pyruvate (a three-carbon molecules).
- It is an anaerobic process (no oxygen) and occur in the cytoplasm.
- It is divided into two stages:
  - A- five reactions and consume energy
  - B- five reactions that produce energy
In reactions 1-5 of glycolysis,

- Energy is required to add phosphate groups to glucose.
- Glucose is converted through five enzymatically catalyzed reactions to two three-carbon molecules.
In reactions 6-10 of glycolysis, energy is generated as:

- Sugar phosphates are cleaved to triose phosphates.
- Four ATP molecules are produced.
Glycolysis: Overall Reaction

In glycolysis,
- Two ATP add phosphate to glucose and fructose-6-phosphate.
- Four ATP are formed in energy-generation by direct transfers of phosphate groups to four ADP.
- There is a net gain of 2 ATP and 2 NADH.

In other pathway
- In mitochondria, each of the 2NADH is converted to NAD$^+$ and 3ATP are produced (2x 3 = 6ATP)

\[
\begin{align*}
\text{C}_6\text{H}_{12}\text{O}_6 + 2\text{ADP} + 2\text{Pi} + 2\text{NAD}^+ & \quad \rightarrow \\
\text{Glucose} & \\
2\text{C}_3\text{H}_3\text{O}_3^- + 2\text{ATP} + 2\text{NADH} + 4\text{H}^+ & \quad \rightarrow \\
\text{Pyruvate}
\end{align*}
\]
The Fate of pyruvate produced from glycolysis
Krebs cycle

- It needs oxygen, so it occurs in all aerobic organisms.
- It is called **citric acid cycle**, **tricarboxylic acid (TCA) cycle** or the Krebs cycle.
- It generates energy through the oxidation of acetyl-CoA derived from **carbohydrates, fats and proteins** into CO₂ and chemical energy in the form of adenosine triphosphate (ATP).
- It occurs only in mitochondria which is called the “Power House”
Glycogenesis

- It is the storing of glucose (monosaccharide) by converting to glycogen (polysaccharide) in liver and muscles.
- It operates when high levels of glucose-6-phosphate are formed in the first reaction of glycolysis.
- It does not operate when energy stores (glycogen) are full, which means that additional glucose is converted to body fat.
Glycogenolysis

In glycogenolysis

- Glycogen stores in liver and muscles is broken down to glucose.
- Glucose molecules are removed one by one from the end of the glycogen chain to yield glucose-1-phosphate.
- It occurs when the blood glucose level is decreasing to less than the lower limit (70 mg%) to compensate this decrease.
Gluconeogenesis

- It is the generation of glucose from certain non-carbohydrate carbon substrates like the **metabolic products of carbohydrates, amino acids and lipid**.
- It occurs when glycogen stores are depleted as a result of starvation or if the body cannot utilize glucose as in the case of diabetes.
Pentose Phosphate Pathway (PPP)

- The pentose phosphate pathway is a metabolic pathway parallel to glycolysis.
- It generates NADPH and pentoses as well as Ribose 5-phosphate, the last one a precursor for the synthesis of nucleotides.

\[
6 \text{ Glucose 6-phosphate} + 12 \text{ NADP}^+ \\
6 \text{ Ribulose 5-phosphate} + 6 \text{ CO}_2 + 12 \text{ NADPH} + 12 \text{ H}^+ + \text{pi}
\]

\[\downarrow \text{5 glucose 6-phosphate}\]
Cori Cycle

The Cori cycle

- It is the flow of lactate and glucose between the muscles and the liver.
- It occurs when anaerobic conditions occur in active muscle and glycolysis produces lactate.
- It operates when lactate moves through the blood stream to the liver, where it is oxidized back to pyruvate.
- It converts pyruvate to glucose, which is carried back to the muscles.

Notice: the formation of glucose from lactate consumes 6 ATP molecules.
Pathways for Glucose are derived from