# **Carbohydrates Metabolism**

Course Code: ZOOL 4008 (Biochemistry and Metabolism) M.Sc. (Zoology), Semester –II





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# Carbohydrates

•Most abundant organic molecule on earth.

•Carbohydrates are defined as aldehyde or keto derivatives of polyhydric alcohols.

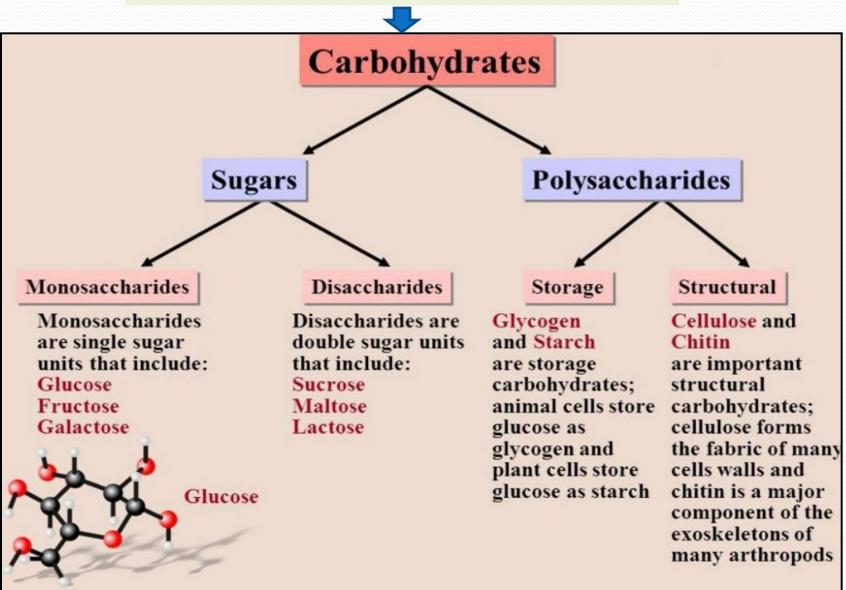
•All carbohydrates have the general formula CnH2nOn [or it can be re-written as [Cn(H2O)n ]

•Main source of energy in the body. Energy production from carbohydrates will be 4 kcalories/g (16 k Joules/g).

•Storage form of energy (starch and glycogen).

• Excess carbohydrate is converted to fat.

#### Classification of Carbohydrates



#### **Metabolism**

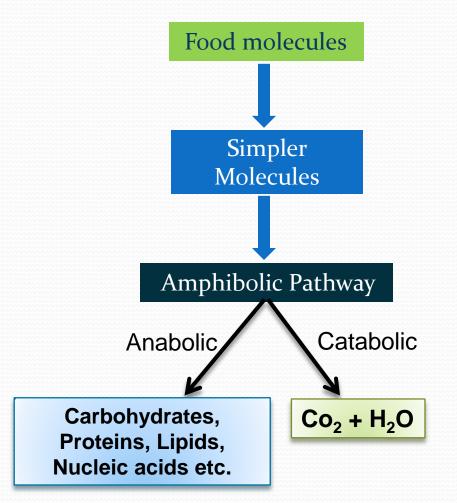
•Carbohydrate metabolism is a fundamental biochemical process that ensures a constant supply of energy to the living cells.

•It is the central metabolic pathway associated with the formation and breakdown of carbohydrates with energy generation.

•The most important **carbohydrate** is **glucose**, which is broken down via glycolysis, enter into the Kreb's cycle and oxidative phosphorylation to generate ATP.



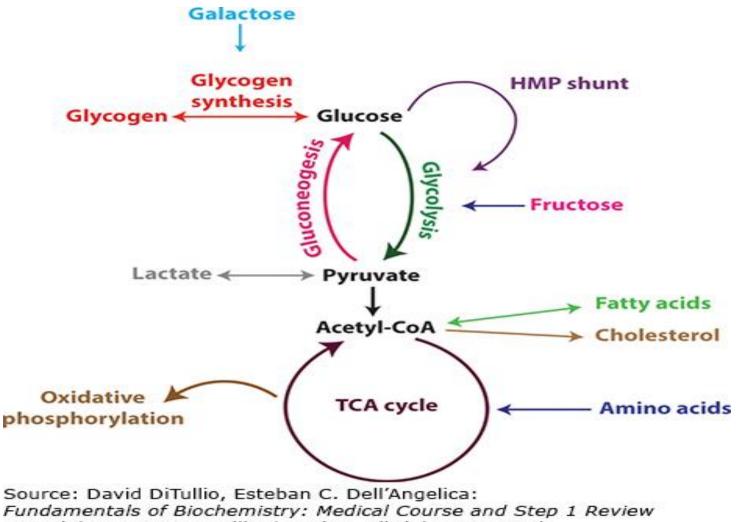
#### **The Common Metabolic steps**



#### **Major pathway of Carbohydrates Metabolism**

- 1. Glycolysis
- 2. Citric Acid Cycle
- 3. Gluconeogenesis
- 4. Glycogenesis
- 5. Glycogenolysis
- 6. Hexose monophosphate shunt
- 7. Galactose Metabolism

#### **Overview of metabolic pathways**



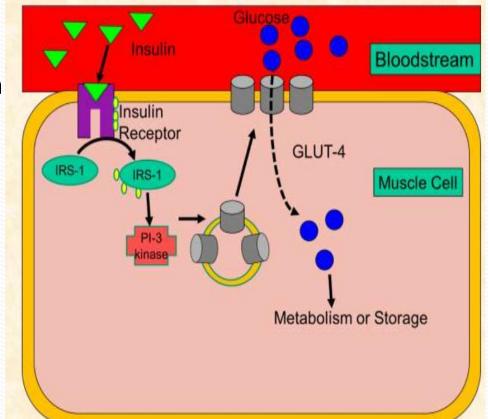
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#### How does Glucose entered in to the cells?

**1.Insulin-independent transport system of glucose:** Not depends on insulin via GLUT1 receptors presents in hepatocytes, erythrocytes and brain.

#### 2. Insulin dependent Pathway:

Through GLUT-4 receptors in adipose and muscles tissue.



Note# In Type 2 diabetes mellitus: Glucose transporter-4 (GLUT4), one of the most important glucose transporters, plays a key role in the development of type 2 diabetes and insulin resistance observed.

-Due to reduction in of GLUT-4 receptors in insulin deficient patients.

## 1. Glycolysis

Glycolysis is central metabolic reactions converting glucose (or glycogen) to pyruvate or lactate, with the production of energy in form of ATP.
Enzyme for glycolysis is present in Cytosol.

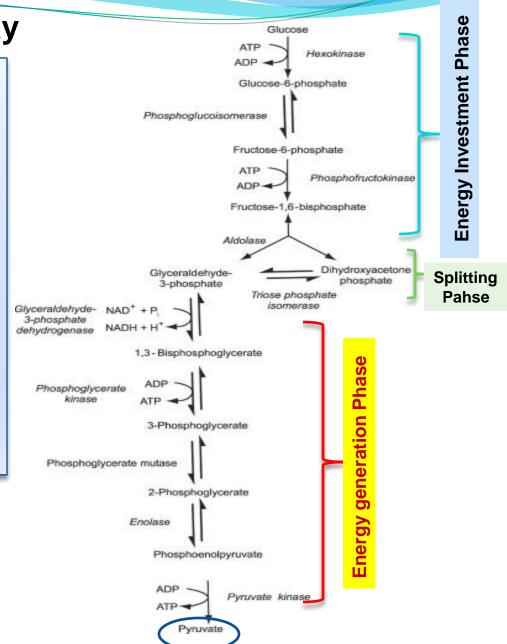
• Lactate is end product in anaerobic condition, where as **Pyruvate** is end product in aerobic condition, which is finally oxidize to form Co2 and H2O and releases ATP.

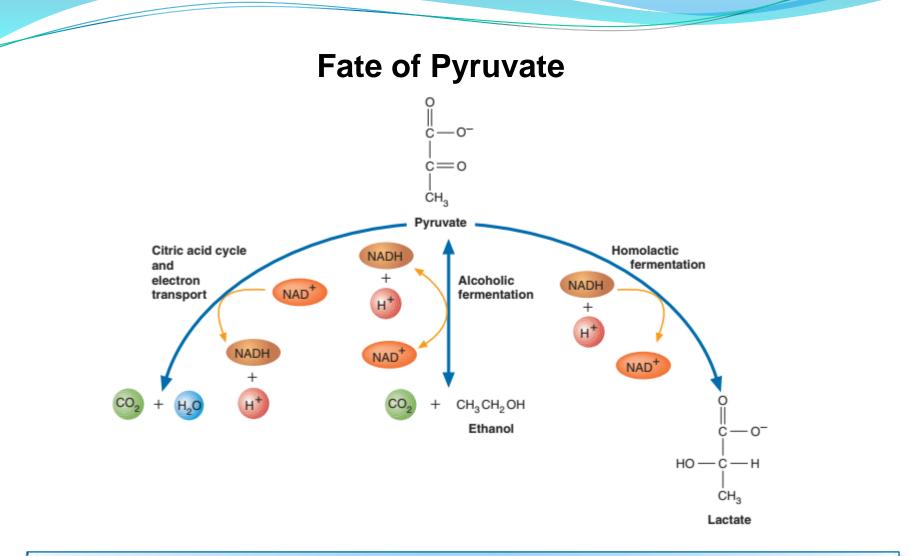
•Reversal of glycolysis – results in gluconeogenesis.

• Glycolysis is Major pathway of energy generation in tissue lacking Mitochondria.

#### **Glycolysis** Pathway

- •During glycolysis, glucose is converted to
- two molecules of pyruvate. The result of glycolysis is the production of **two ATPs and two NADHs** per molecule of glucose.
- In anaerobic organisms, pyruvate is converted to waste products in a process called fermentation.
- In the presence of oxygen the cells of aerobic organisms convert pyruvate into CO<sub>2</sub> and H<sub>2</sub>O.





•Under aerobic conditions, convert pyruvate into acetyl-CoA, the entry-level substrate for the **citric acid cycle**, an amphibolic pathway that completely oxidizes the two acetyl carbons to form CO<sub>2</sub> and and the reduced molecules NADH and FADH<sub>2</sub>.

• Under Anaerobic condition Pyruvtae converted in to Lactate, and Ethanol+Co2.

## 2. Citric Acid Cycle

•The end product of glycolysis, pyruvate is transported into the mitochondria and loses carbon dioxide to form acetyl-CoA.

•The Krebs cycle occurs inside the mitochondria and generates a pool of chemical energy.

•When acetyl-CoA is oxidized to carbon dioxide in the Krebs cycle, chemical energy is released in the form of **3 NADH**, **1FADH2**, and **1 ATP**.

•The cycle starts and ends with oxaloacetate.

• This cycle is also called the Krebs cycle and the citric acid cycle (TCA).

•This Cycle utilizes about two-third of total oxygen consumed by the body.

- •TCA cycle is strictly **aerobic** in contrast to glycolysis.
- Oxidation of 3 NADH by electron transport chain coupled with oxidative phosphorylation results in 9ATP, FADH2 provides 2 ATP.

•Total of **12 ATP** are produced from one acetyl CoA .

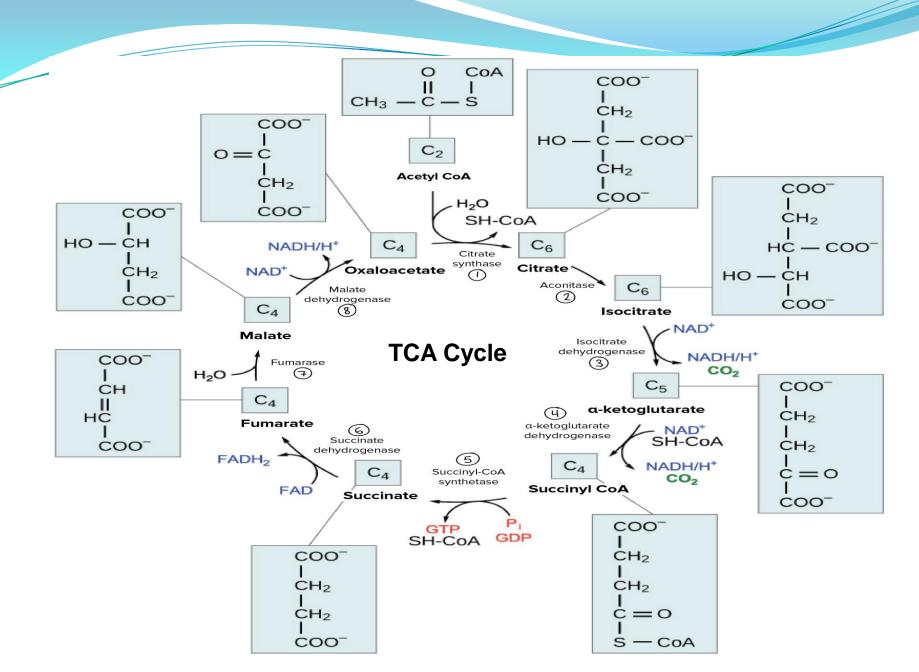
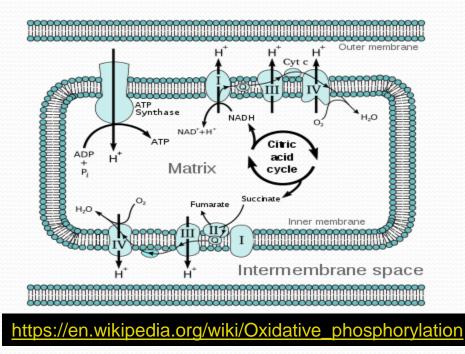


Image credit: modified from "Oxidation of pyruvate and citric acid cycle:" by OpenStax College, Biology, CC BY 3.0

# Oxidative phosphorylation is Coupled with Citric acid Cycle:

•It is the process in which ATP is formed as a result of the transfer of electrons from NADH or FADH <sub>2</sub> to O <sub>2</sub> by a series of electron carriersCalled electron transport chain.

• It is takes place in mitochondria, which is major source of ATP production in aerobic organisms.



**TOTAL ATP** Production from one Glucose molecule

Glycolysis: (Net yields)

Stage I.	ATP	<b>2 ATP</b>
	2 NADH+H <sup>+</sup> $\rightarrow$ 2 FADH <sub>2</sub> (to ETC)	3 ATP
Stage II.	<b>Conversion of pyruvate to ACoA</b>	
	2 NADH + H <sup>+</sup> (to ETC)	5 ATP
Stage III.	TCA cycle	
	ATP (at one site)	2 ATP
	NADH+H <sup>+</sup> at three steps (to ETC)	<b>15 ATP</b>
	FADH <sub>2</sub> at one step (to ETC)	3 ATP

Total ATP from one molecule of glucose = 30 ATP

#### 3. Gluconeogenesis

•Gluconeogenesis is the generation of glucose from non-sugar carbon substrates like glycerol, lactate, pyruvate, and glucogenic amino acids.

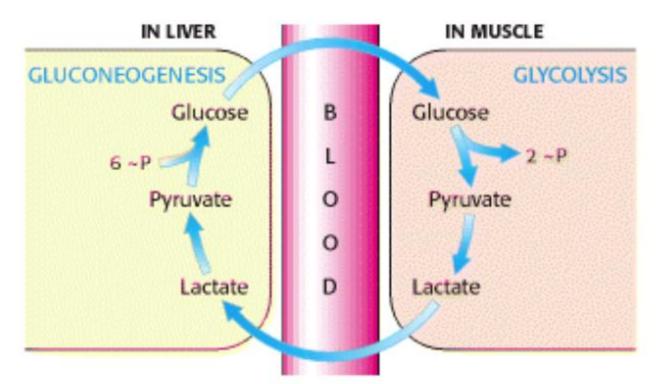
•The vast majority of gluconeogenesis takes place in the liver (90%) and in smaller extent, in the kidney (10%) cortex.

•Gluconeogenesis occurs during periods of fasting, starvation, or intense exercise and it is highly endergonic process(energy intensive).

•Gluconeogenesis is often associated with ketosis

Gluconeogenesis is not simply the reverse of glycolysis.

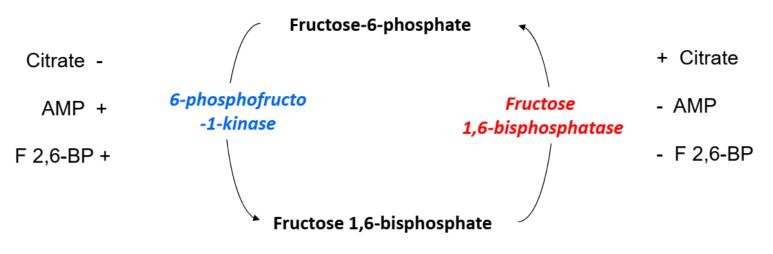
•It utilizes unique enzymes (pyruvate carboxylase, PEPCK, fructose-1,6-bisphosphatase, and glucose-6-phosphatase) for irreversible reactions.



6 ATP equivalents are consumed in synthesizing 1 glucose from pyruvate in this pathway.

**Gluconeogenesis and Glycolysis are reciprocally regulated** 

- Fructose 1,6-bisphosphatase is main regulatory step in gluconeogenesis.
- Corresponding step in glycolysis is 6-phosphofructo-1-kinase (PFK-1).
- These two enzymes are regulated in a reciprocal manner by several metabolites.



**Reciprocal control—prevents simultaneous reactions in same cell.** 

References:

•Stryer, Lubert. *Biochemistry (Third Edition)*.New York, NY: W.H. Freeman and Company, 1988. Page 187-191 .

• Lehninger principles of biochemistry (4th ed.): Nelson, D., and Cox, M, W.H. Freeman and Company, New York, 2005. Thank You