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 $C_nH_{2n}O_n$ [or it can be re-written as $[C_n(H_2O)_n]$]
- 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.

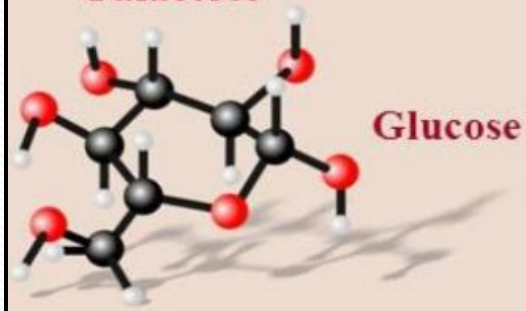
Classification of Carbohydrates

Carbohydrates

Sugars

Monosaccharides

Monosaccharides are single sugar units that include:
Glucose
Fructose
Galactose



Glucose

Disaccharides

Disaccharides are double sugar units that include:
Sucrose
Maltose
Lactose

Polysaccharides

Storage

Glycogen and Starch are storage carbohydrates; animal cells store glucose as glycogen and plant cells store glucose as starch

Structural

Cellulose and Chitin are important structural carbohydrates; cellulose forms the fabric of many cells walls and chitin is a major component of the exoskeletons of many arthropods

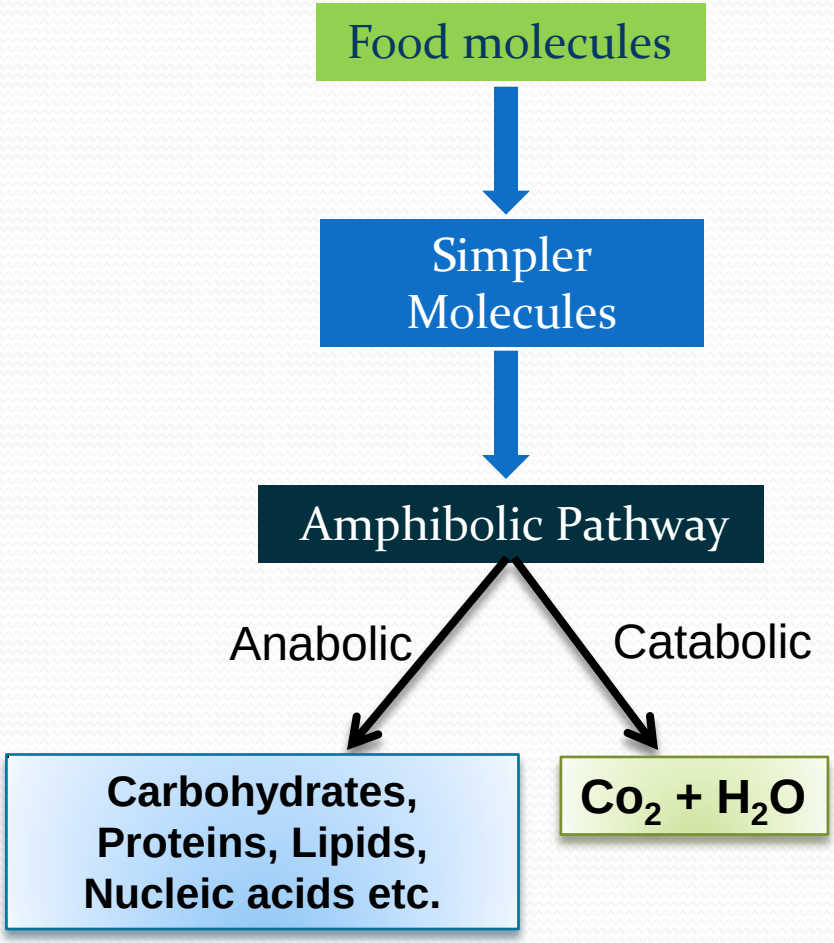
Metabolism

•**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.

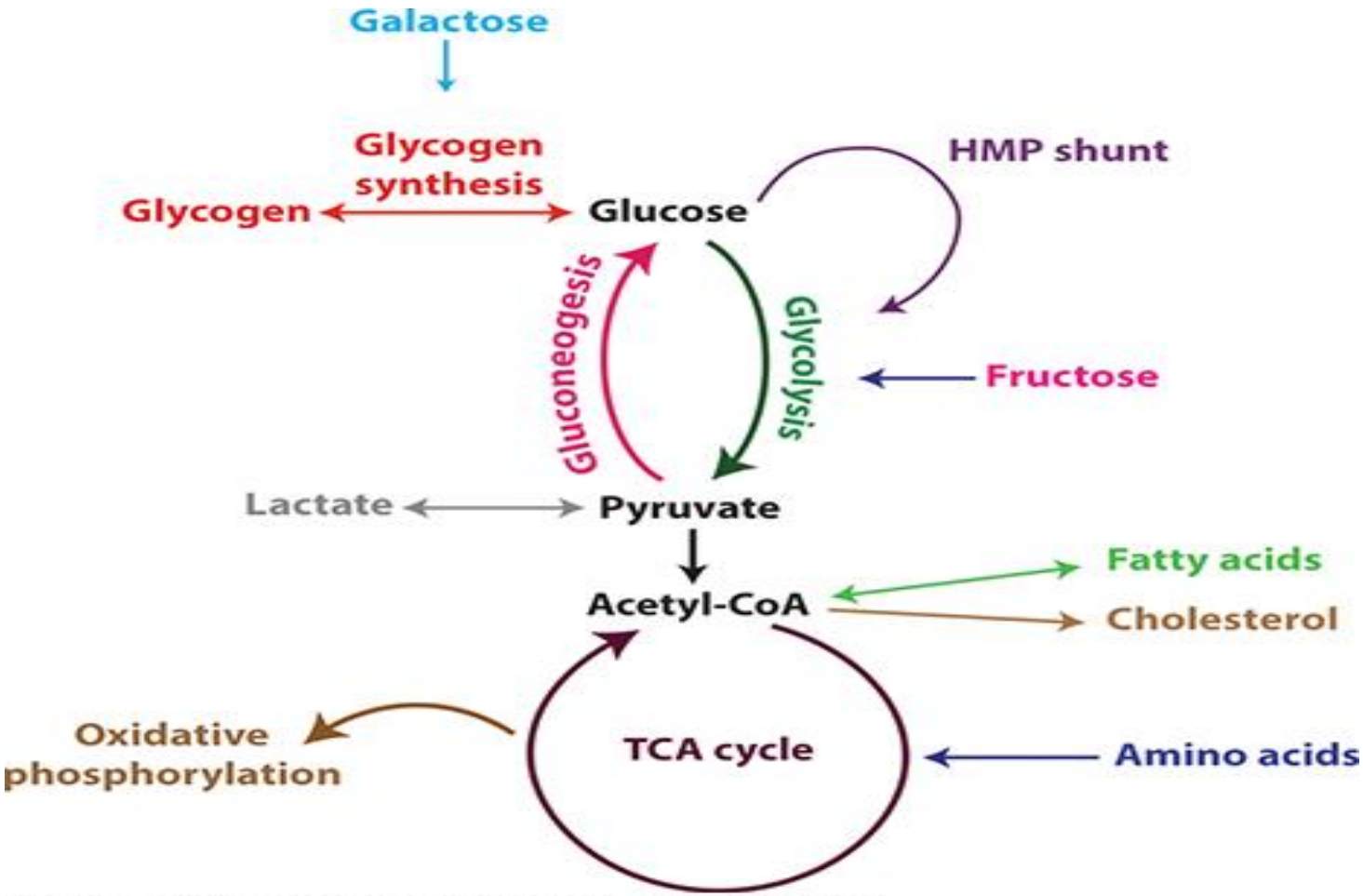
The Common Metabolic steps



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

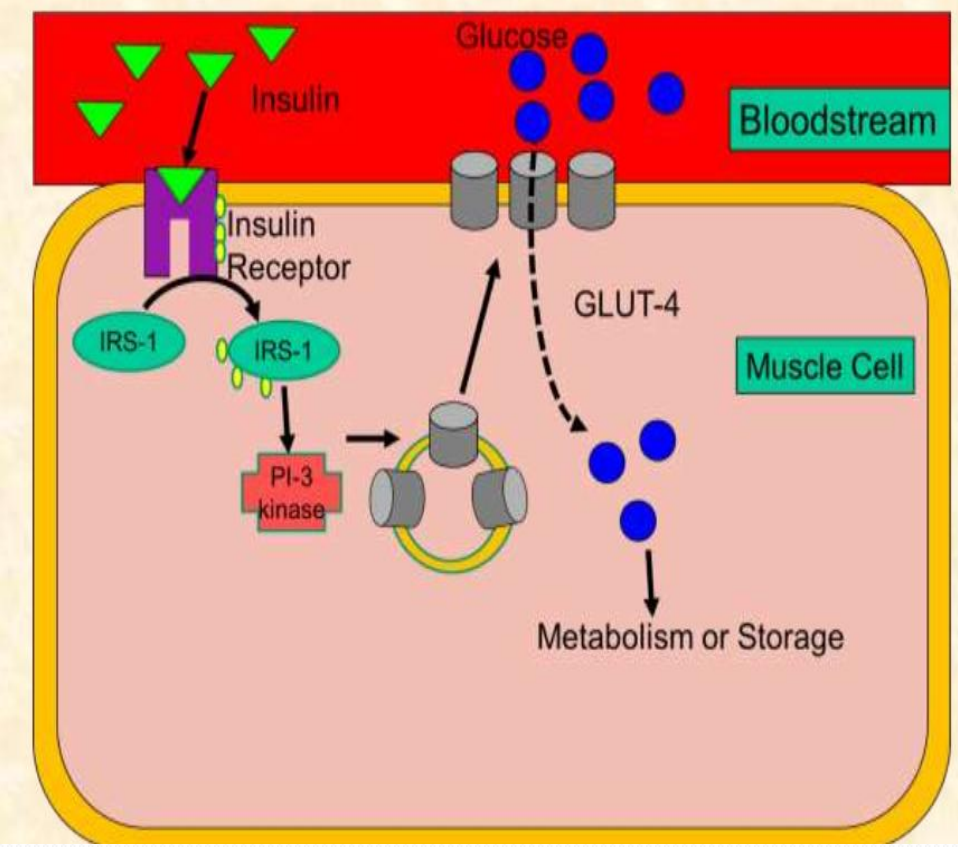


Source: David DiTullio, Esteban C. Dell'Angelica:
Fundamentals of Biochemistry: Medical Course and Step 1 Review

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.

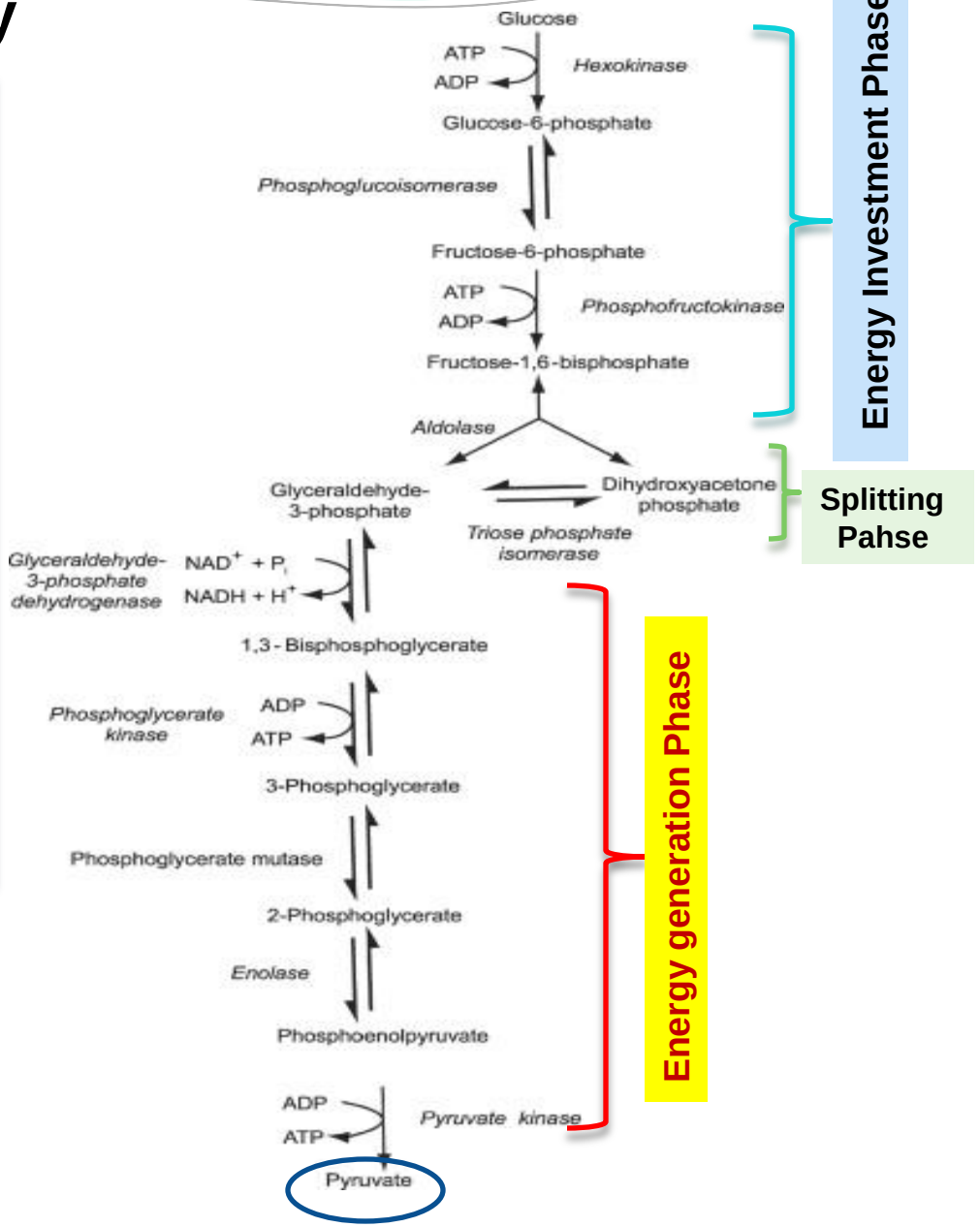
• **Lactate** is end product in anaerobic condition, where as **Pyruvate** is end product in aerobic condition, which is finally oxidize to form Co2 and H2O and releases ATP.

•Reversal of glycolysis – results in gluconeogenesis.

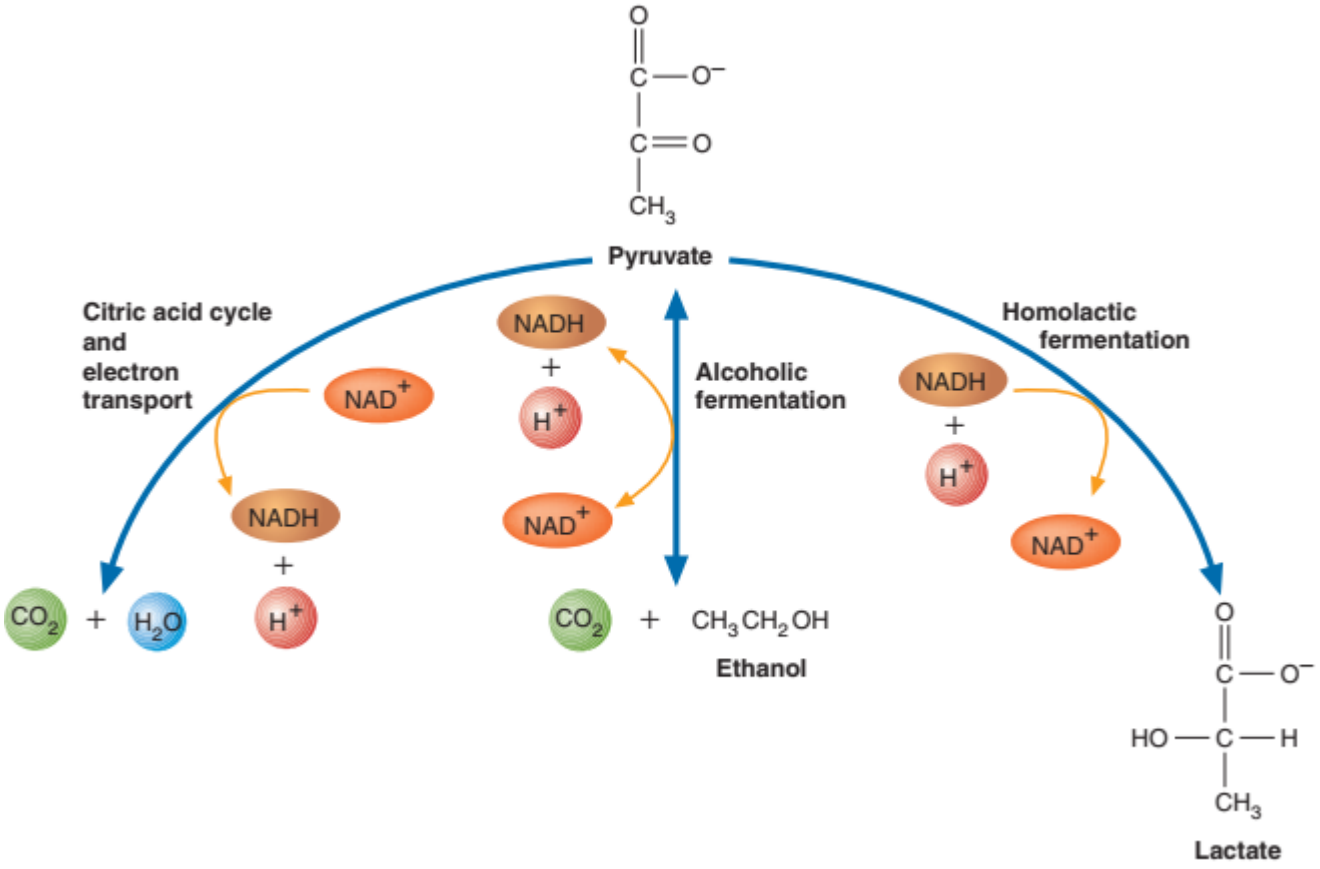
• Glycolysis is Major pathway of energy generation in tissue lacking Mitochondria.

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_2 and H_2O.



Fate of Pyruvate



•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 CO2 and and the reduced molecules NADH and FADH2.

- 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 .

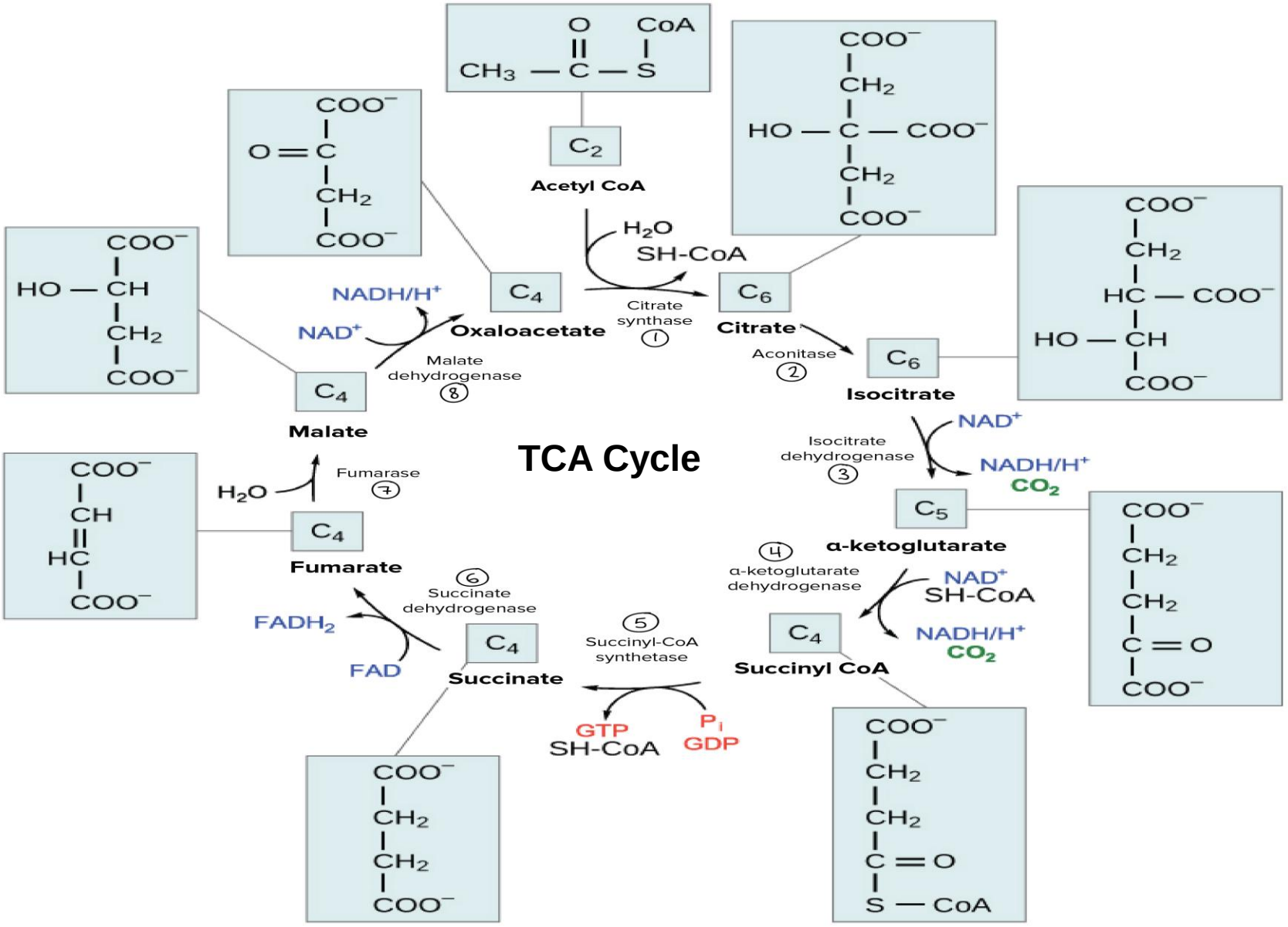
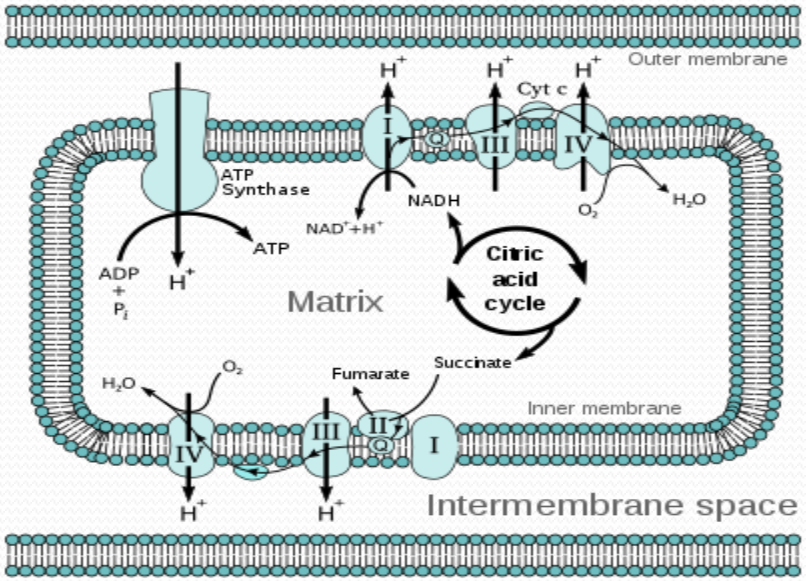


Image credit: modified from "Oxidation of pyruvate and citric acid cycle:" by OpenStax College, Biology, CC BY 3.0

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 $FADH_2$ to O_2 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.



https://en.wikipedia.org/wiki/Oxidative_phosphorylation

TOTAL ATP Production from one Glucose molecule

Glycolysis: (Net yields)

Stage I.

ATP	**2 ATP**
2 NADH+H$^+$ → 2 FADH$_2$ (to ETC)	**3 ATP**

Stage II. **Conversion of pyruvate to ACoA**

2 NADH + H$^+$ (to ETC)	**5 ATP**

Stage III. **TCA cycle**

ATP (at one site)	**2 ATP**
NADH+H$^+$ at three steps (to ETC)	**15 ATP**
FADH$_2$ 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.**

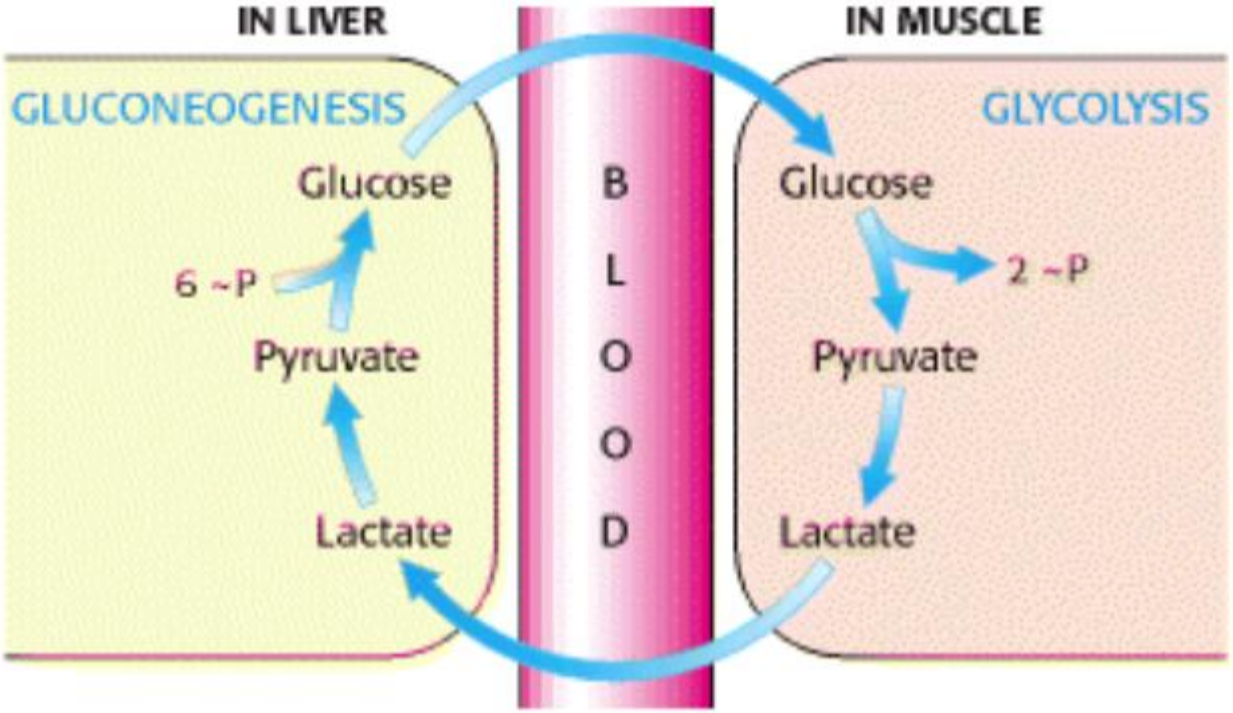
•The vast majority of gluconeogenesis takes place in the liver (90%) and in smaller extent, in the kidney (10%) cortex.

•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.

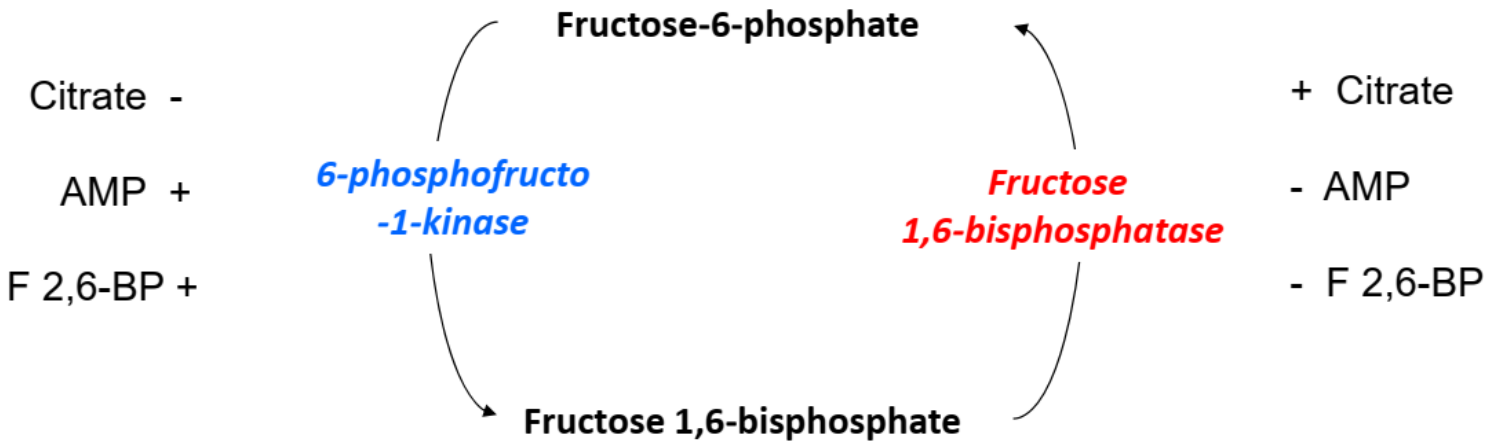
•It utilizes unique enzymes (pyruvate carboxylase, PEPCK, fructose-1,6-bisphosphatase, and glucose-6-phosphatase) for irreversible reactions.



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.

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•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