



University of Al-Ameed  
Faculty of Nursing



## **Biochemistry**

Lec.1

**Chemistry of Carbohydrate**

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# Objectives

- ▶ Define carbohydrates and describe their biological importance
- ▶ Classify carbohydrates based on structure
- ▶ Explain digestion and absorption of dietary carbohydrates
- ▶ Explain the major pathways of carbohydrate metabolism, with emphasis on glycolysis and the Krebs cycle

# Content

- ▶ Functions of Carbohydrates
- ▶ Classification And Structure of Carbohydrates
- ▶ Dietary Carbohydrate Digestion
- ▶ Metabolism of Carbohydrate.
  - ❖ Glycogenesis
  - ❖ Krebs Cycle

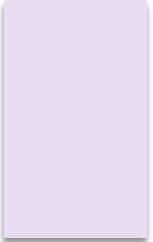
# Carbohydrates

- **Carbohydrates are the most abundant organic molecules in nature.**
- **They have a wide range of functions, including:**
  1. providing a significant fraction of the dietary calories for most organisms.
  2. acting as a storage form of energy in the body
  3. It served as a cell membrane component mediating some forms of intercellular communication.

# Carbohydrates

4. serves as a structural component of many organisms, including the cell walls of bacteria, the exoskeleton of many insects, and the fibrous cellulose of plants.

**The formula for many of the simpler carbohydrates is  $(\text{CH}_2\text{O})_n$ , hence the name “hydrate of carbon.**



# **Classification And Structure of Carbohydrates**

# Classification Of Carbohydrates

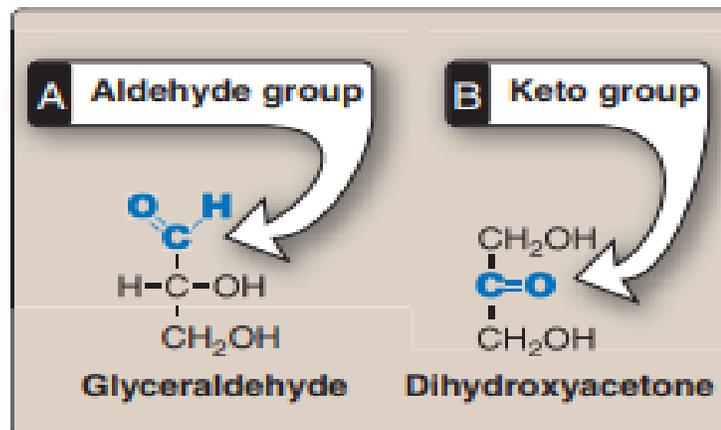
**Monosaccharides** or simple sugars can be classified according to the number of carbon atoms they contain.

Examples of some monosaccharides commonly found in humans are listed.

<u>Generic names</u>	<u>Examples</u>
3 Carbons: trioses	Glyceraldehyde
4 Carbons: tetroses	Erythrose
5 Carbons: pentoses	Ribose
6 Carbons: hexoses	Glucose
7 Carbons: heptoses	Sedoheptulose
9 Carbons: nonoses	Neuraminic acid

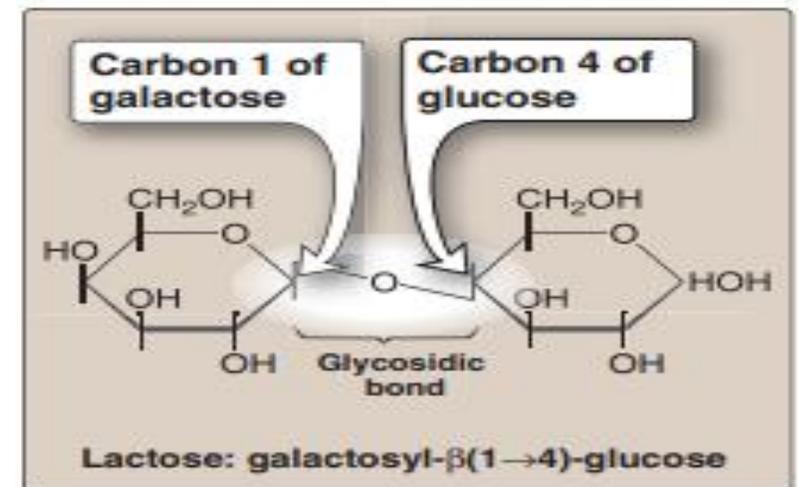
# Monosaccharides

They can also be classified by the type of **carbonyl group** they contain. Carbohydrates with an **aldehyde** as their carbonyl group are called **aldoses**, whereas those with a **keto** as their carbonyl group are called **ketoses**. For example, **glyceraldehyde is an aldoses, whereas dihydroxyacetone is a ketoses.**



# Disaccharides

- Monosaccharides can be linked by **glycosidic bonds** to create larger structures .
- Disaccharides contain **two monosaccharide units**, oligosaccharides **contain 3 to 10 monosaccharide units**, and polysaccharides **contain more than 10 monosaccharide units** and can be hundreds of sugar units in length.



# Joining of monosaccharides

Monosaccharides can be joined to form disaccharides, oligosaccharides, and polysaccharides.

- Important disaccharides include

lactose: (galactose + glucose)

sucrose: (glucose + fructose)

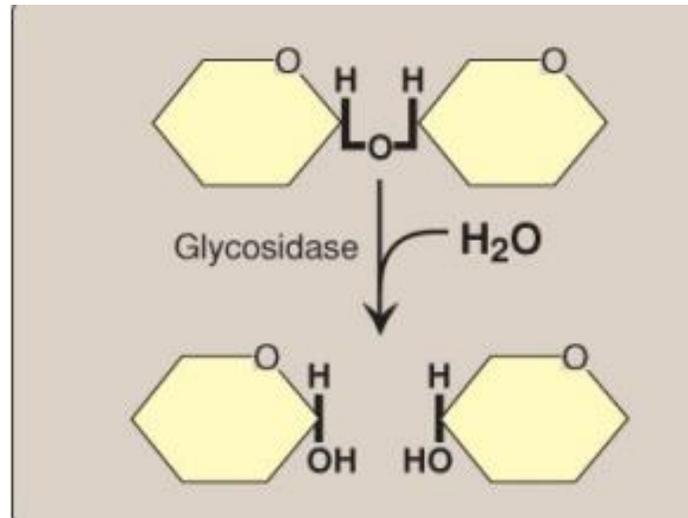
maltose: (glucose + glucose)

- Important polysaccharides include branched **glycogen** (from animal sources) **starch** (plant sources) and unbranched **cellulose** (plant sources); each is a polymer of glucose.

**The bonds that link sugars are called glycosidic bonds**

# Dietary Carbohydrate Digestion

The principal sites of dietary carbohydrate digestion are the **mouth and intestinal lumen**. This digestion is **rapid** and is catalyzed by enzymes known as **glycoside hydrolases (glycosidases)** that hydrolyze **glycosidic bonds**



# Dietary Carbohydrate Digestion

- Digestion of carbohydrates begins in the mouth

The major dietary polysaccharides are of plant (starch, composed of amylose and amylopectin) and animal (glycogen) origin. During mastication, salivary  **$\alpha$ -amylase** acts briefly on dietary starch and glycogen, hydrolyzing random  **$\alpha(1\rightarrow4)$  bonds**.

**Carbohydrate digestion stops temporarily in the stomach, because the high acidity inactivates salivary  $\alpha$ -amylase.**

# Dietary Carbohydrate Digestion

- Digestion of carbohydrates by pancreatic enzymes:

**Further occurs in the small intestine .**

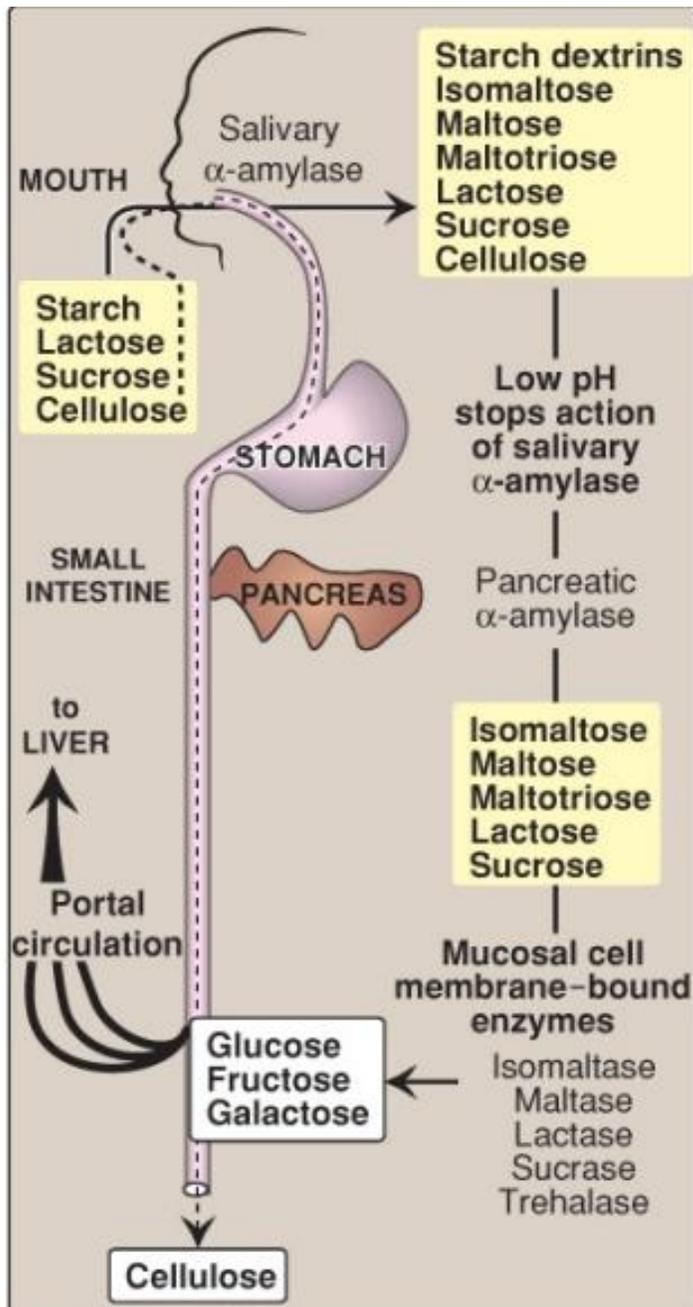
When the acidic stomach contents reach the small intestine, they are neutralized by **bicarbonate** secreted by the pancreas, and **pancreatic  $\alpha$ -amylase** continues the process of starch digestion.

# Dietary Carbohydrate Digestion

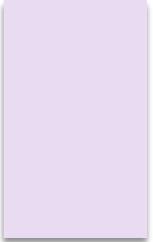
- Digestion by enzymes synthesized by the intestinal mucosal cells:  
The final digestive processes occur primarily at the mucosal lining of the upper jejunum and include the action of several disaccharidases

## For example,

- isomaltase cleaves the  $\alpha(1\rightarrow6)$  bond in isomaltose, and maltase cleaves maltose, and maltotriose, each producing glucose,
- Sucrase cleaves sucrose producing glucose and fructose,
- Lactase cleaves lactose producing galactose and glucose.



Digestion of carbohydrates



# **Metabolism of Carbohydrate**

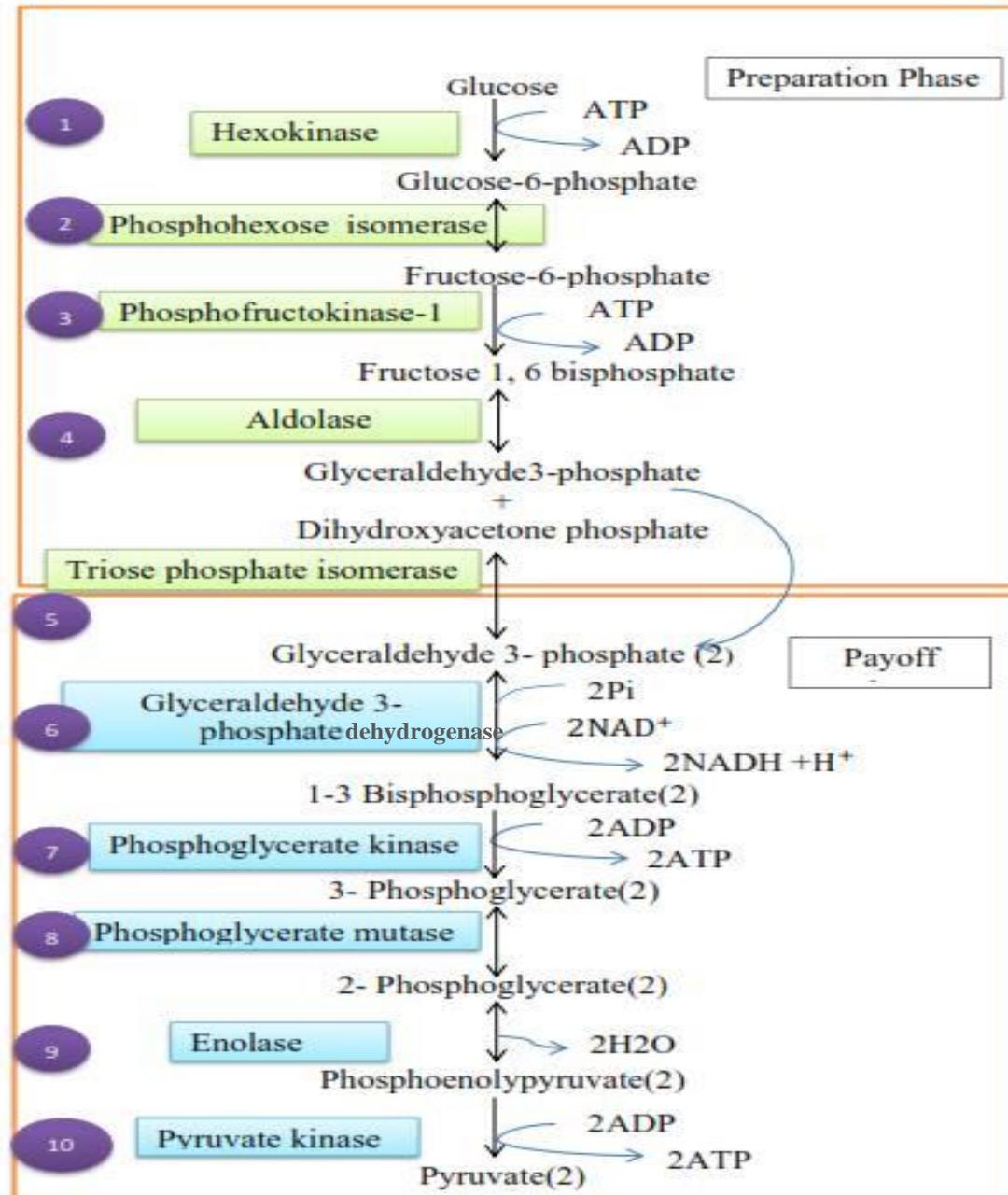
# Metabolism of Carbohydrate

in order to extract energy from sugar and transfer this energy to a molecule called adenosine triphosphate (ATP). There are four stages in cellular respiration. These stages are

1. glycolysis
2. Pyruvate oxidation (The link reaction )
3. Krebs cycle
4. oxidative phosphorylation

# Glycolysis

- Glycolysis, the major pathway for **glucose oxidation**, occurs in the **cytosol** of all cells.
- It is unique, in that it can function either aerobically or anaerobically, depending on the availability of oxygen.
- In the glycolytic pathway, glucose is always converted to **pyruvate**. But **under anaerobic conditions**, pyruvate is then reduced to **lactate**



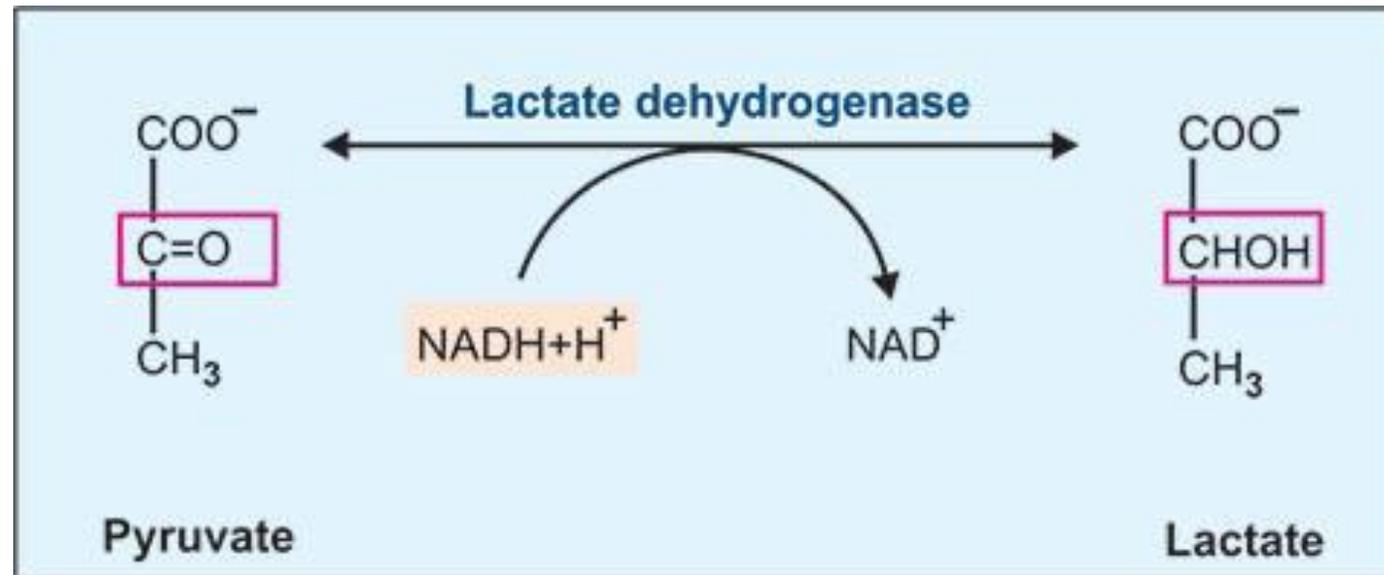
The glycolytic pathway steps

# Glycolysis

There are two phases of glycolysis

- For each molecule of glucose that passes through the **preparatory phase**, two molecules of glyceraldehyde-3-phosphate are formed; both pass through the **payoff phase**. Pyruvate is the end product of the second phase of glycolysis.
- For each glucose molecule, **two ATP are consumed in the preparatory phase** and **four ATP are produced in the payoff phase**, giving a **net yield of two ATP** per molecule of glucose converted to pyruvate

# Anaerobic glycolysis

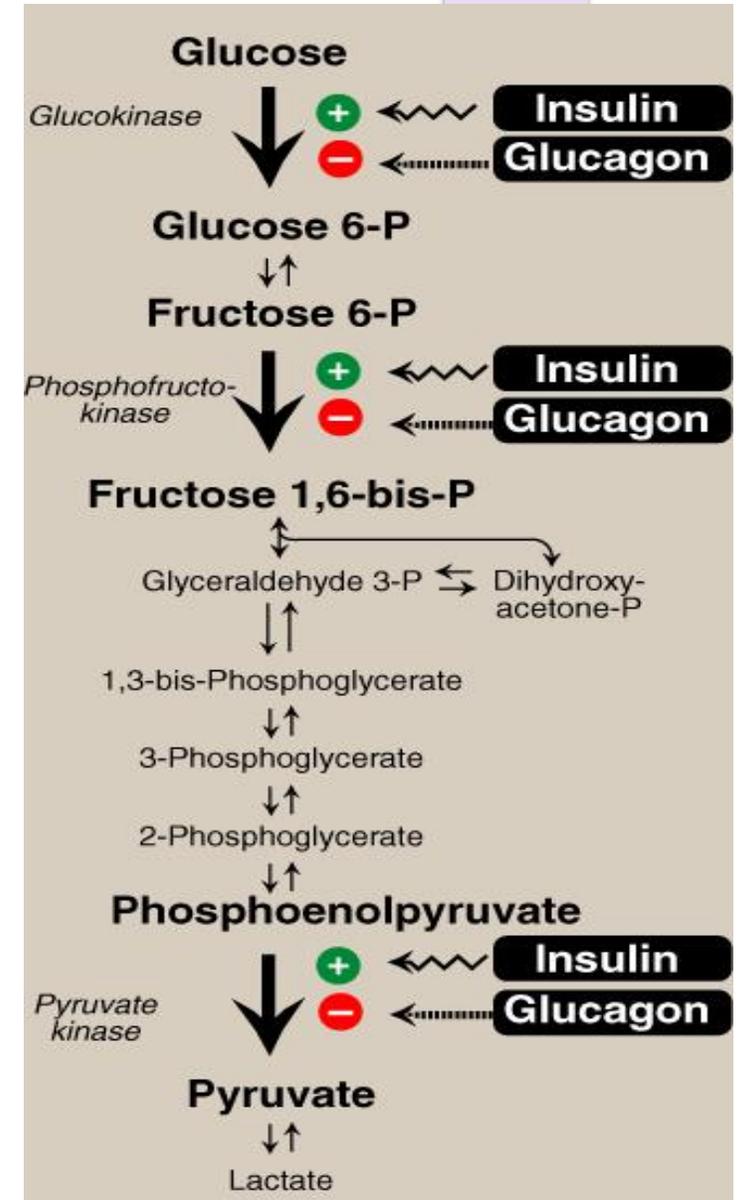


Interconversion of pyruvate and lactate by lactate dehydrogenase (LDH) in anaerobic glycolysis.

# Regulation of Glycolysis

The regulatory enzymes or key enzymes of glycolysis are:

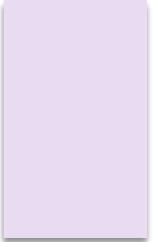
1. Hexokinase, step 1  
( glucokinase, in liver)
1. Phosphofructokinase, step 3
2. Pyruvate kinase, step 10.



# Energetics of glycolysis

Number of ATP generated per molecule of glucose in <b>aerobic condition</b>			
Step	Enzyme	Source	No of ATP gained per glucose mol
1	Hexokinase	-	Minus 1
3	Phosphofructokinase	-	Minus 1
5	Glyceraldehyde-3-phosphate dehydrogenase	NADH	$2.5 \times 2 = 5$
6	1,3-bisphosphoglycerate kinase	ATP	$1 \times 2 = 2$
9	Pyruvate kinase	ATP	$1 \times 2 = 2$
Total = 9 minus 2 = 7			

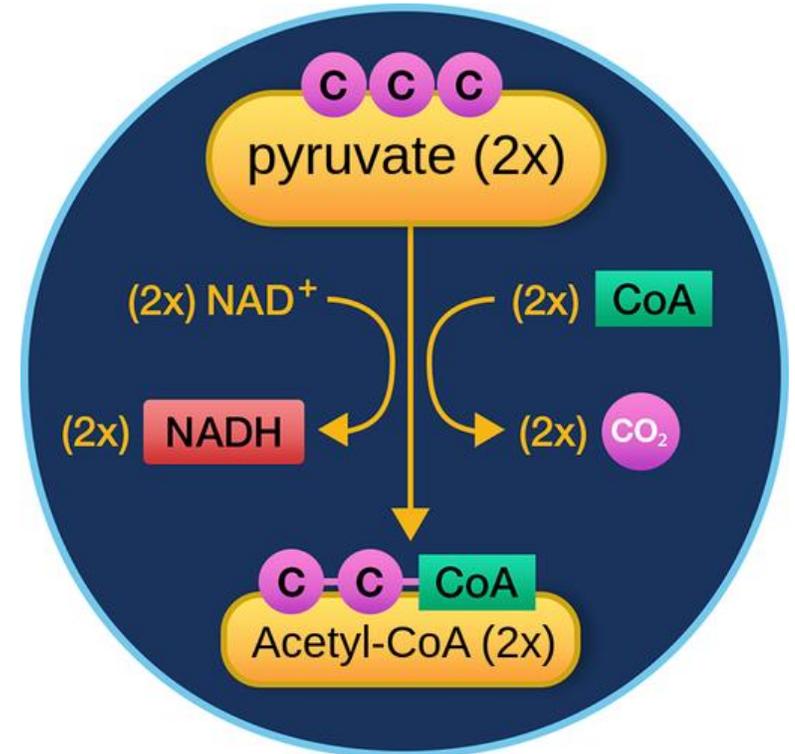
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1	Hexokinase	-	Minus 1
3	Phosphofructokinase	-	Minus 1
6	1,3-bisphosphoglycerate kinase	ATP	$1 \times 2 = 2$
9	Pyruvate kinase	ATP	$1 \times 2 = 2$
Total = 4 minus 2 = 2			



# **Pyruvate oxidation and Krebs cycle**

# Pyruvate oxidation

- Pyruvate oxidation, also known as pyruvate decarboxylation is a connecting step of cellular respiration, linking glycolysis and the Krebs cycle. pyruvate gets oxidized to acetyl-CoA by the multienzyme **pyruvate dehydrogenase complex** (PDH complex, or PDHC).
- this process takes place in the **mitochondrial matrix**,



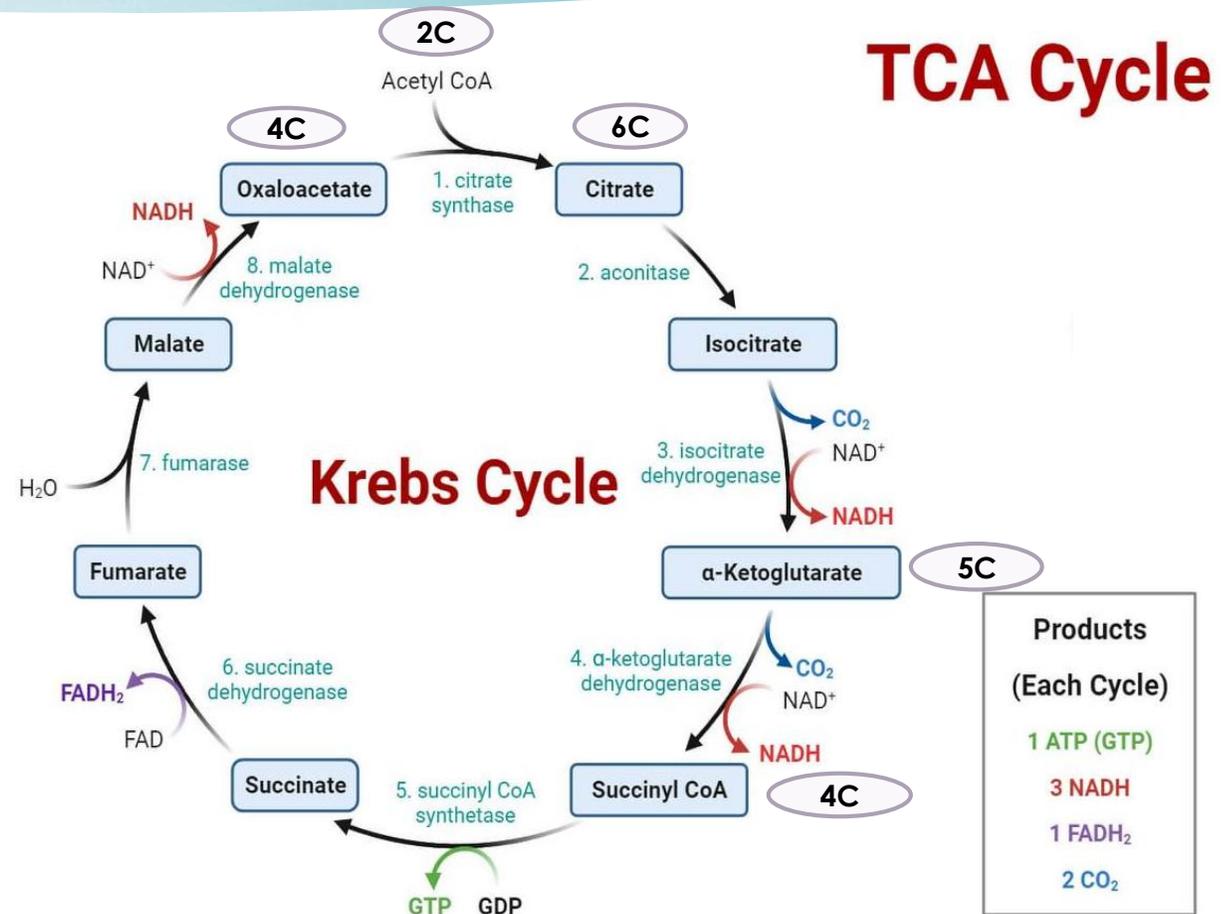
Krebs cycle preparation:

# Krebs cycle

- The tricarboxylic acid (TCA) cycle, also known as the Krebs or citric acid cycle,
- begins with the combination of the acetyl group of acetyl-CoA from the Krebs cycle preparation with the four-carbon compound oxaloacetate to form the six-carbon citric acid compound.
- During the cycle, 2 additional CO<sub>2</sub> molecules, 1 ATP, 3 NADH, and 1 FADH<sub>2</sub> molecule are formed per pyruvate molecule.
- In the end of the cycle, oxaloacetate is regenerated to return as an acetyl acceptor to re-start the cycle.
- It comprises 8 enzymes all enzyme within the mitochondrial matrix except the outlier succinate dehydrogenase in the inner mitochondrial membrane.

# Reactions of the citric acid cycle

Acetyl-CoA enters the cycle, and is completely oxidized. During this process, energy is trapped



\*(NAD) nicotinamide adenine dinucleotide

\*(FAD)flavin adenine dinucleotide

# Krebs cycle Steps

**Step 1:** Formation of Citric Acid (The 4 carbon, oxaloacetate condenses with 2 carbon, acetyl-CoA to form 6 carbon compound the citrate by citrate synthase)

**Step 2:** Formation of Isocitrate (Isocitrate is produced from citrate by aconitase)

**Step 3:** Formation of Alpha Ketoglutarate (Isocitrate is converted to alpha-ketoglutarate via oxidation. One molecule of NADH is created, and one molecule of CO<sub>2</sub> is released.)

**Step 4:** Formation of Succinyl-CoA (Succinyl CoA is formed when alpha-ketoglutarate is oxidized by alpha ketoglutarate dehydrogenase . The second molecule of NADH and a second molecule of carbon dioxide are produced)

# Krebs cycle Steps

**Step 5:** Generation of Succinate( Succinate is formed from succinyl CoA,One molecule of GTP is created)

**Step 6:** Formation of Fumarate(Succinate is dehydrogenated to fumarate, by succinate dehydrogenase, The hydrogen atoms are accepted by FAD. The FADH<sub>2</sub> then enters into ETC to generate ATPs.)

**Step 7:** Formation of Malate (The formation of malate from fumarate is catalyzed by fumarase)

**Step 8:** Regeneration of Oxaloacetate (malate is oxidized to oxaloacetate by malate dehydrogenase , This step produces the third molecule of NADH. which enters the electron transport chain, when ATPs are produced.)

## ENERGY PRODUCED BY Krebs CYCLE

**3 NADH generated**

$$3 * 2.5 = 7.5 \text{ ATP}$$

**1 FADH<sub>2</sub> generated**

$$1 * 1.5 = 1.5 \text{ ATP}$$

**1 GPT generated**

$$= 1 \text{ ATP}$$

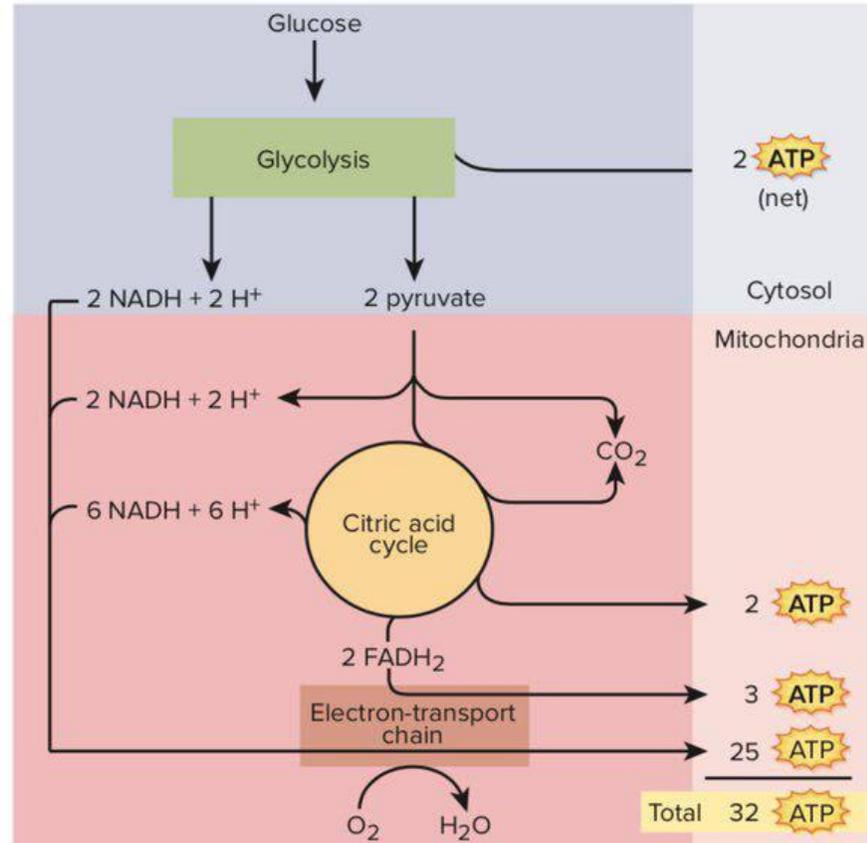
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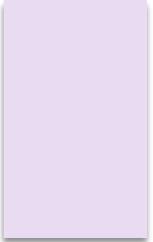
Total 10 ATP per Cycle

## Three enzymes have regulatory properties

- **citrate synthase**: is inhibited by NADH, ATP, succinyl CoA .
- **isocitrate dehydrogenase**: allosteric effectors: (+) ADP; (-) NADH, ATP.
- **$\alpha$ -ketoglutarate dehydrogenase complex** : Inhibition by ATP, NADH , succinyl CoA .

# Summary: total ATP Production from the complete oxidation of one Glucose molecule





*Thank You*