# Carbohydrate digestion and Metabolism

3rd stage

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# References


- ✓ Harper's Illustrated biochemistry, 26th edition
- ✓ Biochemistry – Berg, Tymoczko and Stryer, 6th edition
- ✓ Lippincott's Illustrated Reviews: Biochemistry 5th edition

# Learning Outcomes

By the end of this lecture you will be able to Understand:

- The importance of carbon sources in metabolism process
- The role of enzymes in Digestion of carbohydrates
- Fate of absorbed sugars

- **Metabolism**: the chemical reactions that occur in a cell that produce energy and basic materials needed for important life processes

- ✓ Thousands of enzymes
- ✓ Various conditions (fed, fasted, exercise, stress)

- $A \xrightarrow{1} [B] \xrightarrow{2} [C] \xrightarrow{3} D$
- 1,2 and 3 = Metabolic pathways
- [B] and [C] = intermediates

Metabolism consist of 2 parts:

- **Catabolism** : Degradation, pathways by which nutrients and cellular components are broken down for reuse or to generate energy for example, glycolysis and β-oxidation.
- **Anabolism** : Biosynthesis, building up of biomolecules from simpler components. Therefore, these processes require to energy and NADPH or NADH or FADH
- **Metabolism is regulated into three main stages:**
- Stage 1: large molecules are broken down into smaller molecules
- Stage 2: small molecules are degraded to a few simple molecules e.g. glycolysis, produce acetyl coA.
- Stage 3: Citric acid cycle and oxidative

# Carbon sources and energy for cellular life

- **Autotrophic cells:** These cells are use Carbone dioxide ($CO_2$) as a carbon source and sunlight as an energy source and thus can make large biomolecules.

$$6\ CO_2 + 6\ H_2O + \text{energy (sun)} \longrightarrow C_6H_{12}O_6\ \text{(Glucose)} + 6\ O_2$$

- **Heterotrophic cells:** These cells do not use Carbone dioxide as the only carbon source, but depend on other organic compounds that get as a food. These cells are classified into two groups

  - **Aerobes:** They live in the air and use Oxygen to oxidize their food.
  - **Anaerobes:** These can live without Oxygen and can break down their nutrition by using oxidizing materials such as NAD+. Most cells can live aerobic and anaerobic at the same time and this is called **Facultative cells**

- **Photosynthesis:**

Carbone dioxide
Water
energy (sunlight)
Chlorophyll
$\longrightarrow$ **Glucose**

# Carbohydrate Metabolism

- Serve as primary source of energy in the cell.
- Digestible carbohydrates provide 4 - 4.5 kilocalories per gram
- Central to all metabolic processes
- **Carbohydrate Metabolism includes the following processes:**

1- Glycolysis

2- Glycogenesis

3- Glycogenolysis

4- Gluconeogenesis

5- Pentose phosphate pathway

6- Citric acid cycle (Kreb’s cycle) or Tricarboxylic acid cycle (TCA)

7- Photosynthesis

# Digestion of Carbohydrate

- Digestion is the breakdown of large insoluble molecules into smaller soluble molecules to make energy (ATP). The digestion process is carried out by an enzymes that are excreted from various parts of the body
- **In the Mouth**

**Glycogen**
**Starch**

$$\xrightarrow[\textbf{α-amylase}]{\text{In the mouth (saliva)}}$$

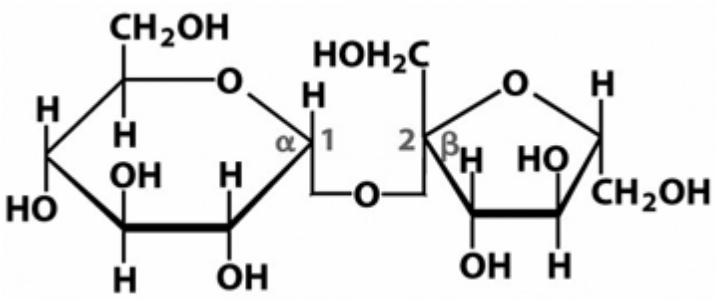
**Maltose, Isomaltose, starch dextrins**

- **α-amylase** is produced by salivary glands. Its optimum **pH is 6.7**
- It acts on cooked starch and glycogen breaking **α 1-4 glycosidic bonds**, converting them into **maltose**.
- The food remains for a short time in the mouth. Therefore, the digestion of glycogen and starch may be incomplete and gives a partial digestion products called **starch dextrins** (amylodextrin, erythrodextrin and achrodextrin).

# Structures of common, di- and polysaccharides

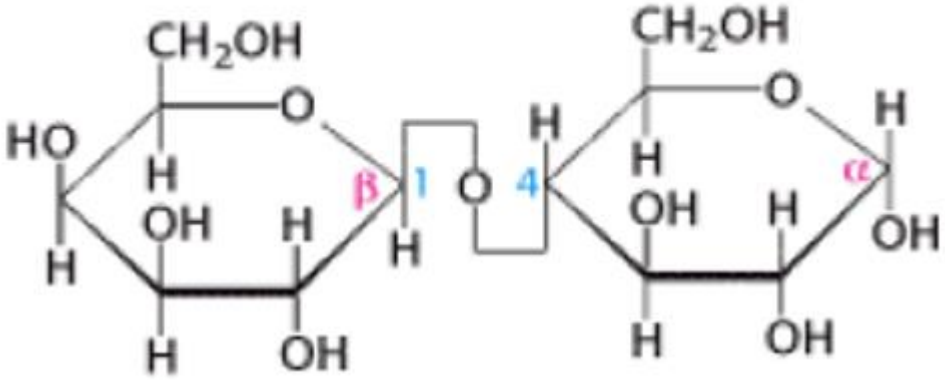
**Sucrose:** disaccharide containing glucose and fructose attached by **α- (1,2)** linkage

**Glucose** **Fructose**

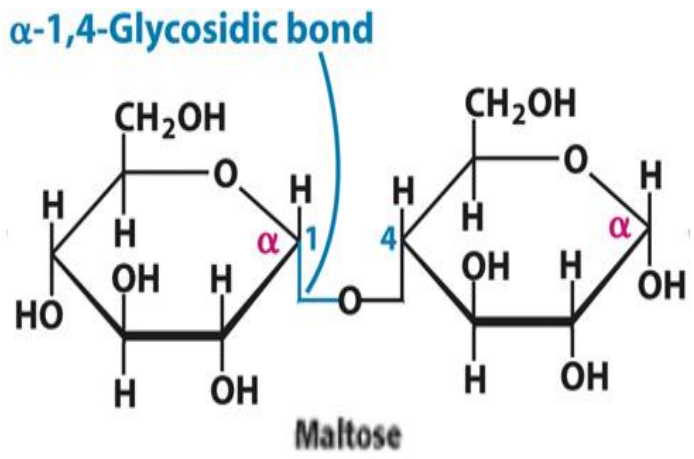



**Lactose:** disaccharide containing **glucose** and **galactose** attached by **β-(1,4)** linkage

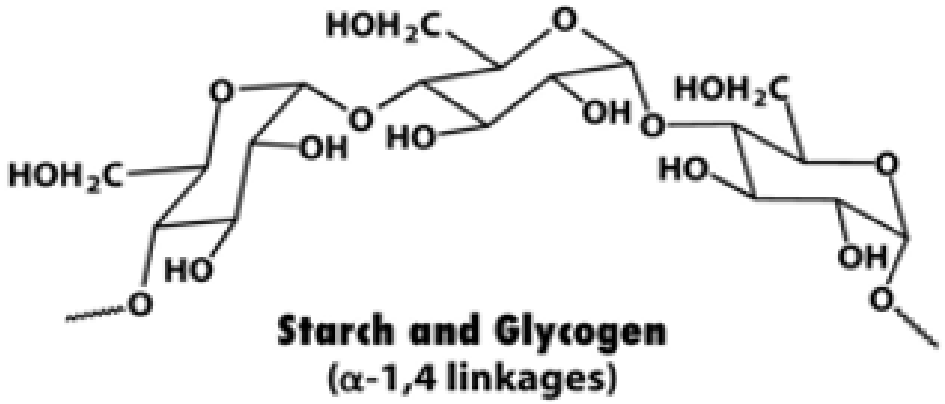
**Galactose** **Glucose**

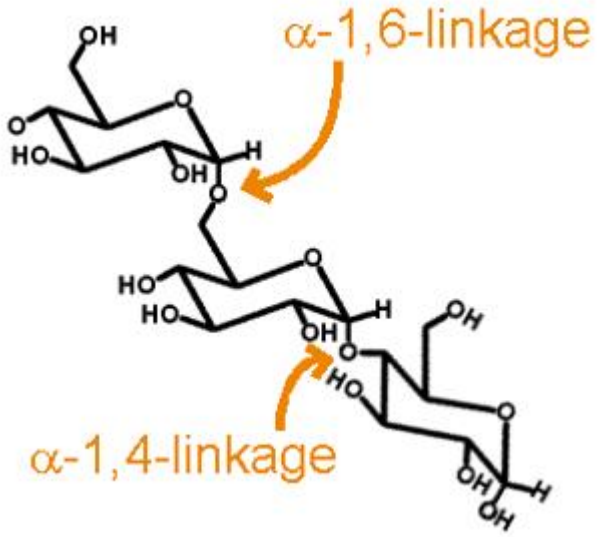


- **Maltose:** disaccharide containing **two glucose** molecules attached by **α-( 1,4) linkage**. This bond is not attacked by **α-amylase**.



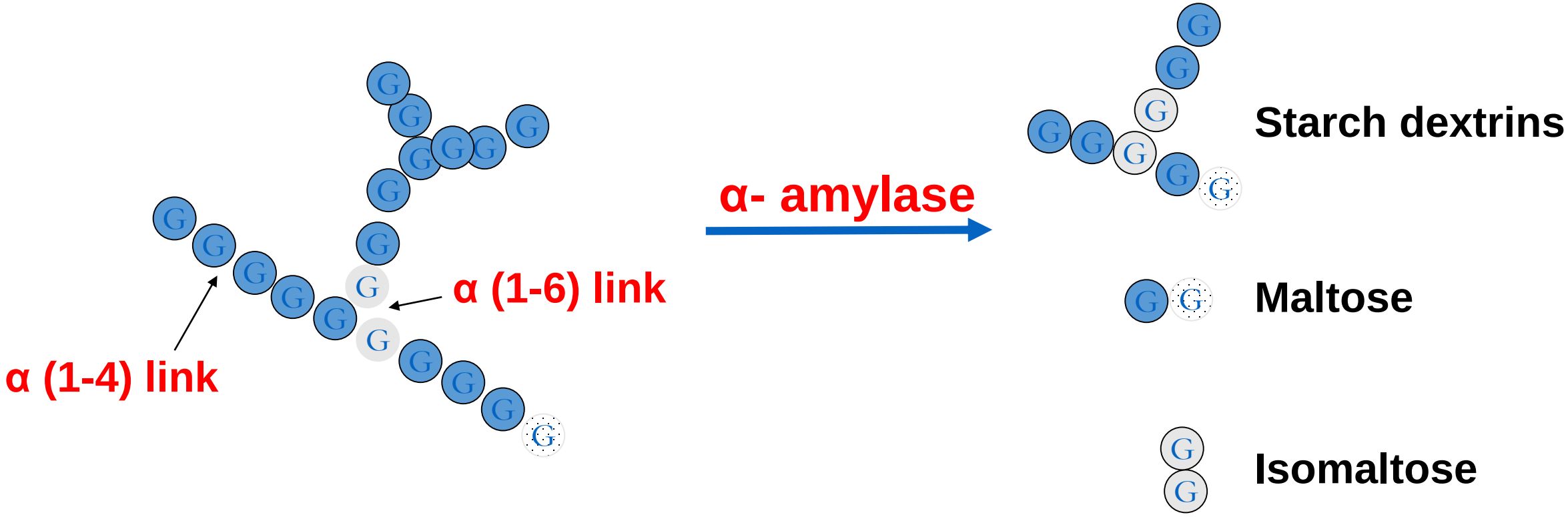

- **Glycogen:** Major storage carbohydrate in **animals**
- **Starch:** Major storage carbohydrate in **plants**




Starch and Glycogen
(**α-1,4 and α-1,6** linkages)

# Digestion of carbohydrates



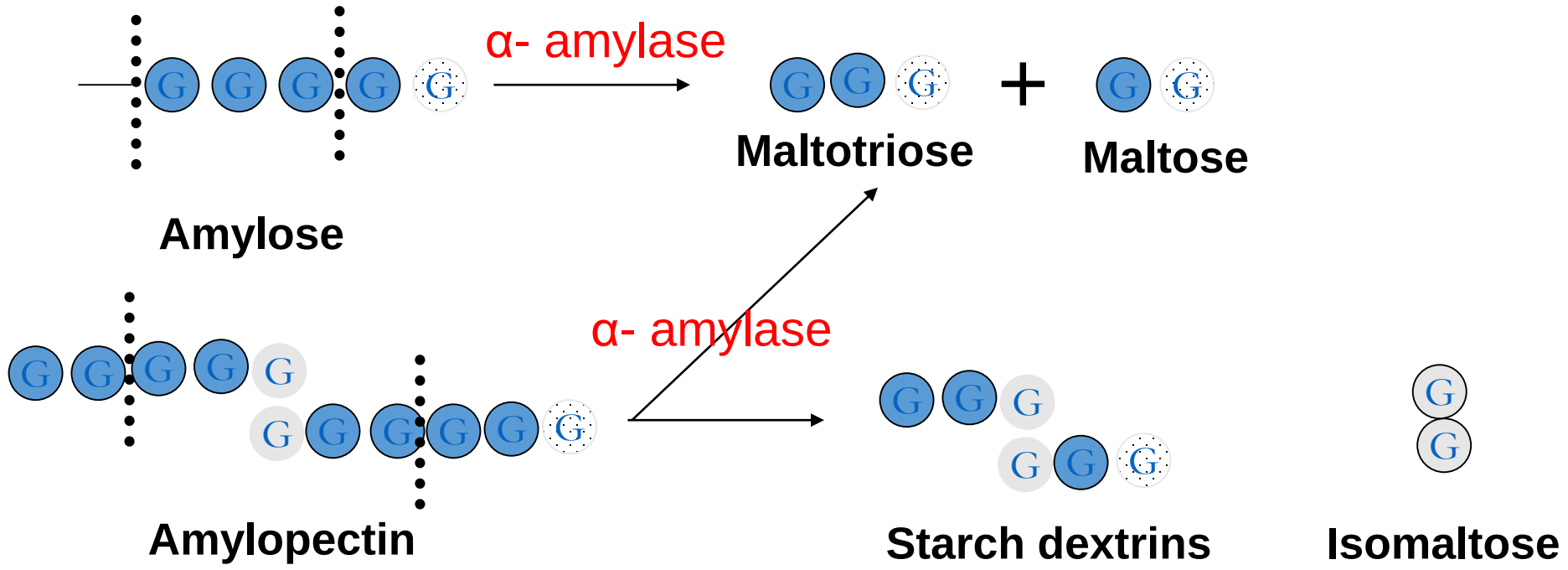

- **α- amylase** cannot attack α1-4 linkage close to α1-6 branch points.
- **Isomaltose:** Two glucose molecules are attached by α1-6 linkage

## ➢ Stomach:

Carbohydrate digestion stops temporarily due to the high acidity, where low pH in the stomach (1.5-3.5) inactivates the action of salivary amylase.

## ➢ Small intestine:

- The digestion of carbohydrate continues by the pancreatic enzyme (α-amylase) in the small intestine
- **α-amylase enzyme** is produced by pancreas and acts in small intestine. Its optimum pH is 7.1



Final carbohydrate digestion occurs at the **small intestine by intestinal enzymes** that secreted through intestinal epithelial cells. These enzymes include the action of several disaccharidases as shown below:

- Maltase enzyme hydrolyses α-(1,4) linkage Maltose into two molecules of glucose:

  Maltose $\xrightarrow{\textbf{Maltase}}$ Glucose + Glucose

- Lactase enzyme hydrolyses β-(1 ,4) linkage Lactose into Glucose and Galactose:

  Lactose $\xrightarrow{\textbf{Lactase}}$ Glucose + Galactose

- Sucrase enzyme hydrolyses α, β -(1 ,2) Sucrose into Glucose and Fructose

  Sucrose $\xrightarrow{\textbf{Sucrase}}$ Glucose + Fructose

- α-dextrinase enzyme hydrolyses (1 ,6) linkage of isomaltose into two molecules of glucose

  Isomaltose $\xrightarrow{\textbf{α-dextrinase}}$ Glucose + Glucose

- Cellulose contains β(1-4) glycosidic bonds. In humans, there is no **cellulase** enzyme that can break down these bonds between glucose molecules. Therefore, cellulose passes as such in stool.

- **Small intestine:**
  - Portal for transport of virtually all nutrients

- **Enzymes associated with intestinal surface membranes are:**
  - α- dextrinase
  - Maltase
  - Lactase
  - Sucrase
  - peptidase

# Absorption of Carbohydrates

- After complete digestion, monosaccharides (Glucose, fructose, and galactose) are absorbed across the membrane of the small intestine and transported to the liver through bloodstream, where they are either used by the liver (Glycogenesis), or further distributed to the rest of the body (Oxidation)
- - Fructose and galactose are converted into glucose by liver cells
- - All cells can use glucose for energy production
- - Liver is central site for carbohydrate metabolism
- - Blood glucose is regulated by insulin
- - Glucose is the main energy source for most organisms

# Fate of absorbed sugars

- **Glucose**
- **Fructose**
- **Galactose**

Liver → **Glucose**

Feeding state

**Oxidation**

- Glycolysis and Kreb's cycle for production of energy
- Pentose (Hexose) phosphate pathway

**Storage**

- glycogen in liver and muscle
- Fat

**Conversion**

- Ribose (RNA), deoxyribose (DNA)
- Lactose → Milk
- Fructose in semen
- Glucosamine