Sawa University

# Biochemistry I

## Carbohydrate Metabolism I


Sawa University — جامعـــــة ســـــــاوة الاهلية

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Stage : 2nd — المرحلـــــــــــــة : الثانية

الجانب النظري محاضرة رقم 6

Theoretical [1]Lecture No. 6


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# Topics

- **Carbohydrate metabolism I:**
  - **Subtopics:**
    - **Digestion of Carbohydrates.**
    - **Transport of Glucose.**
    - **Absorption of Carbohydrates.**

# Carbohydrate metabolism

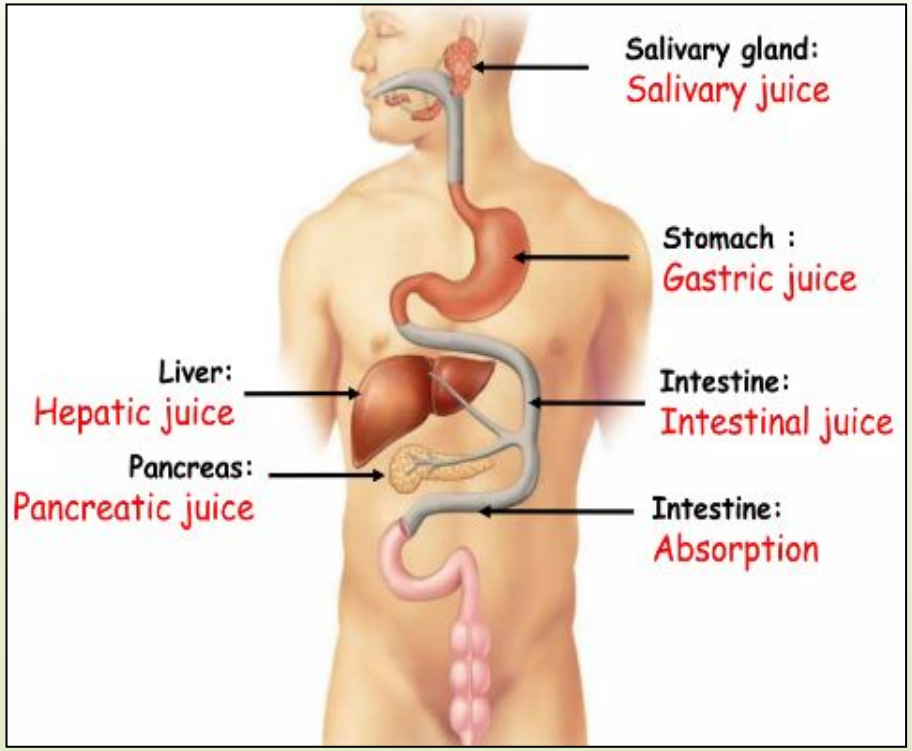
## ❑ Digestion of Carbohydrates

- The principal sites of carbohydrate digestion are the **mouth** and **small intestine.**
- The dietary carbohydrate consists of:

— **Polysaccharides:** **Starch**, **glycogen** and **cellulose**.

— **Disaccharides: Sucrose**, **maltose** and **lactose**.

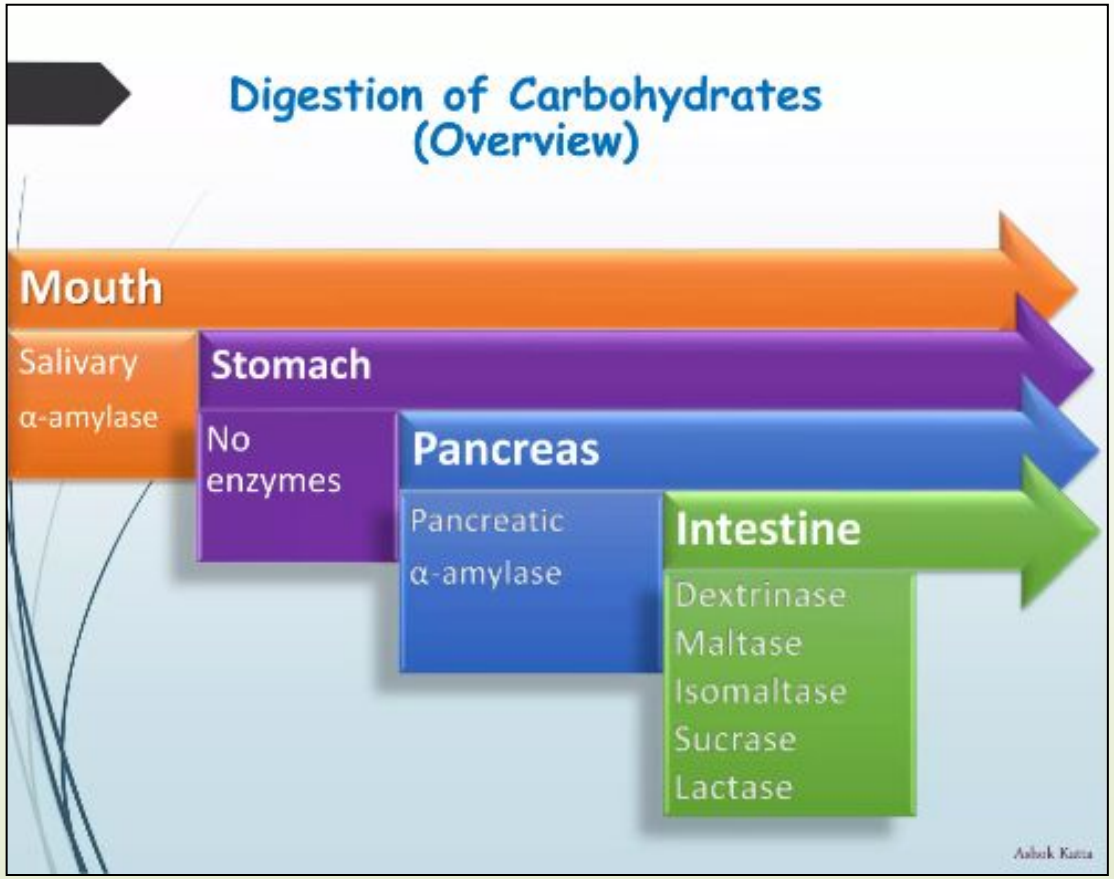
— **Monosaccharides:** Mainly **glucose** and **fructose**.




- **Monosaccharides** need no digestion before absorption, whereas **disaccharides** and **polysaccharides** must be hydrolyzed to simple sugars before absorption.

## 1- Digestion in Mouth

- Digestion of **carbohydrates** begins in the mouth. **Salivary glands** secrete ***α-amylase (ptylin)***, which initiates the hydrolysis of a starch.
- During mastication, **salivary α-amylase** acts briefly on dietary **starch** in random manner breaking some **α-(1→4) bonds**, **α-amylase** hydrolyzes **starch** into **dextrins**.




## 2- Digestion in Stomach

- **Carbohydrate** digestion halts temporarily in the **stomach** because the high acidity inactivates the **salivary α-amylase**.

## 3- Digestion in Intestine

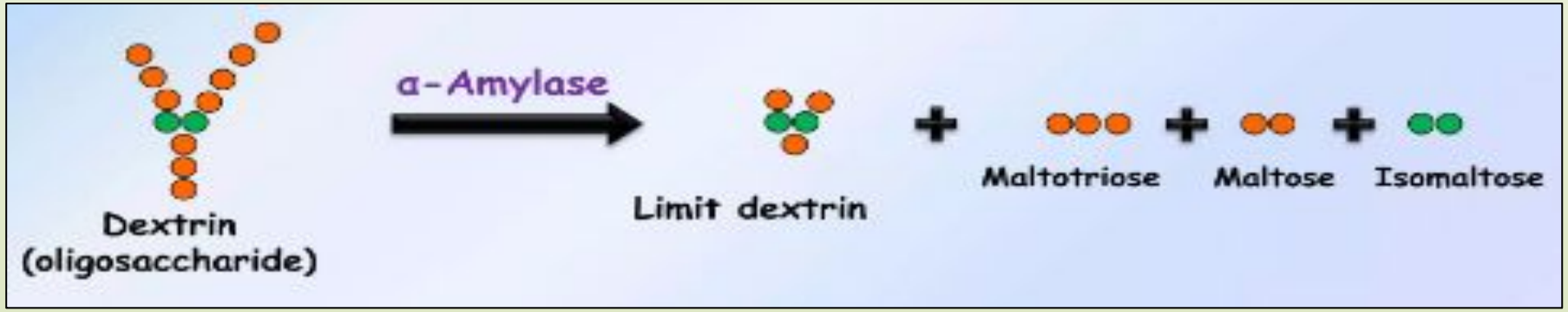
- Further digestion of **carbohydrates** occurs in **the small intestine** by **pancreatic enzymes**.
- **There are two phases of intestinal digestion.**

**A) Digestion due to pancreatic α-amylase.**

**B) Digestion due to intestinal enzymes : sucrase, maltase, lactase** and **isomaltase**.

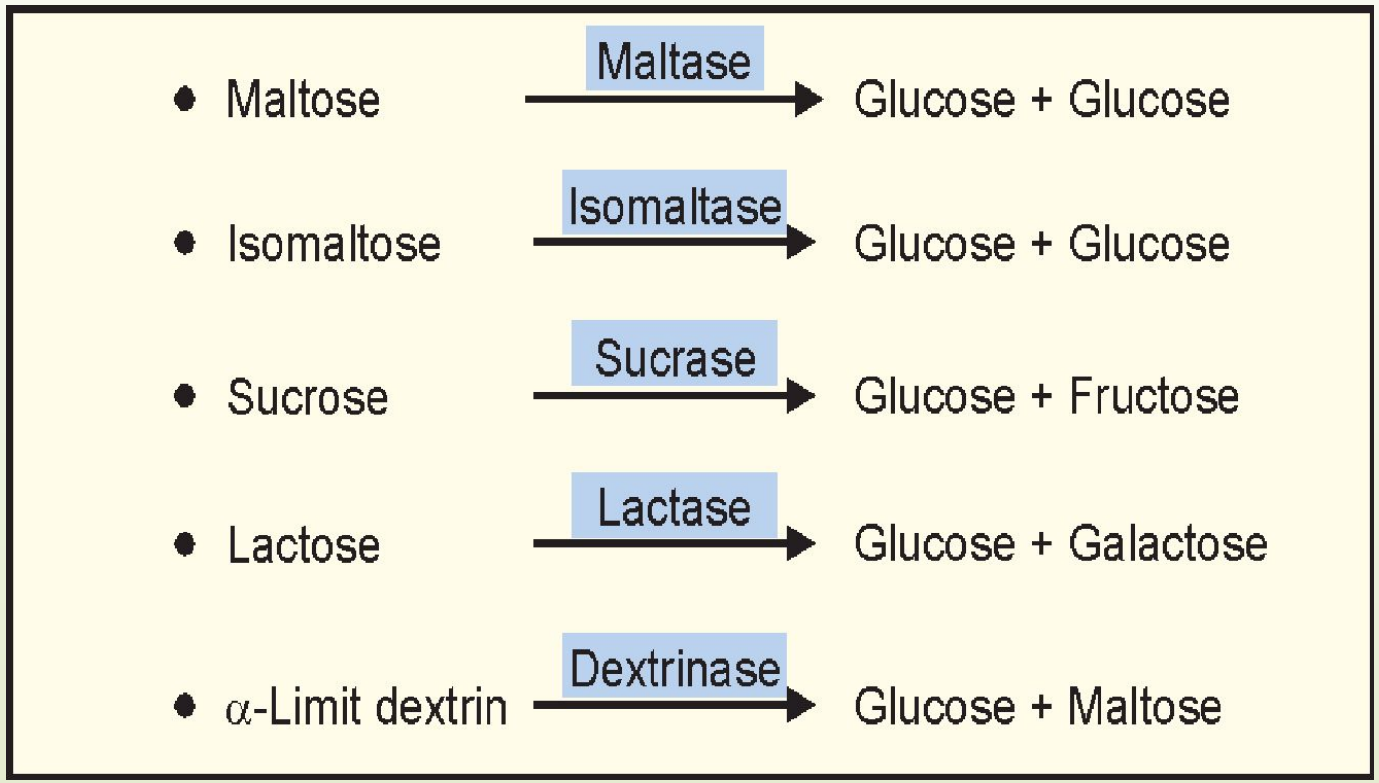
### A) Digestion due to pancreatic α-amylase

- The function of **pancreatic α-amylase** is to degrade **dextrins** further into a mixture of **maltose**, **isomaltose** and **α-limit dextrin**.
- The **α-limit dextrins** are smaller **oligosaccharides** containing **3** to **5 glucose** units.



## A) Digestion due to intestinal enzymes

— Enzymes responsible for the final phase of **carbohydrate** digestion are located in the **brush-border membrane.**




— The end products of **carbohydrate** digestion are ***glucose***, ***fructose*** and ***galactose*** which are readily absorbed through **the intestinal mucosal cells** into the **bloodstream**.

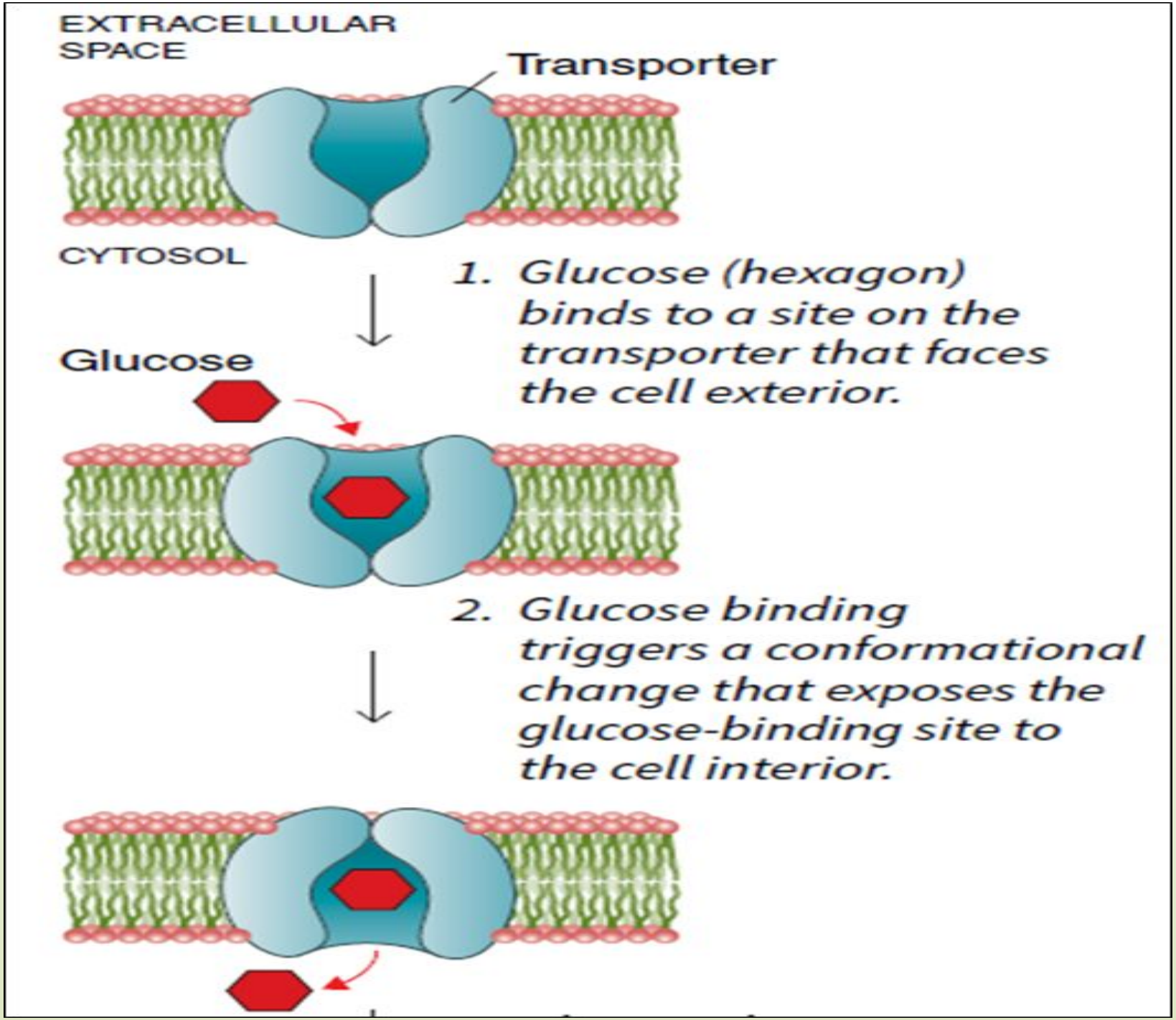
# Transport of Glucose

- **Glucose** cannot diffuse directly into cells, but **enters by one of two transport mechanisms**:

1. **$Na^+$-independent facilitated diffusion transport system (Facilitated transport).**
2. **$Na^+$-monosaccharide co-transporter system (Active transport).**

## 1. $Na^+$-independent facilitated diffusion transport system

- This system is mediated by a family of at least fourteen glucose transporters in cell membranes, designated as **glucose transporters 1** to **14** (**GLUT-1 to GLUT-14**).
- These transporters exist in the membrane in two conformational states.
- **Extracellular**
    1. **Glucose binds to the transporter.**
    2. **Alters its conformation, transporting glucose across the cell Membrane**.


EXTRACELLULAR SPACE
Transporter
CYTOSOL
1. Glucose (hexagon) binds to a site on the transporter that faces the cell exterior.
Glucose
2. Glucose binding triggers a conformational change that exposes the glucose-binding site to the cell interior.

## A) Tissue specificity of GLUT gene

- The glucose transporters display a tissue-specific pattern of expression.
- For example:

- **GLUT-1**: Is abundant in **erythrocytes** and **brain**, but is low in **adult muscle**.
- **GLUT-2** : is found in the **liver**, **kidney**, **small intestine** and **β cells of the pancreas**.
- **GLUT-3**: Is the primary glucose transporter in **neurons** and **placenta**.
- **GLUT-4**: Is abundant in **adipose tissue** , **skeletal muscle** and **cardiac muscle**.

**Note:** The number of **GLUT-4** transporters active in these tissues is increased by **insulin.**

## B) Specialized functions of GLUT isoforms

- In **facilitated diffusion**, **glucose** movement follows a concentration gradient, that is, from a high glucose concentration to a lower one. **For example**, **GLUT-1, GLUT-3,** and **GLUT-4** are primarily involved in glucose uptake from the blood.
- **In contrast** ,**GLUT-2**, can either transport **glucose** into these cells when blood glucose levels are **high**, or transport **glucose** from the cells to the blood when blood glucose levels are **low** (for example, **during fasting**).
- **GLUT-5** is unusual in that it is the primary transporter for **fructose** (**instead of glucose**) in the **small intestine** and **the testes**.

## 2. $Na^+$-monosaccharide co-transporter system

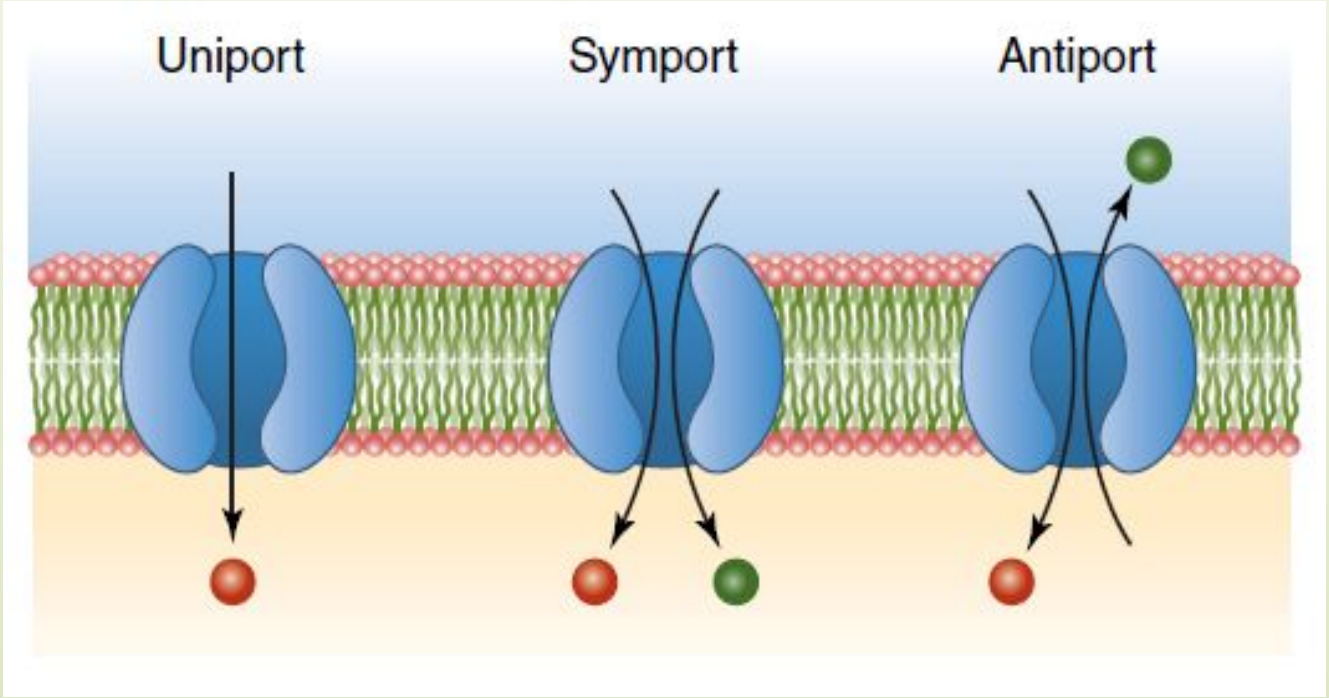
- This is an **energy-requiring** process that transports glucose "**against** " a **concentration gradient** that is, **from low glucose concentrations outside the cell to higher concentrations within the cell**.
- This system is a carrier-mediated process in which the movement of **glucose** is coupled to the concentration gradient of **$Na^+$** which is transported into the cell at the same time **( sodium-dependent glucose transporter SGLT-1)**.
- This type of transport occurs in the **epithelial cells of the intestine**, **renal tubules**, and **choroid plexus**.

**Note:** Some transport proteins can bind more than one type of ligand, so it is useful to classify them according to how they operate:

1) **A uniporter** such as the glucose transporter moves a single substance at a time.

2) **A symporter** transports two different substances across the membrane.

3) **An antiporter** moves two different substances in opposite directions across the membrane.



# Absorption of Carbohydrates

## ❑ Passage to the Small Intestine

— After digestion, simple sugars are transported to **the small intestine**, where the absorption process takes place.

## ❑ Mechanism of Sugar Absorption

### ❖ Absorption through Epithelial Cells

— Specialized cells in **the small intestine**, known as **intestinal epithelial cells**, form the interface between the **intestinal lumen** and **the bloodstream**. **Sugars** are absorbed through these cells via two main mechanisms:

## 1. Facilitated Diffusion:

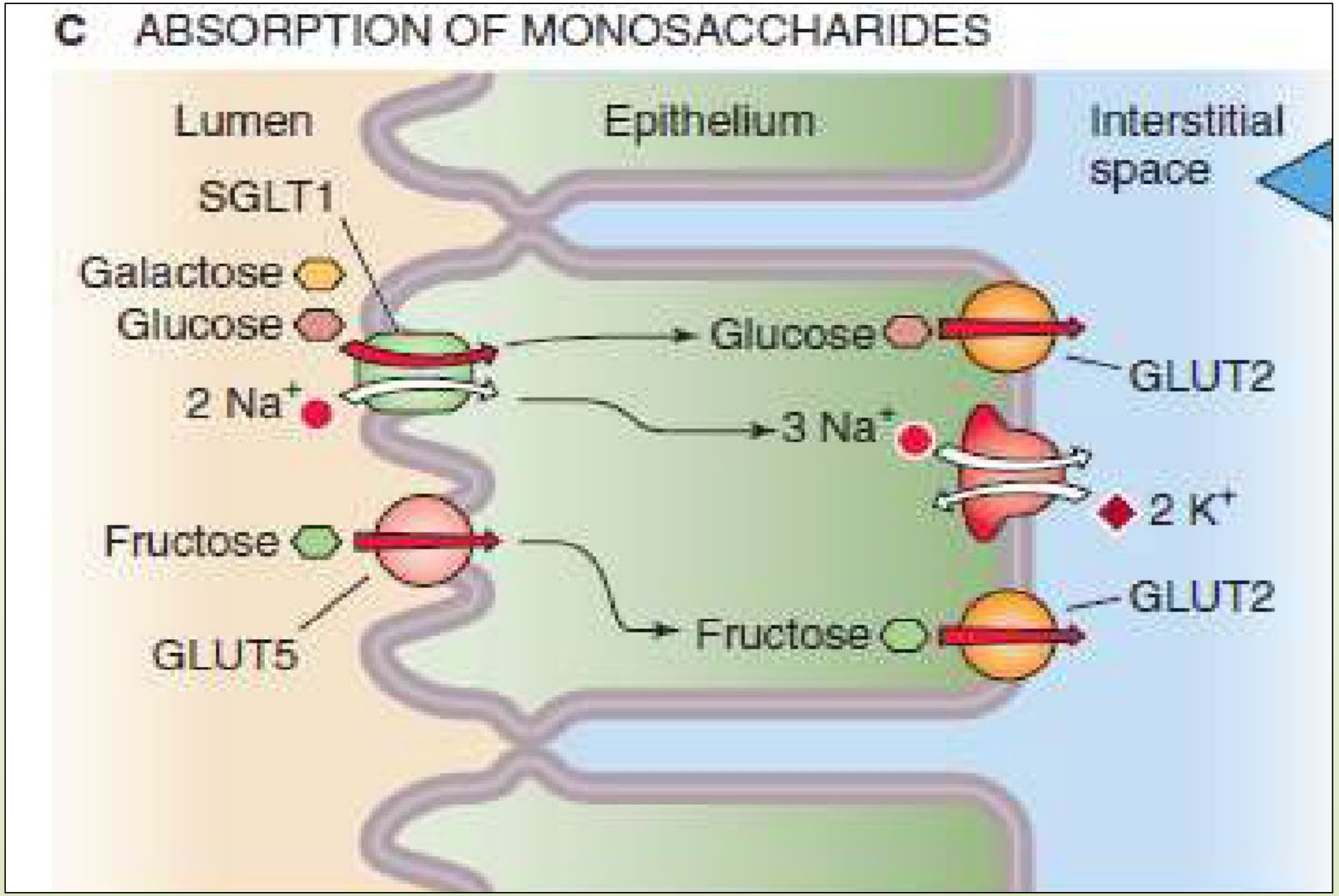
- After **glucose** and **galactose** enter **the epithelial cells**, they are transported into the **bloodstream** via another type of transporter called **GLUT2**. This transport occurs through **facilitated diffusion**, where **glucose** and **galactose** move from an area of higher concentration inside the cells to an area of lower concentration in the blood without the need for energy.

### ❖ Transport of Glucose and Fructose

- **Glucose**: It is absorbed via **SGLT1** and transported into **the bloodstream** through **GLUT2**.
- **Fructose**: It is absorbed via **GLUT5**, which is a transporter specifically for **fructose**, and then transported into **the blood** via **GLUT2**.

## 2. Active Transport:

- **SGLT1**: This is a transporter used for the absorption of **glucose** and **galactose**.
- This transporter relies on moving **glucose** and **galactose** against their concentration gradient (**from an area of low concentration to an area of high concentration**).
- This transport is powered by energy derived from **sodium ions** ($Na^+$).
- The **SGLT1 transporter co-transports sodium** with **glucose** and **galactose** into **the epithelial cells** in a process known as **co-transport** or **secondary active transport**, where **sodium** facilitates the entry of **glucose** and **galactose** into **the epithelial cells**.


C ABSORPTION OF MONOSACCHARIDES
Lumen
Epithelium
Interstitial space
SGLT1
Galactose
Glucose
2 Na+
Glucose
GLUT2
3 Na+
2 K+
Fructose
GLUT5
Fructose
GLUT2

## ❑ Role in Regulating Blood Sugar Levels

— After the absorption of sugars, they enter the bloodstream, leading to an increase in blood glucose levels. **The pancreas** responds by releasing **insulin**, which works to:

- ✔ Enhance the uptake of **glucose** into body cells for use as **energy**.
- ✔ Store excess **glucose** in the liver and muscles in the form of **glycogen**.
- ✔ Lower blood **glucose** levels when they are elevated.

# Any questions?