Carbohydrate Metabolism

ILOS

At the end of this lecture, students will be able to:

1. Describe how carbohydrates are digested
2. Explain how the products are absorbed into the blood
3. Explain defects in carbohydrates digestion.
4. Mention types and function of glucose transporters.

Contents

Carbohydrate Metabolism

- More than 60% of our foods are Carbohydrates.
- Glucose is the main source of energy for human cells.
- **Metabolism**:

- It is the reactions occurring inside our body
- Includes: 1. Anabolism: synthesis
  2. Catabolism: breakdown

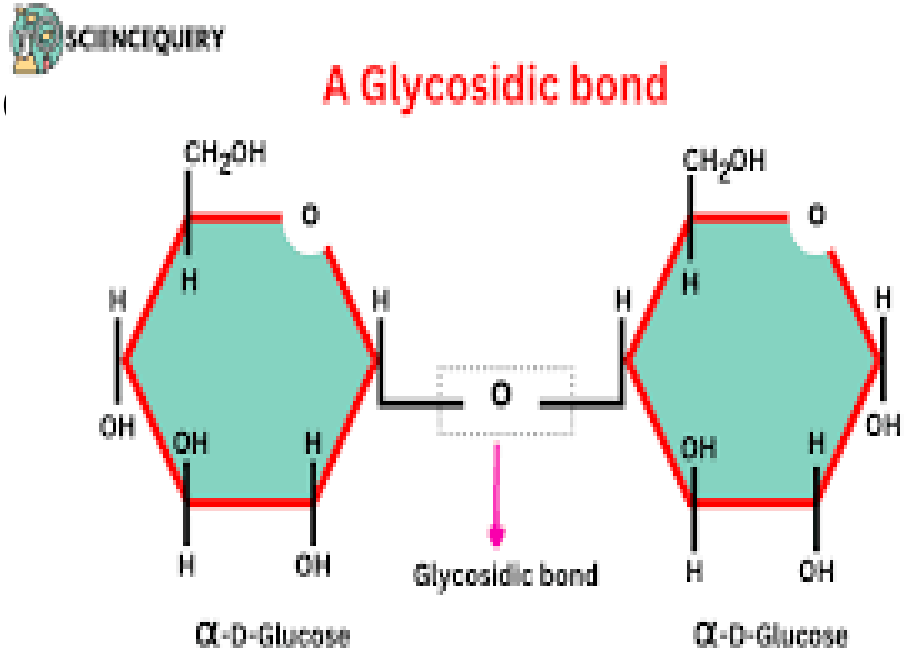
DIGESTION OF CARBOHYDRATES

- **The dietary carbohydrate consist of:**
- **Polysaccharides** : Starch, glycogen and cellulose
- **Disaccharides** : Sucrose and Lactose
- **Monosaccharides** : Mainly glucose and fructose

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

Digestion of carbohydrates:

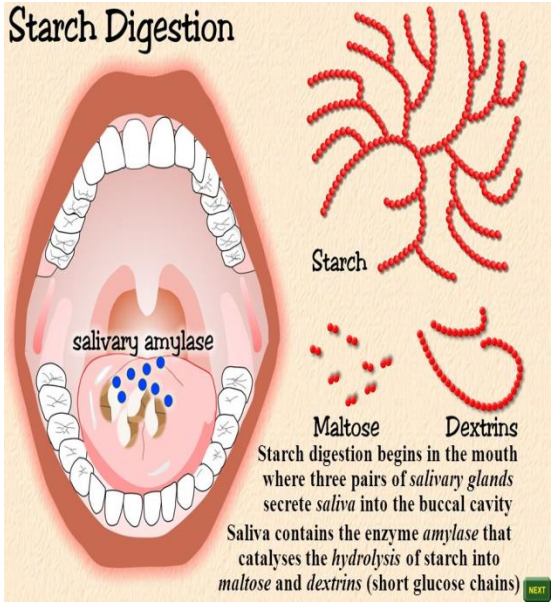
- It means **hydrolysis** of **glycosidic linkage** and conversion of carbohydrates into monosaccharides.



- The principle sites of carbohydrate digestion are the **mouth** and **small intestine**

A. Digestion of carbohydrates begins in the mouth

1. In the mouth:



Carbohydrates are digested by **salivary α amylase (ptyalin):**

- Produced by: salivary glands.
- Optimum pH : 6.7
- Activated by : chloride ions.
- Acts on: α 1-4 glycosidic bonds in cooked starch
- End product: It hydrolyses starch into dextrin (Partial hydrolysis)

DIGESTION OF CARBOHYDRATES

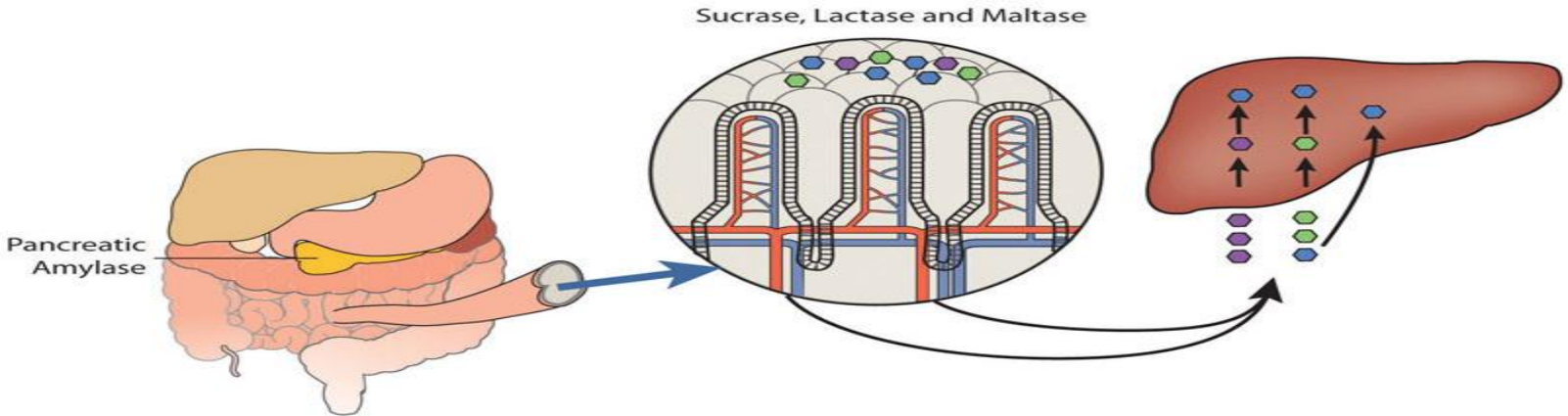
2. In the stomach

- The action of salivary amylase on starch is **stopped** in the stomach after few minutes due to high acidity of stomach which inactivates the enzyme.

DIGESTION OF CARBOHYDRATES

3. In the small intestine:

Further digestion of carbohydrates occurs in the small intestine by pancreatic enzymes (***pancreatic amylase)*** and ***(Disaccharidases)***.



DIGESTION OF CARBOHYDRATES

3. In the small intestine:

*A- Digestion of carbohydrates by **pancreatic amylase:***

- Produced by: pancreatic juice.
- Optimum pH : 7.1
- Activated by : chloride ions.

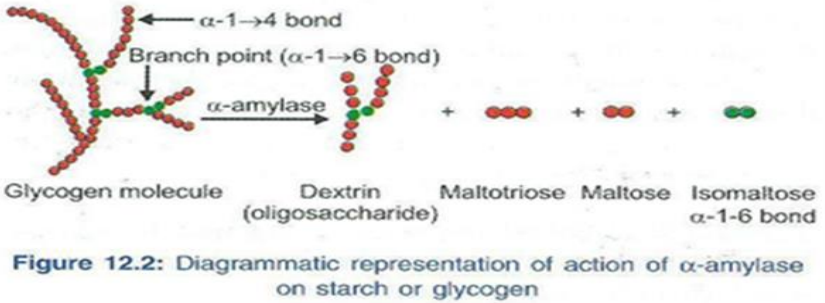


Figure 12.2: Diagrammatic representation of action of α-amylase on starch or glycogen

- Acts on: α1-4 glycosidic bonds in cooked and uncooked starch converting them into maltose and isomaltose .

DIGESTION OF CARBOHYDRATES

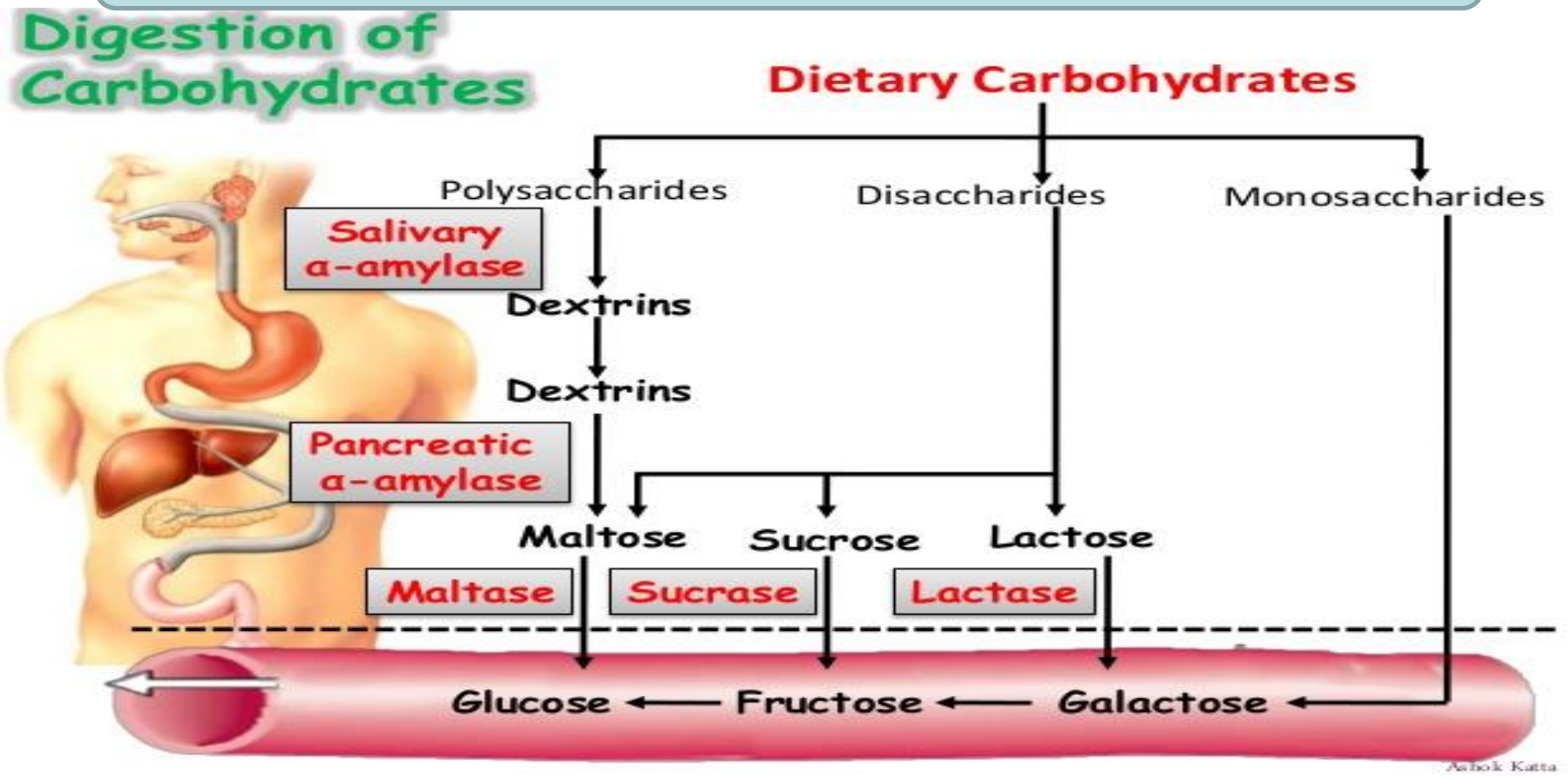
3. In the small intestine:

*B- Digestion of carbohydrates by **Disaccharidases:***

- Produced by: (secreted from intestinal mucosal cells).
- They include:

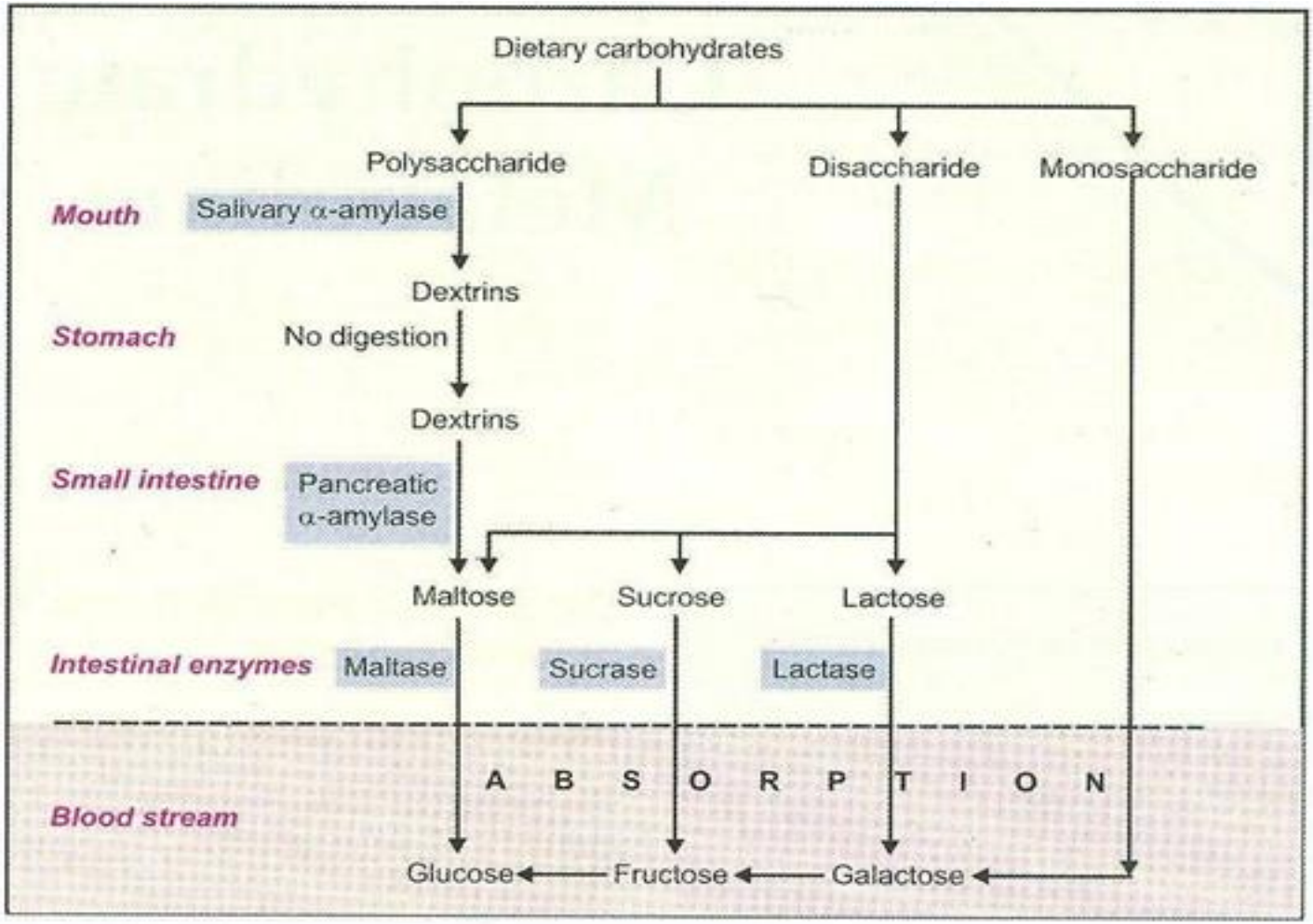
Enzyme	Action
Maltase	Hydrolyses **maltose** into 2 glucose molecules.
Dextrinase	Hydrolyses 1, 6 bonds of **isomaltose** giving 2 glucose molecules
Sucrase	Hydrolyses **sucrose** into glucose and fructose
Lactase	Hydrolyses **lactose** into glucose and galactose

Overview of Digestion of Carbohydrates



End products of carbohydrates digestion

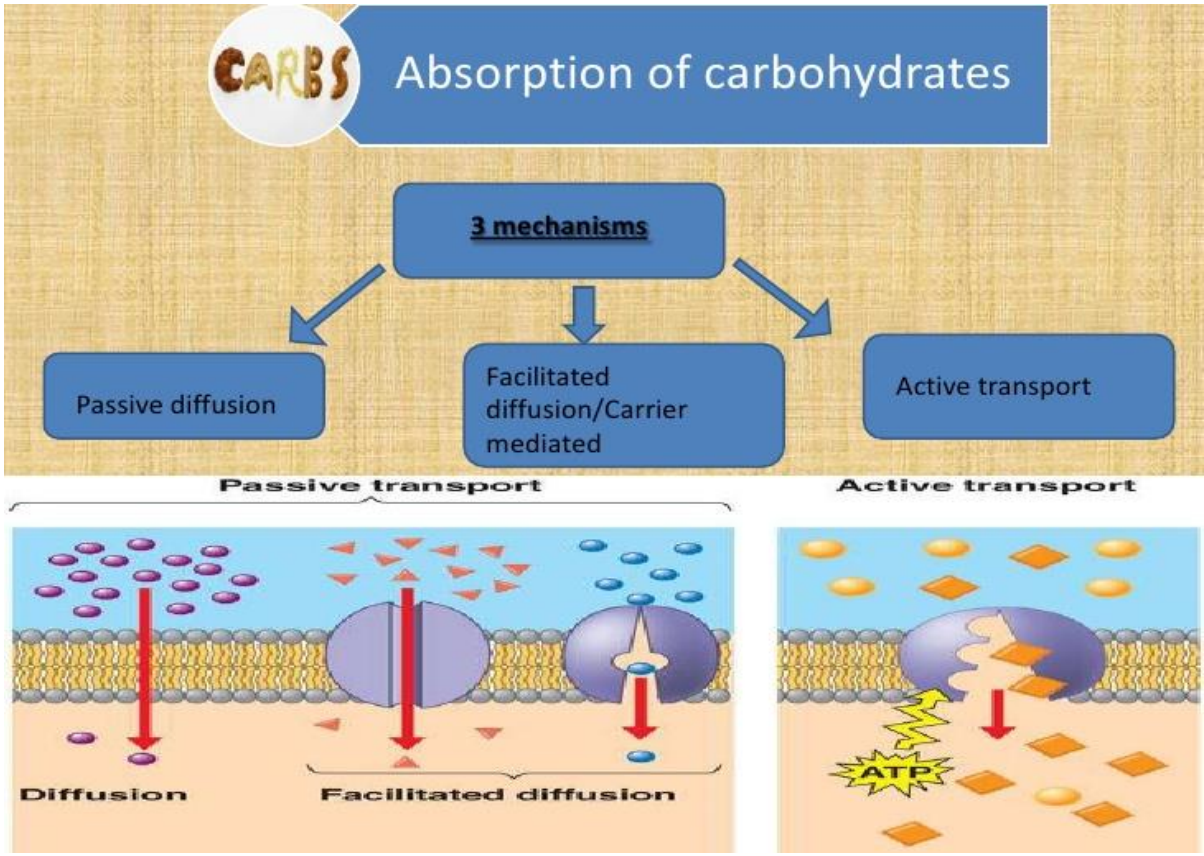
are glucose , fructose and galactose



Absorption of carbohydrates:

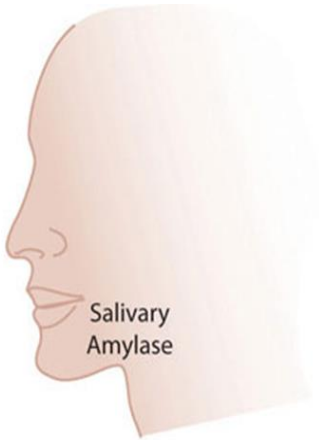
- **Mechanisms of absorption:**

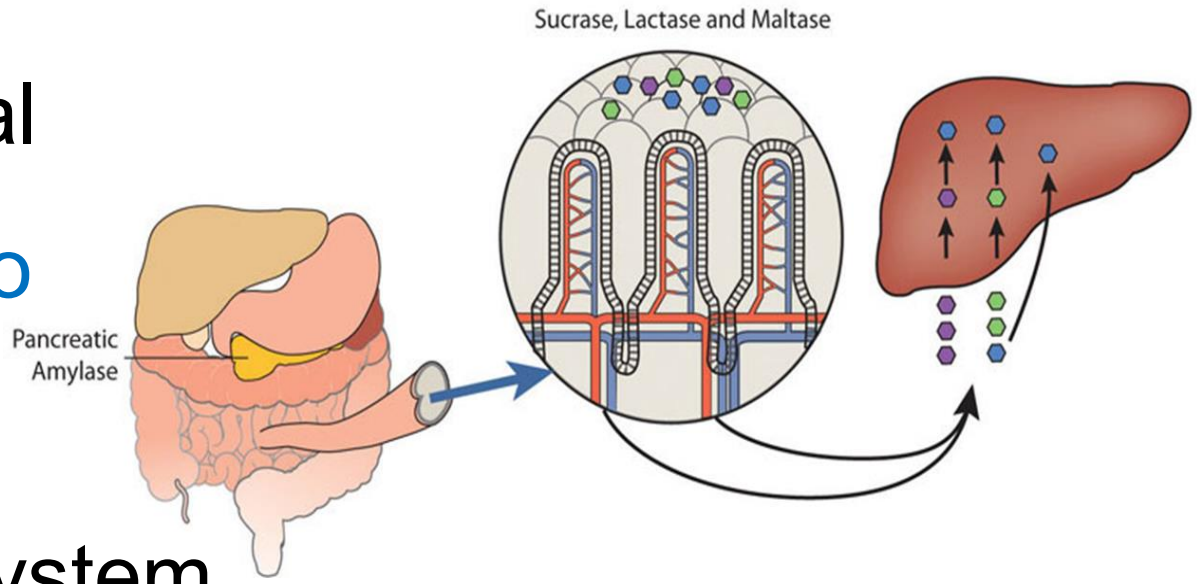
1. Passive transport
2. Active transport
3. Facilitated diffusion



Absorption of mono-saccharides

- CHO are absorbed as mono-saccharides from intestinal lumen through mucosal epithelial cells to blood stream of portal venous system





Absorption of monosaccharides by intestinal mucosal cells

1-Passive transport

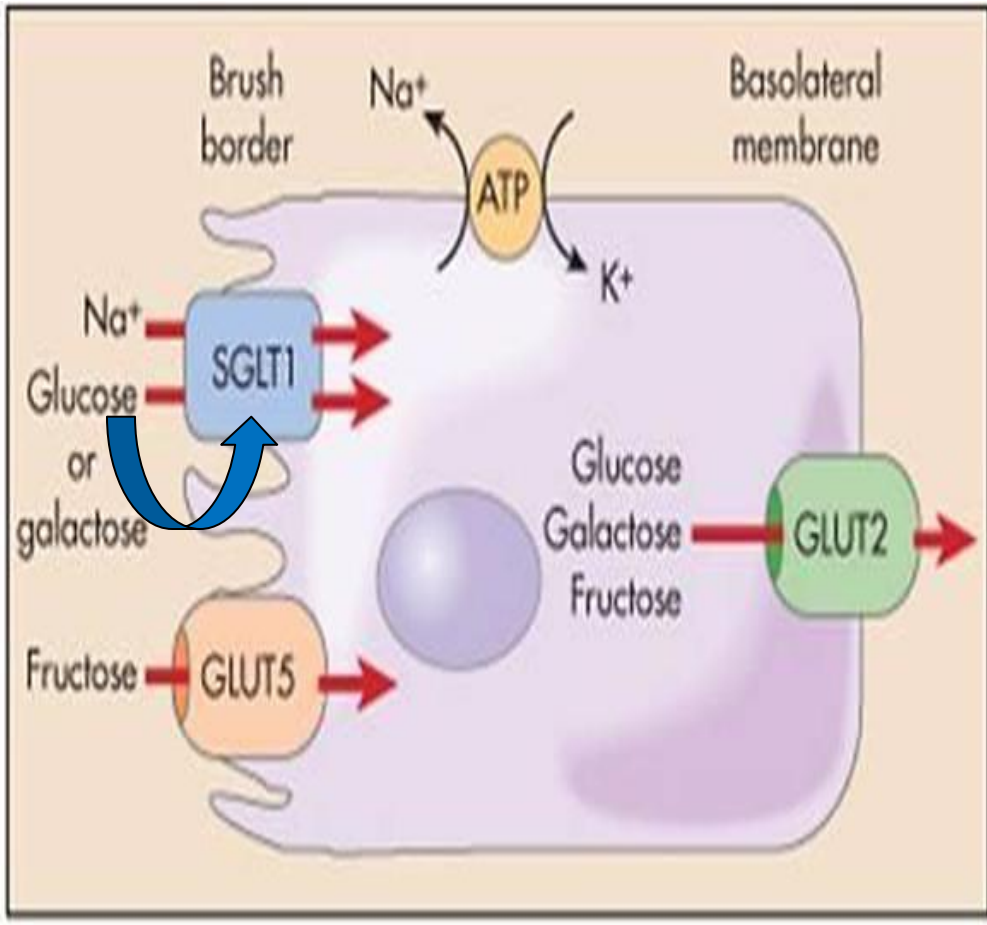
- The absorption occurs with concentration gradient (downhill i.e. from high concentration to low concentrations).
- Doesn't need ATP.
- Needs carriers (Na-independent glucose transporter - **GLUT5).**
- Eg: For transport of pentoses and fructose.

2-Active transport

- The absorption occurs against concentration gradient (uphill process i.e. from low glucose concentration outside the cell to high glucose concentration within the cell.
- Energy requiring process
- Requires specific transport protein and presence of Na ions **(SGLUT-1) .**
- Eg: For transport of glucose and galactose across the brush border membrane of mucosal cells.

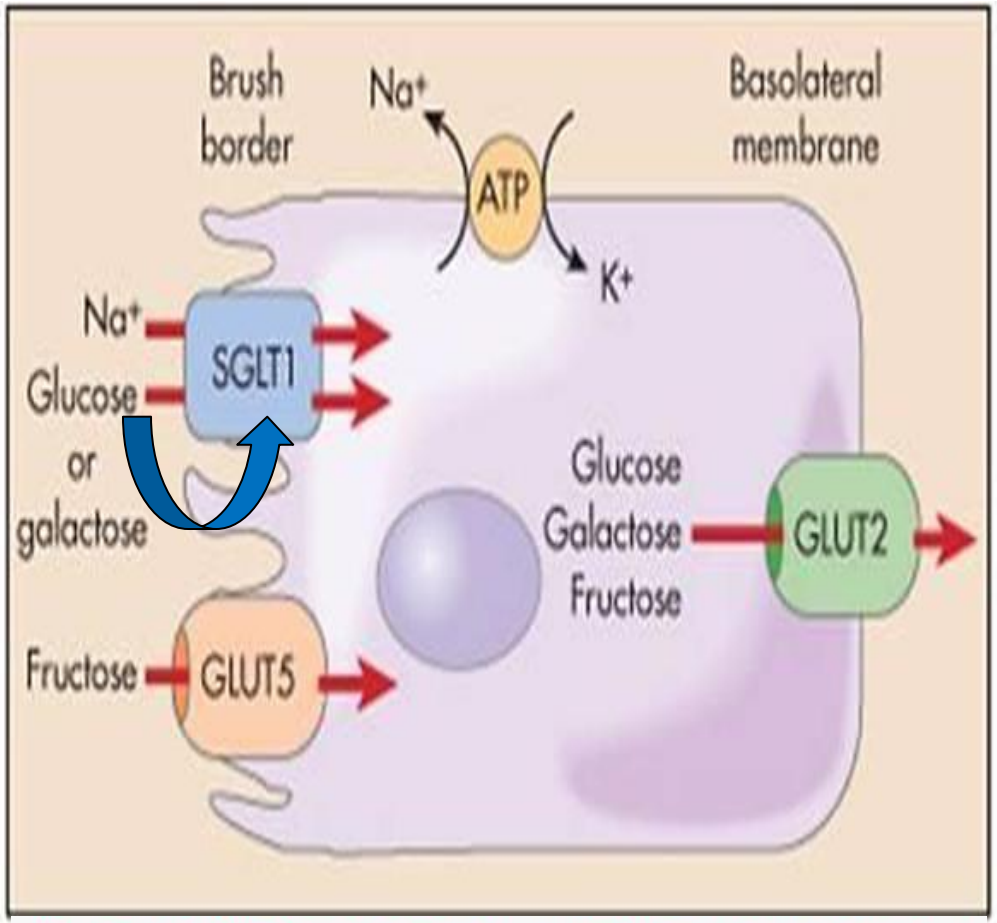
2-Active transport (SGLUT-1)

- Sodium dependent glucose transporter (SGLUT-1) binds both glucose and Na ions at separate sites and transports them through intestinal mucosal cell membranes.



2-Active transport (SGLUT-1)

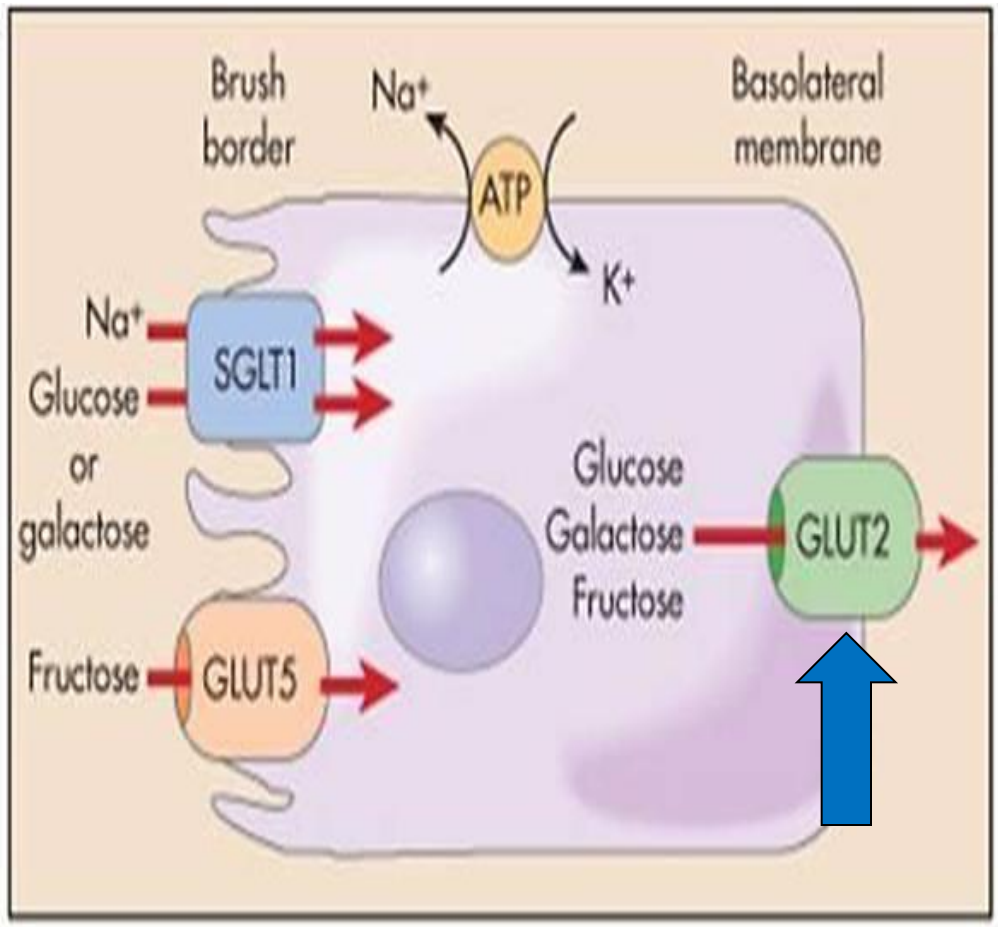
- Na is transported across cell memb. down its conc. gradiant (from high to low conc.),
- ATP is used to pump Na out through Na-K ATPase pump (hydrolysis of ATP which expels 3 Na+ from the cell in exchange of 2 K+).



SOdium is PUMPED out because it is osmotically active and if it remained it would lead to osmotic flow into proximal tubule epithelial cell. It is also inhibitory to many enzymes

2- Facilitative transport (GLUT-2)

- Exit of all sugars from mucosal cells to the blood occurs by **facilitative transport** through **GLUT2**.



Defects of absorption of carbohydrates:

1) Lactase deficiency (Lactose intolerance)

- ✓ **Causes:** Due to Deficiency of lactase enzyme which digest lactose into glucose and galactose.
- ✓ **Effect:** Accumulation of lactose in the intestine and its fermentation by intestinal bacteria with production of acids and gases with increase in the osmotic pressure.
- ✓ **Manifestations:** Distention, abdominal cramps, osmotic diarrhea and dehydration.
- ✓ **Treatment:** For infant : prevent the child from taking his mother's milk , and giving him lactose free milk formula

For adult : lactose free diet , yoghurt, green vegetables to ensure adequate calcium intake.

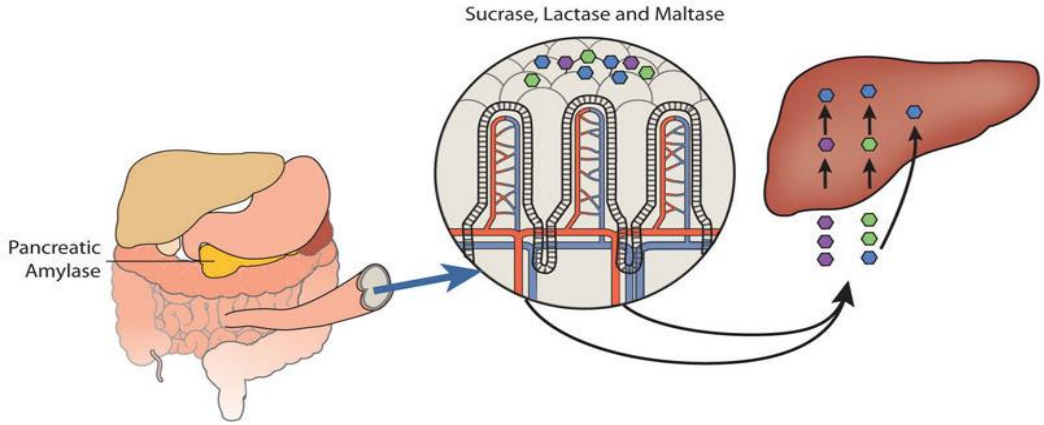
2) Sucrase deficiency

- ✓ Rare condition
- ✓ With the symptoms and signs of lactase deficiency in early childhood.

Fate of Absorbed Sugar

✓Monosaccharides (glucose, galactose and fructose) are passed from intestine via portal circulation to **the liver** where **galactose and fructose** are converted into glucose.

✓**Glucose** passes from the liver to systemic circulation where it undergoes several directions:



Fate of Absorbed Sugar

1) Uptake by tissues

- **All tissues** take glucose by several types of glucose transporters (GLUTs) . There are 5 types of GLUTs). All are **non-insulin dependent** except GLUT 4 which is **insulin dependent** and located in **muscles and adipose tissue**:

1) Glucose uptake by tissues

Glucose is transported through cell membrane of different tissues by different protein carriers or transporters. GLUT-1 to GLUT-14

- **$GLUT_1$: present mainly in red blood cells, and retina.**
- **$GLUT_2$: present in liver, kidneys, pancreatic B cells and lateral border of small intestine. For rapid uptake & release of glucose**
- **$GLUT_3$: present mainly in brain.**
- **$GLUT_4$: present in heart, skeletal muscles, and adipose tissues. It is for insulin-stimulated uptake of glucose (insulin-dependent).**
- **$GLUT_5$: small intestine and the testes transporter for fructose**

1) Glucose uptake by tissues

- **SGLUT1:** present in small intestine and kidneys, sodium-dependent, for active transport of glucose and galactose from lumen of small intestine and reabsorption of 10% glucose from glomerular filtrate in proximal renal tubules in kidney (90% of glucose reabsorption in proximal renal tubules occurs through SGLUT 2)

Fate of Absorbed Glucose

2) Glucose utilization by tissues:

- **Oxidation:**

a- Major pathway : Mainly for production of energy: glycolysis, and Kreb's cycle.

b- Minor pathway : Not for energy production:

- Pentose shunt for synthesis of pentoses and NADPH+H.

- **Synthesis of other CHO substances as:**

1.Galactose for lactose synthesis in mammary gland.

2.Fructose in seminal vesicles. formation.

3.Amino-sugar (glucosamine) for mucopolysaccharides formation.

4.Glucuronic acid for mucopolysaccharides formation.

3) Storage of glucose

Excess glucose is converted into:

a) **Glycogen** (Glycogenesis)and stored in liver and muscles

b) **Lipid** (lipogenesis) and stored in adipose tissue

4) Excretion of glucose

- ✓ **Under normal condition,** glucose is not excreted in urine
- ✓ **When blood glucose level exceeds glucose renal threshold** (180 mg/dL), glucose is excreted in urine because the kidney reaches the maximal tubular reabsorption .


Thank You