DIGESTION, ABSORPTION AND TRANSPORT OF CARBOHYDRATES

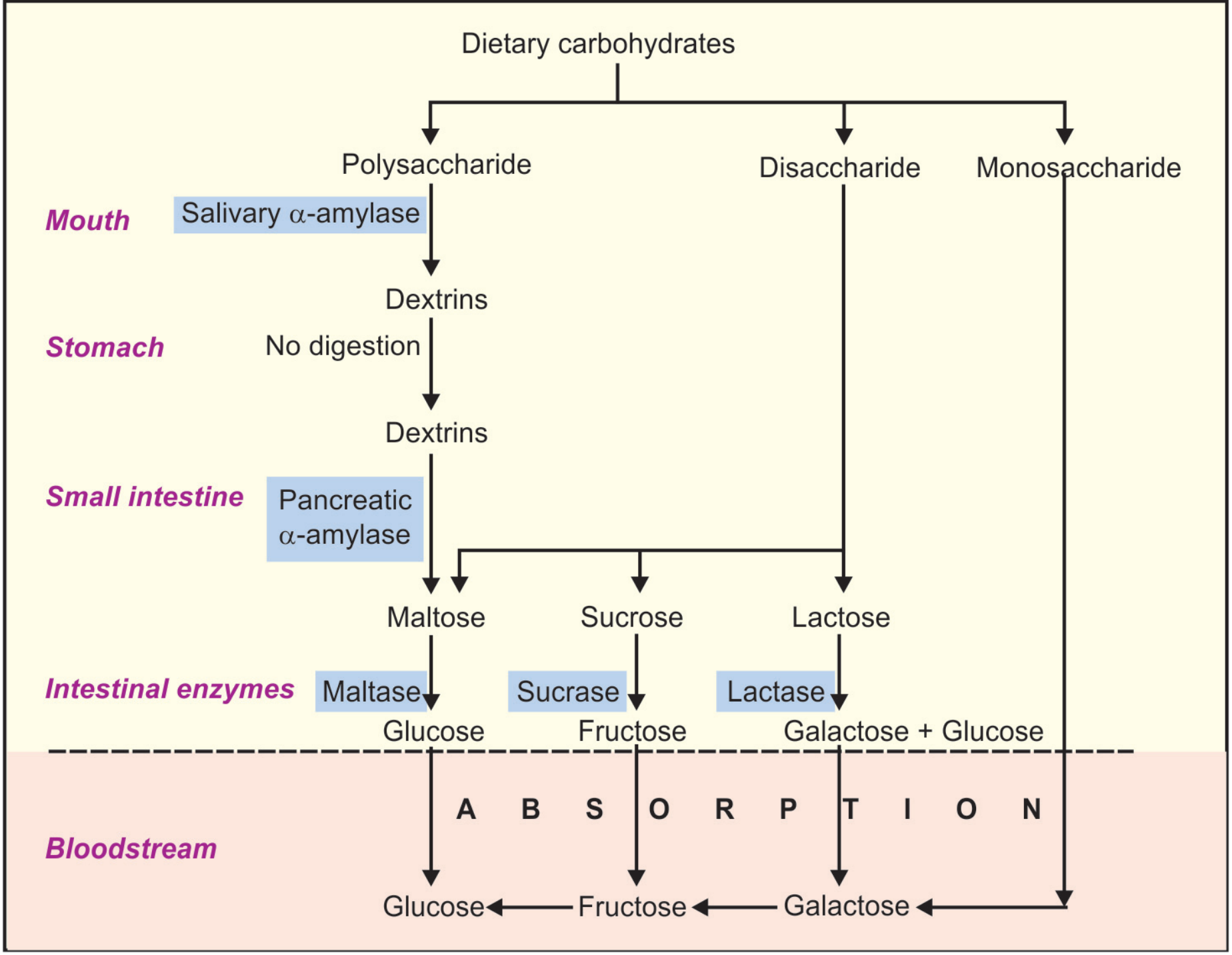
INTRODUCTION

- The major source of carbohydrates is found in plants.
- Glucose is the universal fuel for human cells.
- The glucose concentrations in the body are maintained within limits by various metabolic processes.

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 prior to absorption, whereas disaccharides and polysaccharides must be hydrolyzed to simple sugars before their absorption.

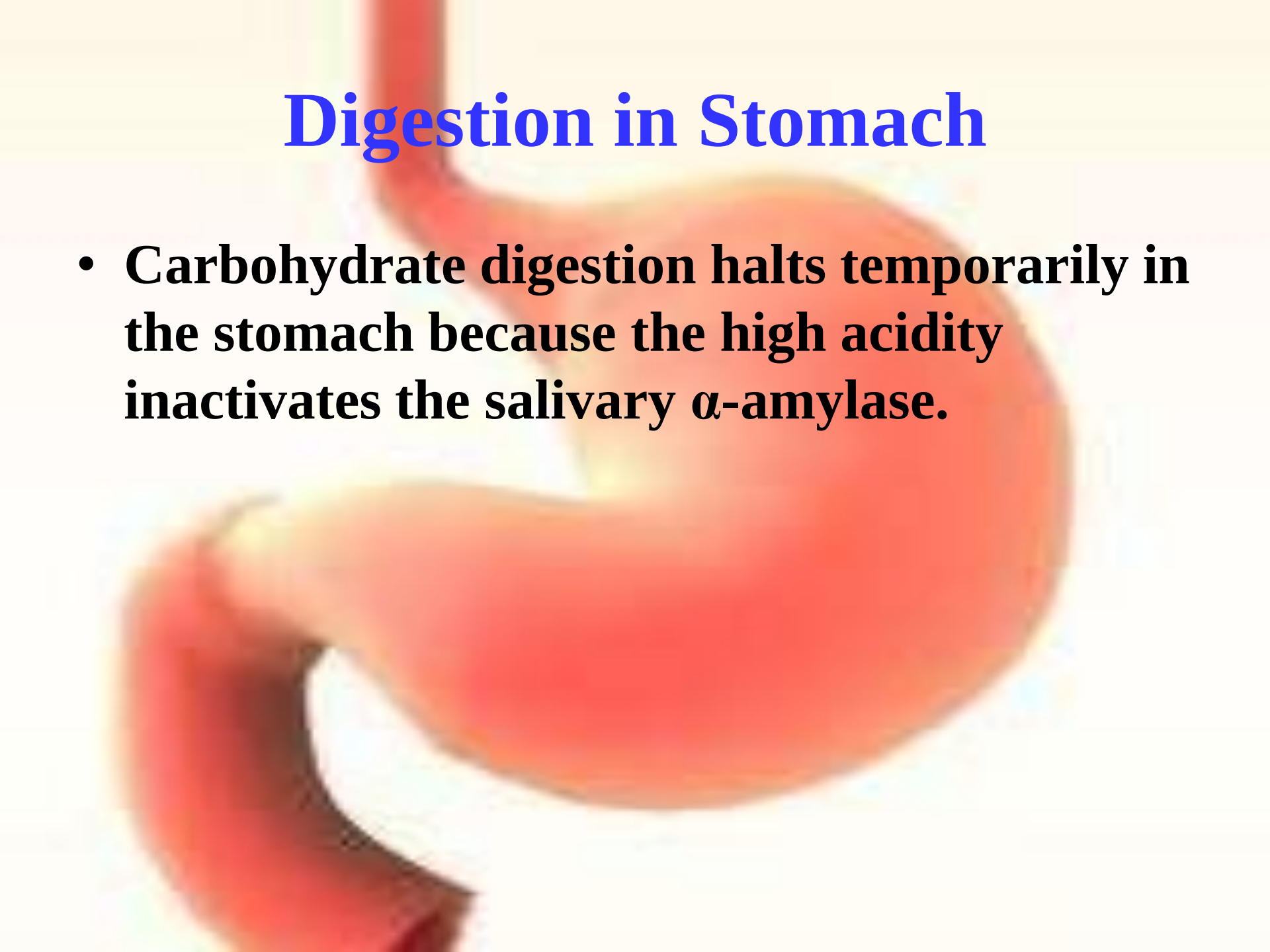

Dietary carbohydrates
Polysaccharide
Disaccharide
Monosaccharide
Mouth
Salivary α-amylase
Dextrins
Stomach
No digestion
Dextrins
Small intestine
Pancreatic α-amylase
Maltose
Sucrose
Lactose
Intestinal enzymes
Maltase
Sucrase
Lactase
Glucose
Fructose
Galactose + Glucose
A B S O R P T I O N
Bloodstream
Glucose
Fructose
Galactose

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.

Digestion in Stomach

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



Digestion in Intestine

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

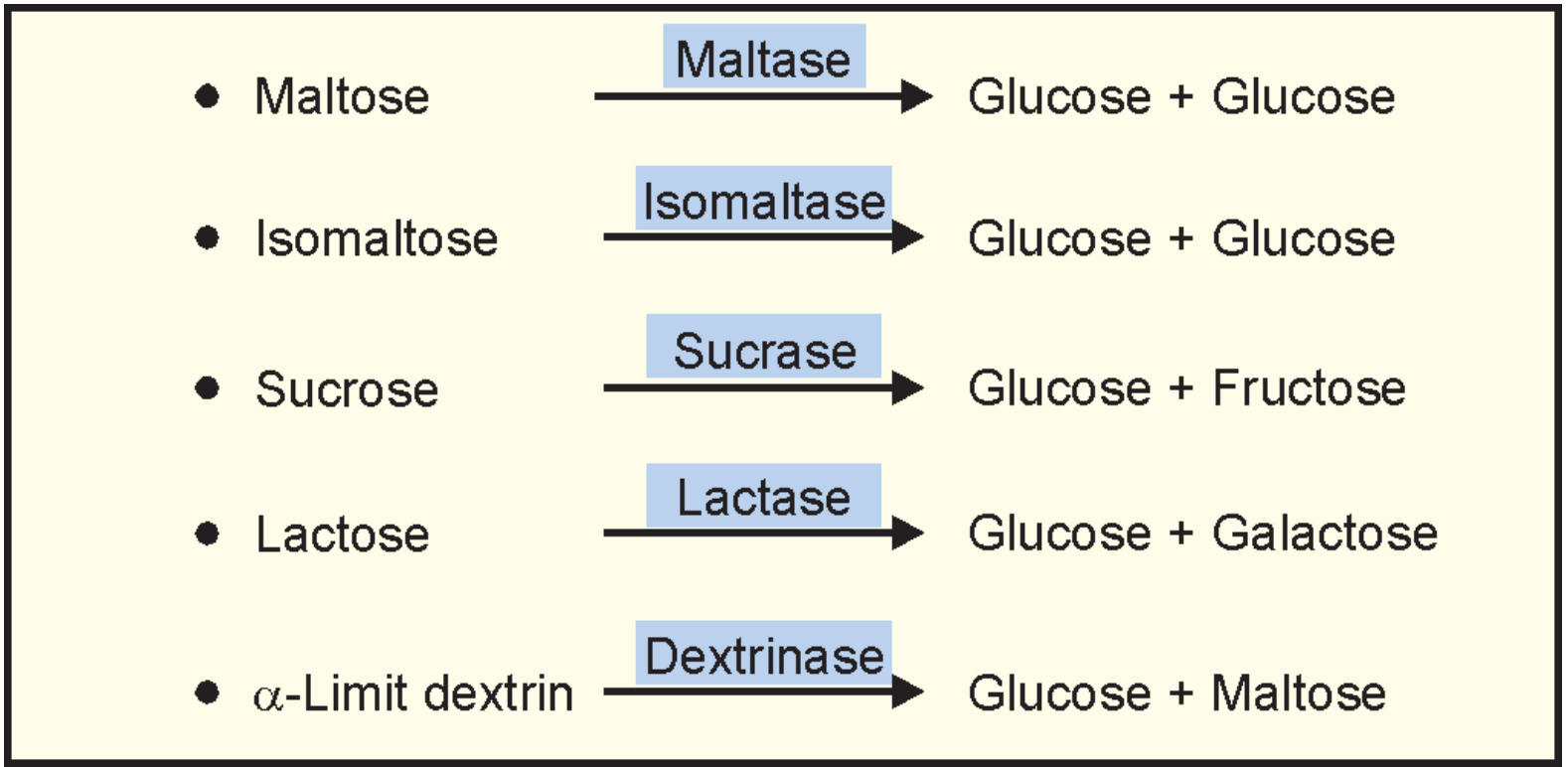
1. Digestion due to pancreatic **α-amylase**
2. Digestion due to intestinal enzymes : **sucrase, maltase, lactase, isomaltase.**

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.

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.

Absorption of Carbohydrates

- Carbohydrates are absorbed as monosaccharides from the intestinal lumen.
- Two mechanisms are responsible for the absorption of monosaccharides:

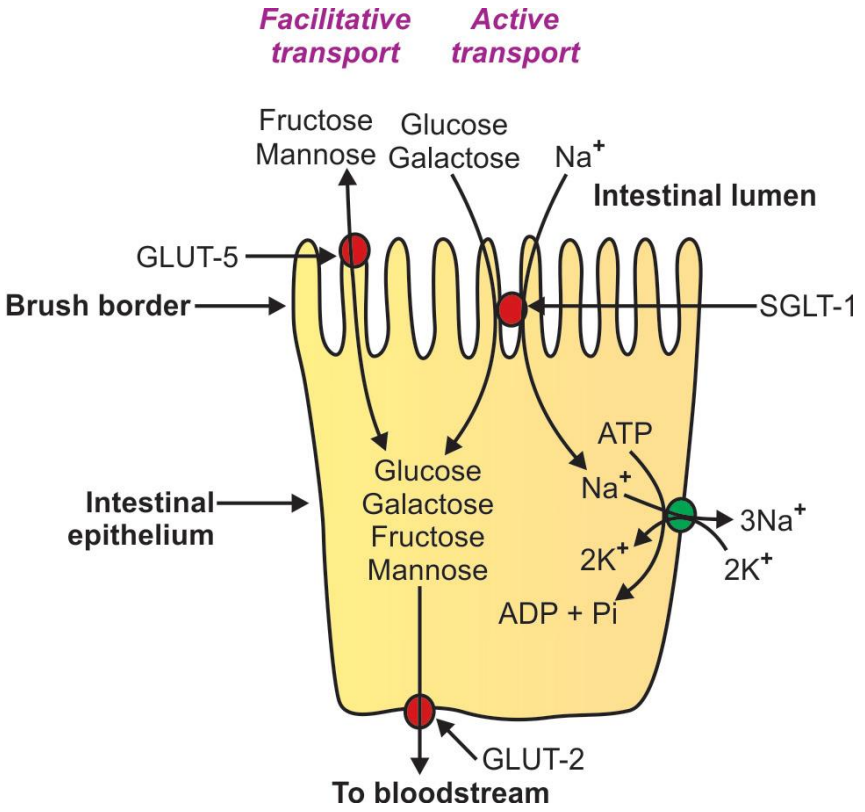
1. Active transport against a concentration gradient, i.e. from a low glucose concentration to a higher concentration.
2. Facilitative transport, with concentration gradient, i.e. from a higher concentration to a lower one.

Active Transport

- The transport of glucose and galactose across the brushborder membrane of mucosal cells occurs by an ***active transport.***
- Active transport is an energy requiring process that requires a specific transport protein and the presence of sodium ions

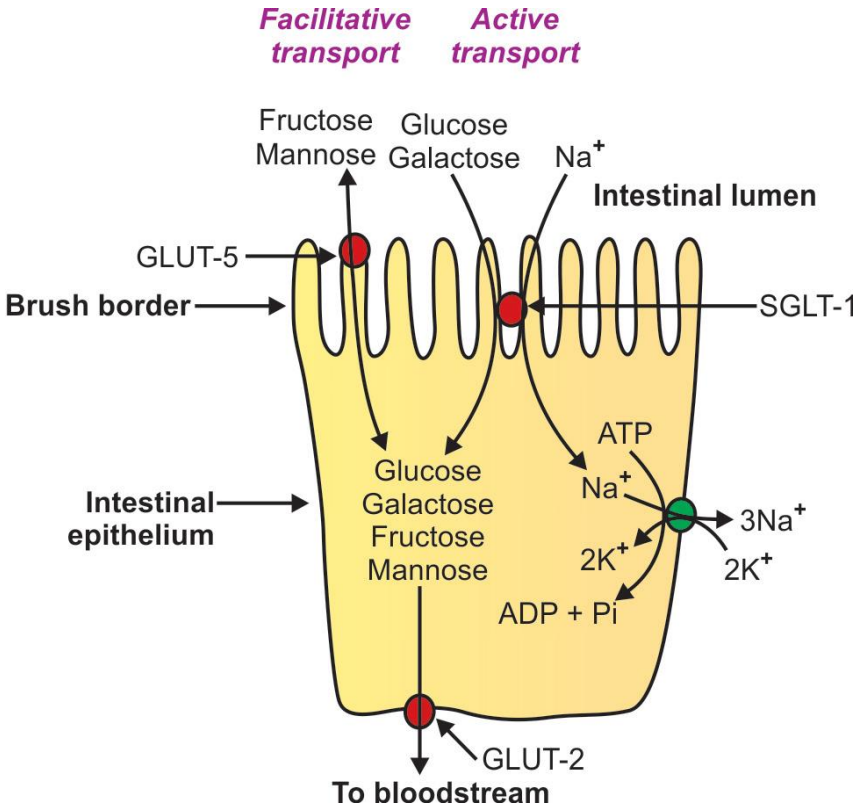
Active Transport

- A sodium dependent glucose transporter (SGLT-1) binds both glucose and Na+ at separate sites and transports them both through the plasma membrane of the intestinal cell.



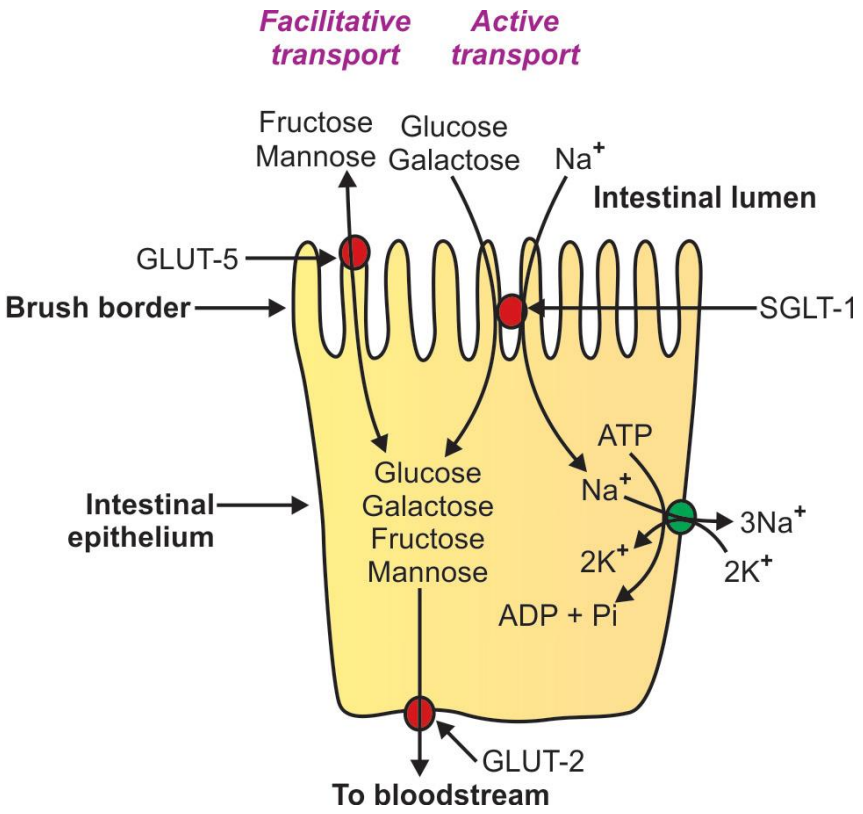
Active Transport

- The Na+ is transported down its concentration gradient (higher concentration to lower concentration) and at the same time glucose is transported against its concentration gradient.



Active Transport

- The free energy required for this active transport is obtained from the hydrolysis of ATP linked to a **sodium pump** that expels Na+ from the cell in exchange of K+



Facilitative Transport

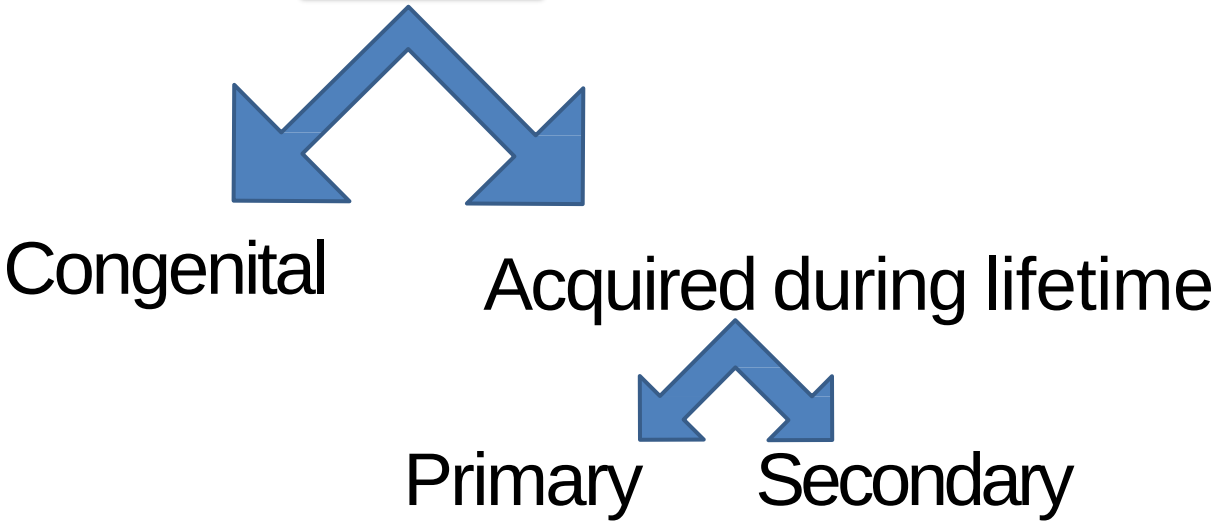
- ***Fructose*** and ***mannose*** are transported across the brush border by a Na+ independent facilitative diffusion process, requiring specific glucose transporter, GLUT-5.
- The same transport can also be used by glucose and galactose if the concentration gradient is favorable.

Transport of Carbohydrates

- The sodium independent transporter, GLUT-2 that facilitates transport of sugars out of the mucosal cells, thereby entering the portal circulation and being transported to the liver.

Clinical significance of Digestion

- Lactose intolerance is the inability to digest lactose due to the deficiency of Lactase enzyme.
- Causes



Congenital Lactose intolerance

- It is a congenital disorder
- There is complete absence or deficiency of lactase enzyme.
- The child develops intolerance to lactose immediately after birth.
- It is diagnosed in early infancy.
- Milk feed precipitates symptoms.

Baby with Lactose Intolerance

Primary Lactase deficiency

- Primary lactase deficiency develops over time
- There is no congenital absence of lactase but the deficiency is precipitated during adulthood.
- The gene for lactose is normally expressed upto RNA level but it is not translated to form enzyme.
- It is very common in Asian population.
- There is intolerance to milk + dairy products.

Adult with lactose intolerance

Secondary lactase deficiency

- It may develop in a person with a healthy small intestine during episodes of acute illness.
- This occurs because of mucosal damage or from medications resulting from certain **gastrointestinal diseases**, including exposure to **intestinal parasites** such as Giardia lamblia.
- In such cases the production of lactase may be permanently disrupted.

Secondary lactase deficiency

- A very common cause of **temporary** lactose intolerance is gastroenteritis, particularly when the gastroenteritis is caused by **rotavirus.**

- Another form of temporary lactose intolerance is lactose overload in infants. Secondary lactase deficiency also results from injury to the small intestine that occurs with **celiac disease, Crohn's disease, or chemotherapy**.

- This type of lactase deficiency can occur at any age but is more common in infancy.

Intestinal parasite (Giardia lamblia)

Rotavirus

Clinical manifestations

- In the form of abdominal cramps, distensions, diarrhea, constipation, flatulence upon ingestion of milk or dairy products

Biochemical basis

- Undigested lactose in intestinal lumen is acted upon by bacteria and is converted to CO_2, H_2, 2 carbon compounds and 3 carbon compounds or it may remain undigested.

- CO_2 and H_2 causes Distensions and flatulence
- Lactose + 2C + 3C are osmotically active.

- They withdraw H_2O from intestinal mucosal cell and cause osmotic diarrhea or constipation because of undigested bulk.

Abdominal distension

Flatulence

Diagnosis

- *Two tests are commonly used: -*
- **Hydrogen Breath Test**
- The person drinks a lactose-loaded beverage and then the breath is analyzed at regular intervals to measure the amount of hydrogen. Normally, very little hydrogen is detectable in the breath, but undigested lactose produces high levels of hydrogen. The test takes about 2 to 3 hours.

- **Stool Acidity Test**
- The stool acidity test is used for infants and young children to measure the amount of acid in the stool. Undigested lactose creates lactic acid and other short chain fatty acids that canbe detected in a stool sample. Glucose may also be present in the stool as a result of undigested lactose.
- Besides these tests, urine shows-positive test with **Benedict's test,** since lactose is a reducing sugar and a small amount of lactose is absorbed in the intestinal cell by pinocytosis and is rapidly eliminated through kidneys in to urine.(Lactosuria)
- **Mucosal biopsy** confirms the diagnosis.

Management of lactose intolerance

- Avoidance of dairy products.
- Although the body's ability to produce lactase cannot be changed, the symptoms of lactose intolerance can be managed with dietary changes.
- Most people with lactose intolerance can tolerate some amount of lactose in their diet. Gradually introducing small amounts of milk or milk products may help some people adapt to them with fewer symptoms.
- Partly digested dairy products can also be given.

- **Lactose-free, lactose-reduced milk**, Soy **milk** and other products may be recommended.
- **Lactase enzyme** drops or tablets(Yeast tablets) can also be consumed.
- Getting enough **calcium** is important for people with lactose intolerance when the intake of milk and milk products is limited.
- A balanced diet that provides an adequate amount of nutrients—including calcium and **vitamin D**—and minimizes discomfort is to be planned for the patients of lactose intolerance.