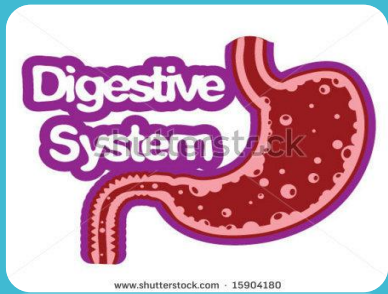


[lecture 5]

Biochemical Aspects of Digestion of Proteins & Carbohydrates



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The Objectives

By the end of this lecture, the student should be able to:

- Understand the overall process of dietary protein and carbohydrates digestion, the organs involved, the enzymes required, and the end products.
- Implement the basic science knowledge of the process of protein & carbohydrates digestion to understand the clinical manifestations of diseases that involve defective protein or carbohydrates digestion &/or absorption

Red =
Import-
ant

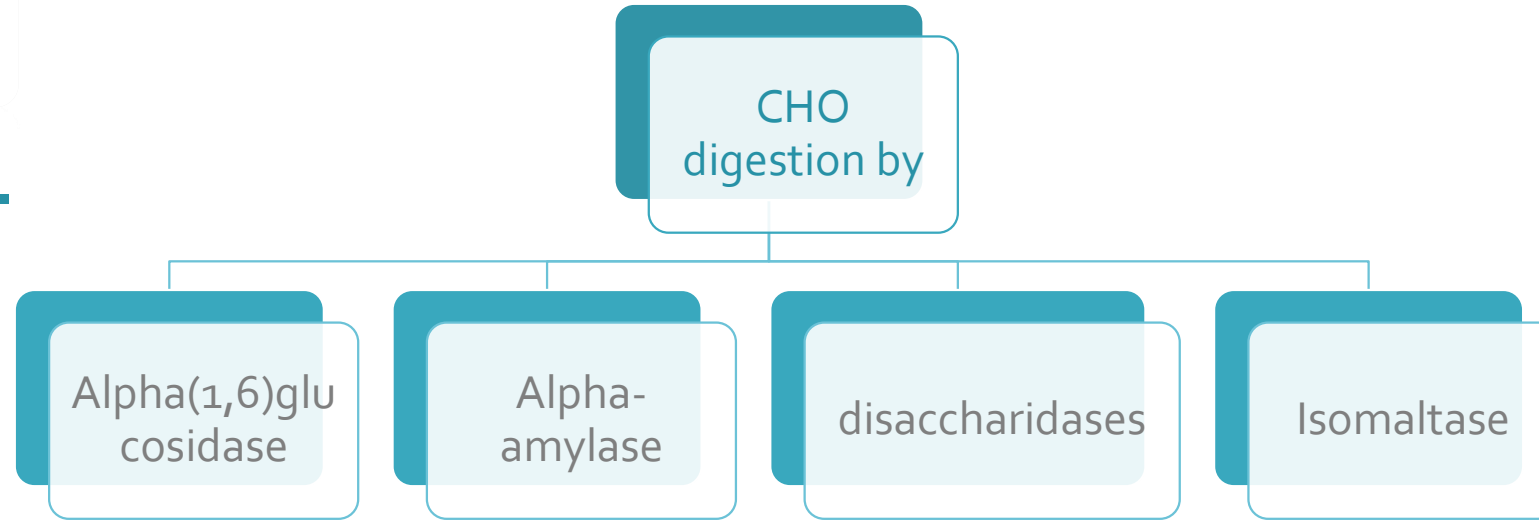
Blue =
explain

Green =
addition
notes

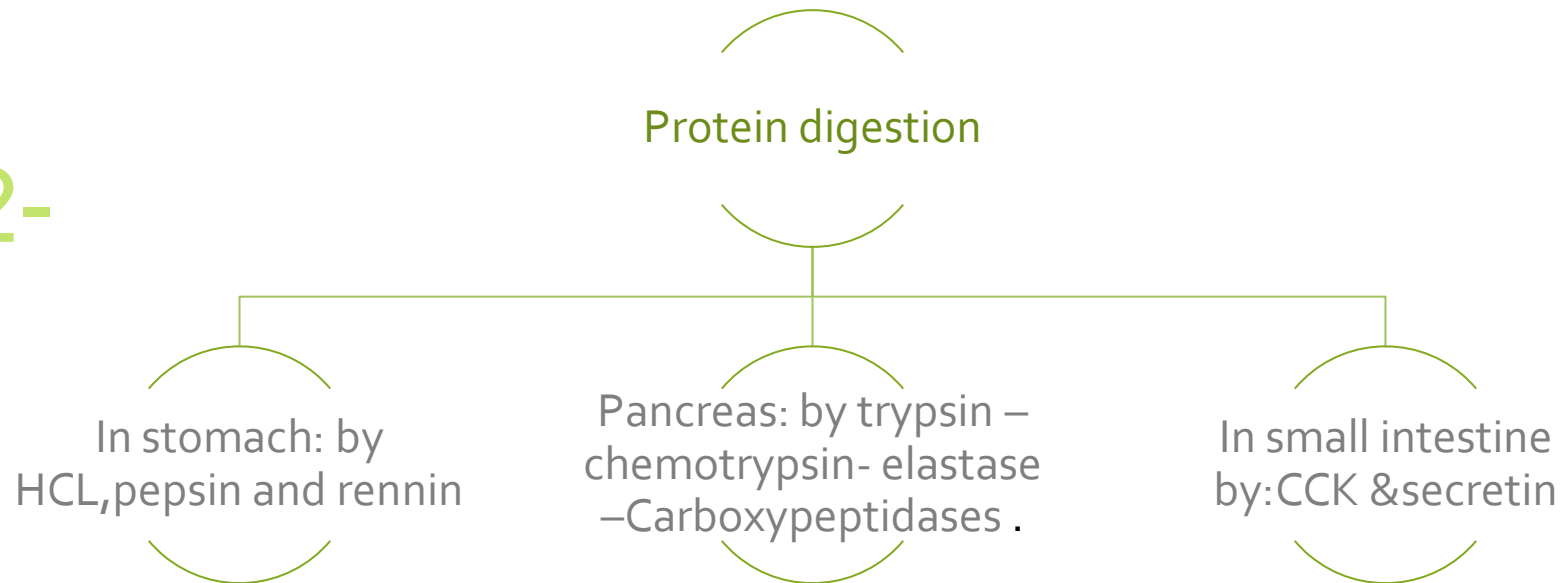
Mind Map



1-



2-

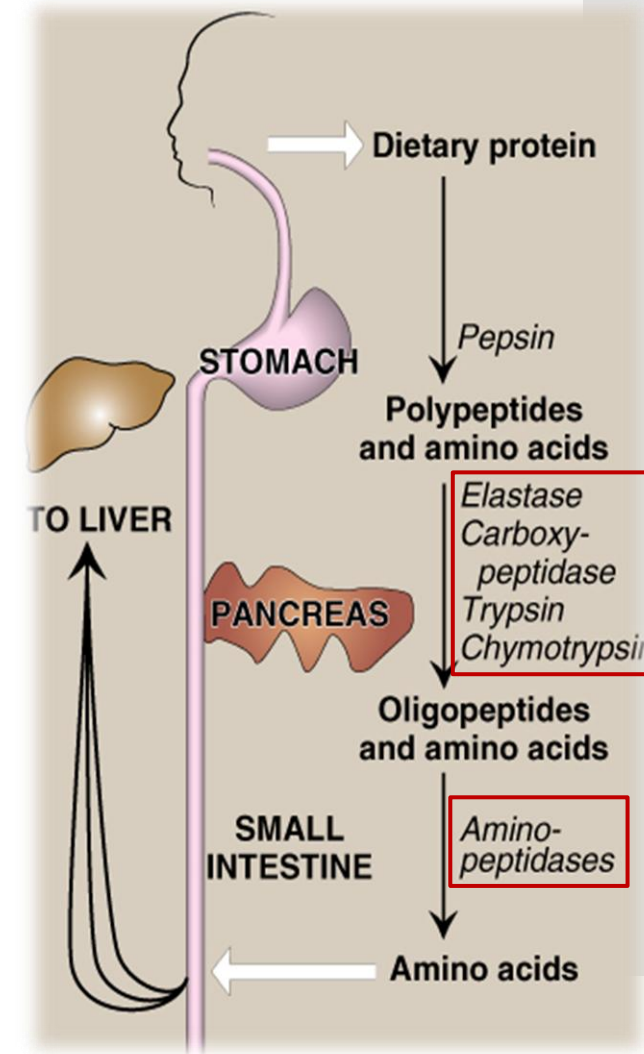
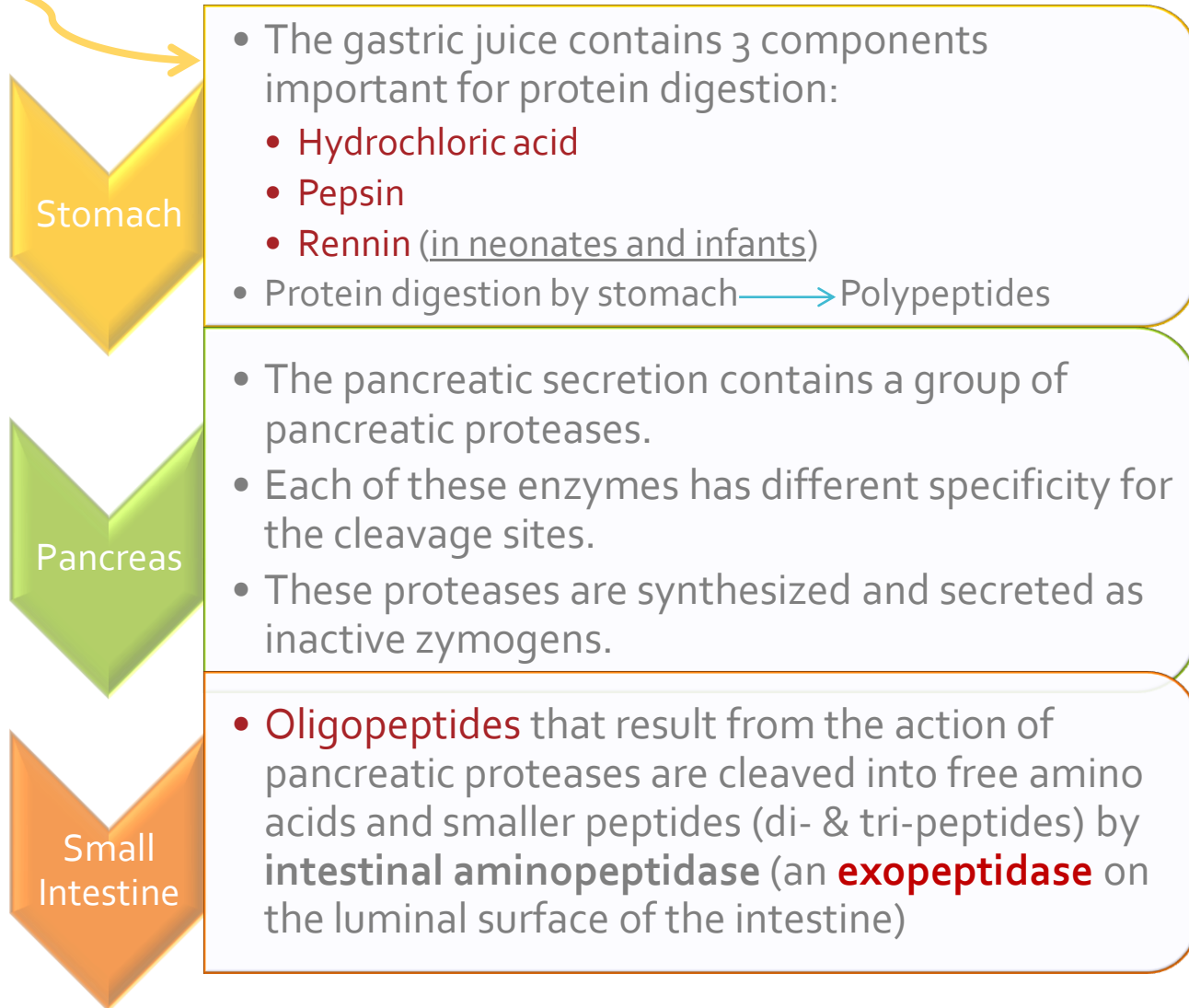




The source of proteolytic enzymes responsible for degrading dietary proteins

Protein Digestion

- Dietary proteins constitute 70-100 g/day.
- Proteins are generally too large to be absorbed by the intestine.
- They must, therefore, be hydrolyzed to their constituent amino acids, which can be absorbed.





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Pancreatic Enzymes

Activation of Pancreatic enzymes

1

Enteropeptidase activates trypsinogen:
It converts trypsinogen (inactive) into trypsin (active)

2

Trypsin then activates all the other pancreatic zymogens (including itself)

3

Enteropeptidase is an enzyme synthesized by, and present on the luminal surface of intestinal mucosal cells (the brush border membrane)



Zymogen	Active enzyme	Activating enzyme
Trypsinogen	Trypsin (endopeptidase)	1-Enteropeptidase 2- Trypsin (autocatalysis)
Chymotrypsinogen	Chymotrypsin (endopeptidase)	Trypsin
Proelastase	Elastase (endopeptidase)	Trypsin
Procarboxypeptidases	Carboxypeptidases (exopeptidases)	Trypsin



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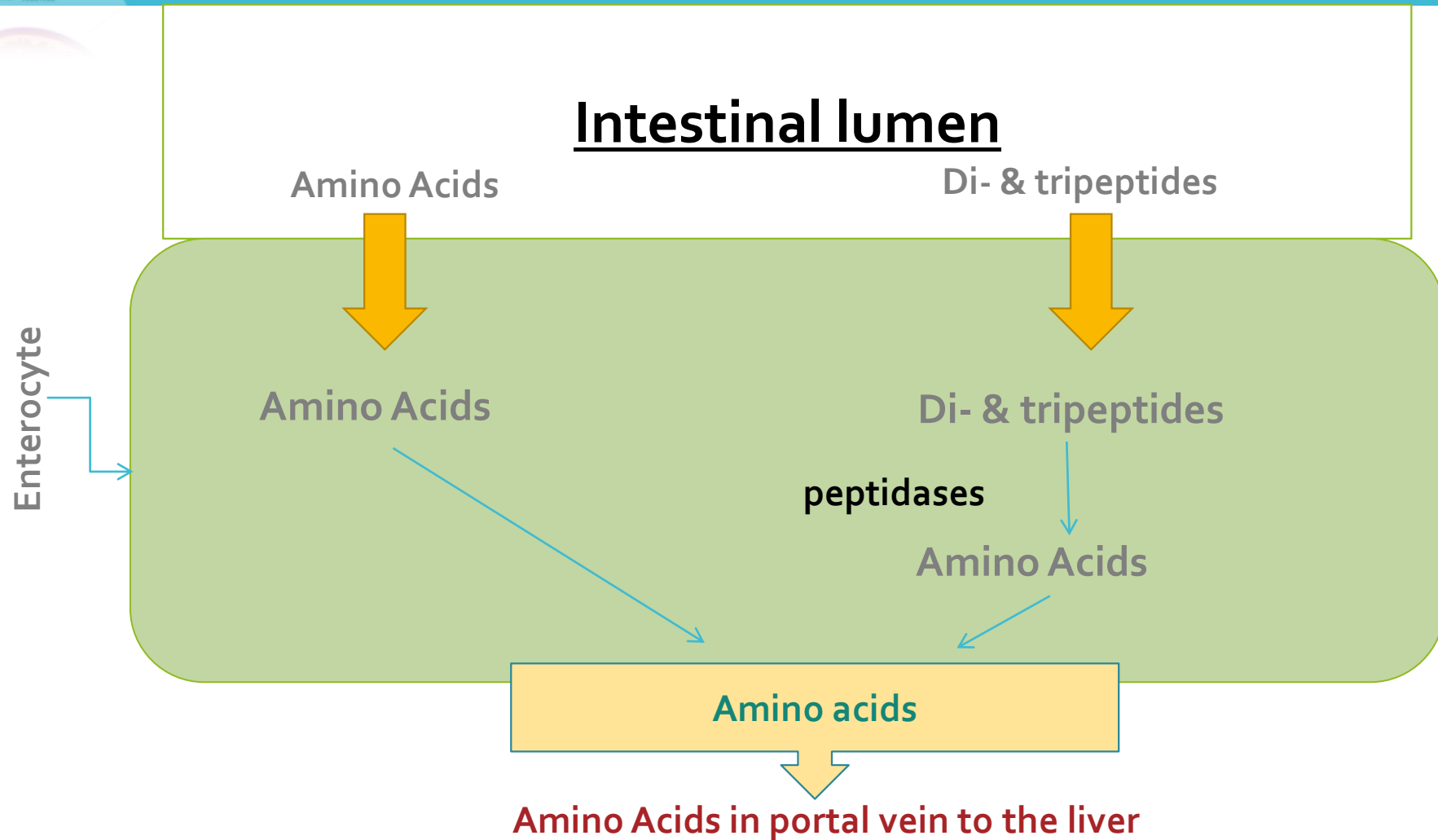


Hormonal control of digestion in small intestine

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The gut hormone	Stimulus for secretion	Effects
1- Cholecystikinin (CCK)	The presence of partially digested proteins (& lipids) in the upper small intestine	<ol style="list-style-type: none">1. Stimulates the release of pancreatic digestive enzymes2. Stimulates the contraction of the gall bladder & release of bile3. Decreases gastric motility → slower release of gastric contents into the small intestine
2- Secretin	Low pH of the chyme entering the intestine	Stimulates the pancreas to release a watery solution rich in bicarbonate to neutralize the pH of the intestinal contents (to reach the optimum pH for digestive activity by pancreatic enzymes)

Absorption of digested proteins





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Abnormalities in protein digestion

Pancreatic insufficiency, e.g., chronic pancreatitis, cystic fibrosis, surgical removal of the pancreas → incomplete digestion & absorption of lipids & proteins → abnormal appearance of lipids (steatorrhea) & undigested proteins in the feces

Celiac Disease (Celiac sprue)

It is a disease of malabsorption resulting from immune-mediated damage to the villi of small intestine in response to ingestion of gluten
Gluten is a protein found in wheat, rye, and barley



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Biochemical aspects of digestion of dietary carbohydrates

Carbohydrate digestion:

Dietary carbohydrates:

Carbohydrate digestion is rapid. Which is why it is recommended to eat proteins for breakfast so that you'll feel full for a longer while than say if you eat donuts. Generally completed by the time the gastric contents reach the junction between the duodenum and jejunum. The site of digestion: mouth and intestinal lumen.

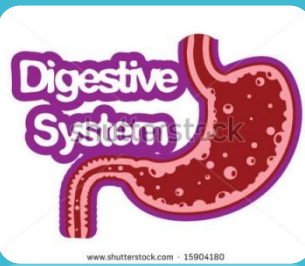
Polysaccharides (mainly)	Oligosaccharides	Disaccharides	Monosaccharides
<ul style="list-style-type: none"> Starch (plants) Glycogen (animal) Cellulose (plants) 	<p>Contain α (1-4) and α (1-6) bonds. Chemically similar in structure</p> <p>Contain β (1-4) bonds.</p>	<ul style="list-style-type: none"> Sucrose Lactose Maltose 	<p><u>Little amounts</u></p>

Enzymes for digestion:

Enzyme	α -amylase (both salivary and pancreatic)	Disaccharidases (intestinal)	Isomaltase and α (1,6) glucosidase (intestinal)
Substrate	Polysaccharides	Disaccharides	Branch points of oligo/disaccharides



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Enzymes for digestion of dietary carbohydrates

- No dietary carbohydrate digestion occurs in the **stomach** (high acidity of stomach inactivates salivary α -amylase).
- Pancreatic α -amylase continues the process of starch and glycogen digestion in the small intestine (secreted by pancreas, worked in the small intestine).

Effect of α -amylase on glycogen

Hydrolysis of:

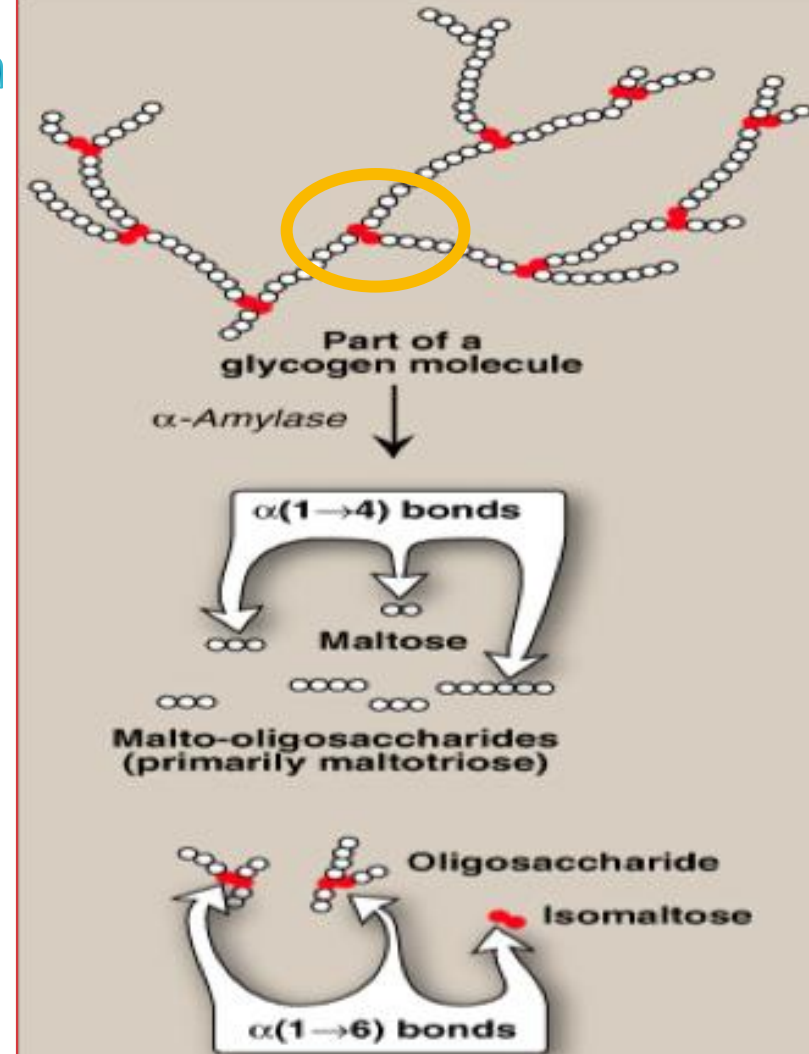
- α (1,4) glycosidic bonds

Products:

- Mixture of short oligosaccharides (branched and unbranched)

Disaccharides:

- Maltose and isomaltose





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Serum levels of α -amylase

25-125U/L

- Normal levels in the serum
- Normally found in very small amounts in the serum as it is not its side of action.

Clinical significance of rising circulating levels of α -amylase activity:

- **Diagnosis of acute pancreatitis** (*damage of pancreatic cells leads to release and activation of the intracellular enzymes into the blood*)

Its levels start to rise within a few hours

Reaches peak within 12-72 hrs

Returns to normal within a few days. **Won't be detected in a week.**



Final digestion of carbohydrates by intestinal enzymes in the small intestine

Enzymes

- Secreted by and remain associated with the brush border membranes of the intestinal mucosal cells.

Location of their action:

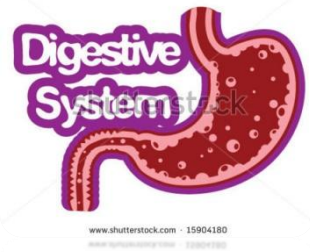
- Mucosal lining of jejunum

They include:

- Disaccharidases
- $\alpha(1-6)$ glucosidase for branched oligosaccharides

Intestinal disaccharidases

<u>Enzyme</u>	<u>Substrate</u>	<u>Product</u>
Isomaltase	isomaltose	2 Glucose
Maltase	Maltose	2 Glucose
Sucrase	Sucrose	Glucose + fructose
Lactase = (β – galactosidase)	lactose	Glucose + galactose



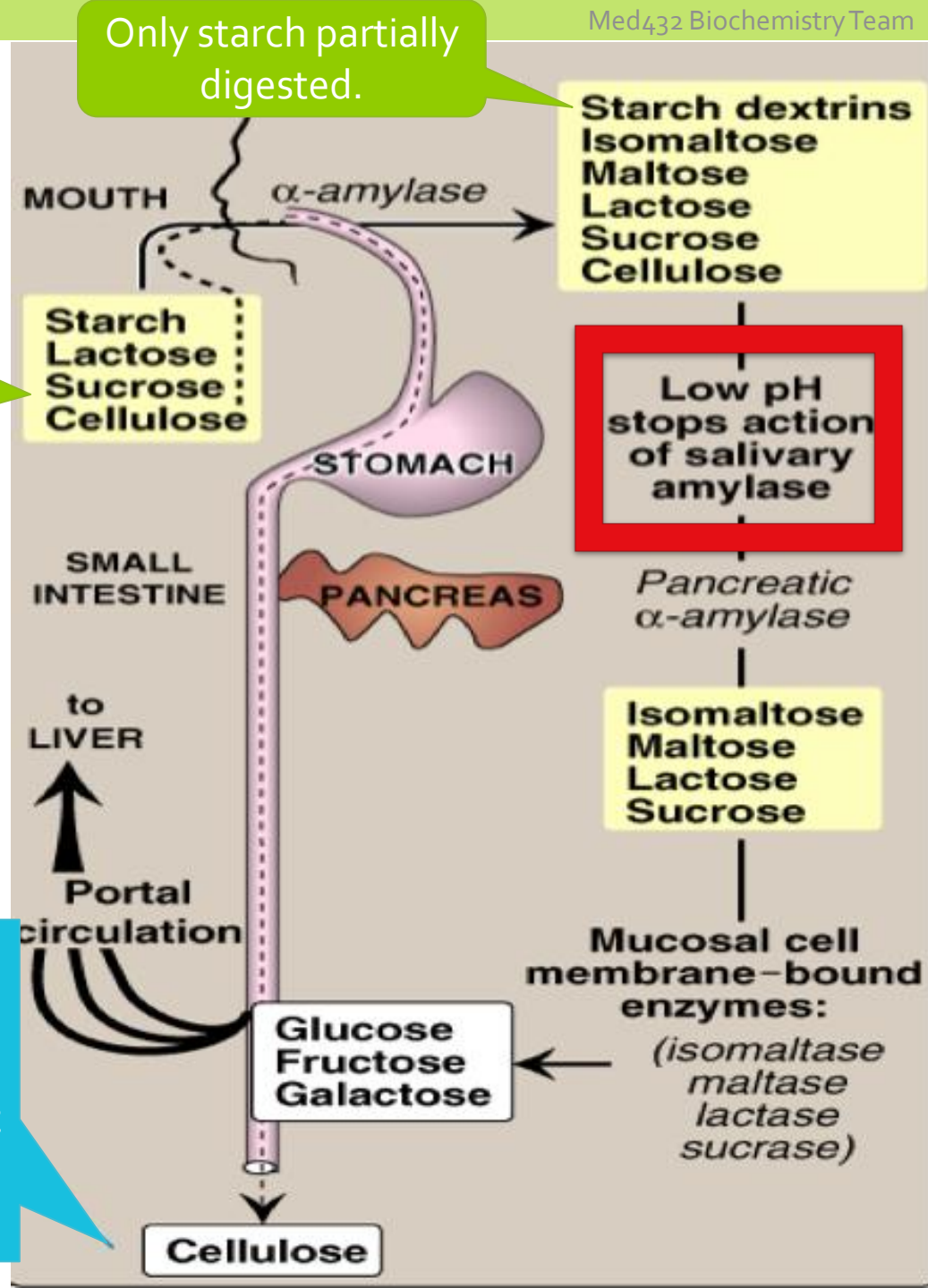
Digestion of carbohydrates

We mostly ingest polysaccharides and disaccharides.

*Even though cellulose is excreted as is. Indigestible. It still has many benefits. It Decreases cholesterol absorption, regulates motility, excretion. Insufficient intake of fibers results in chronic constipation. It is also linked to colon cancer.

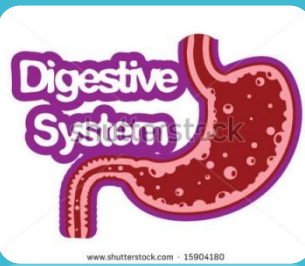
Dietary **cellulose** cannot be digested to the absence of the enzyme that can cleave β (1-4) bonds. It passes through the GIT intact. Despite that, it has many beneficial effects*. Cellulose remains throughout as it is.

Only starch partially digested.





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Absorption of monosaccharides by intestinal mucosal cells

Location:

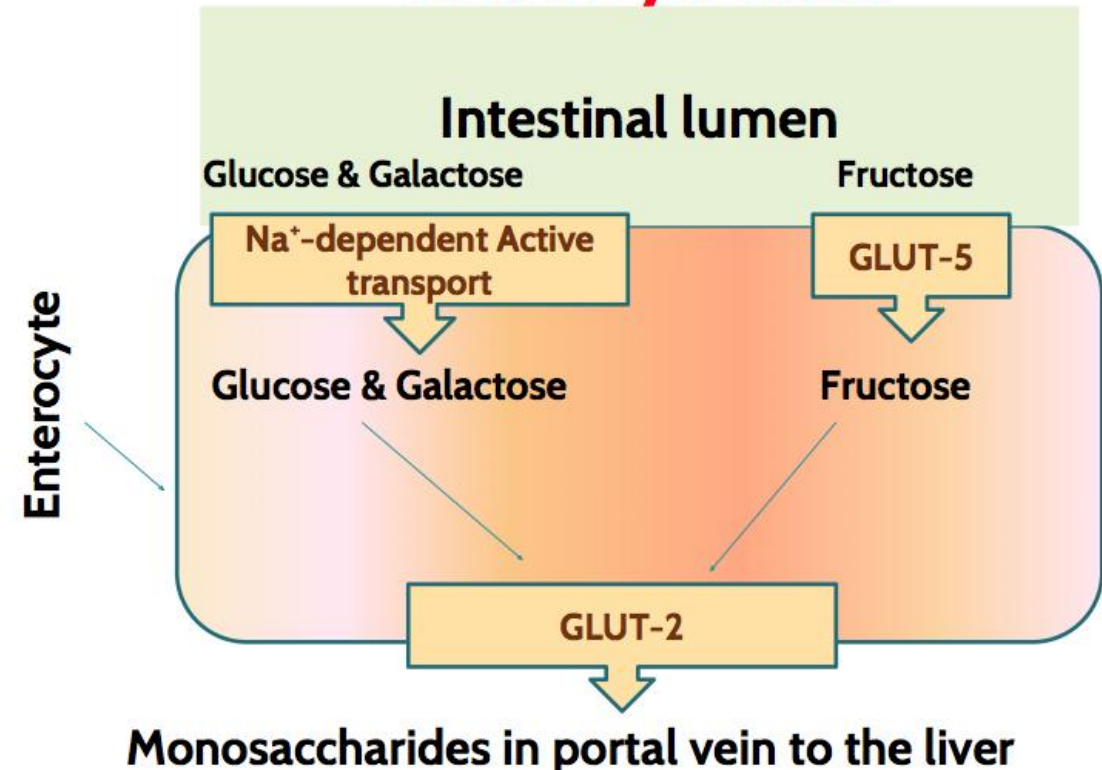
- Duodenum and upper jejunum

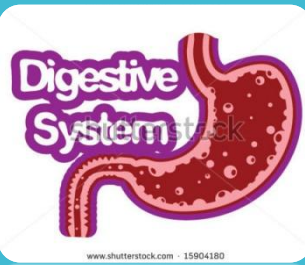
Insulin not required for uptake of glucose by intestinal cells

Different monosaccharides have different mechanisms of absorption

- Facilitated diffusion (GLUT-mediated)
- Active transport (energy dependent): cotransport with Na^+
- Both are needed. No simple diffusion.

Absorption of digested carbohydrates





Abnormal digestion of disaccharides (e.g., lactose)

Lactose intolerance – lactase(β –galactosidase) deficiency

Lactase deficiency

Undigested carbohydrates in the intestine

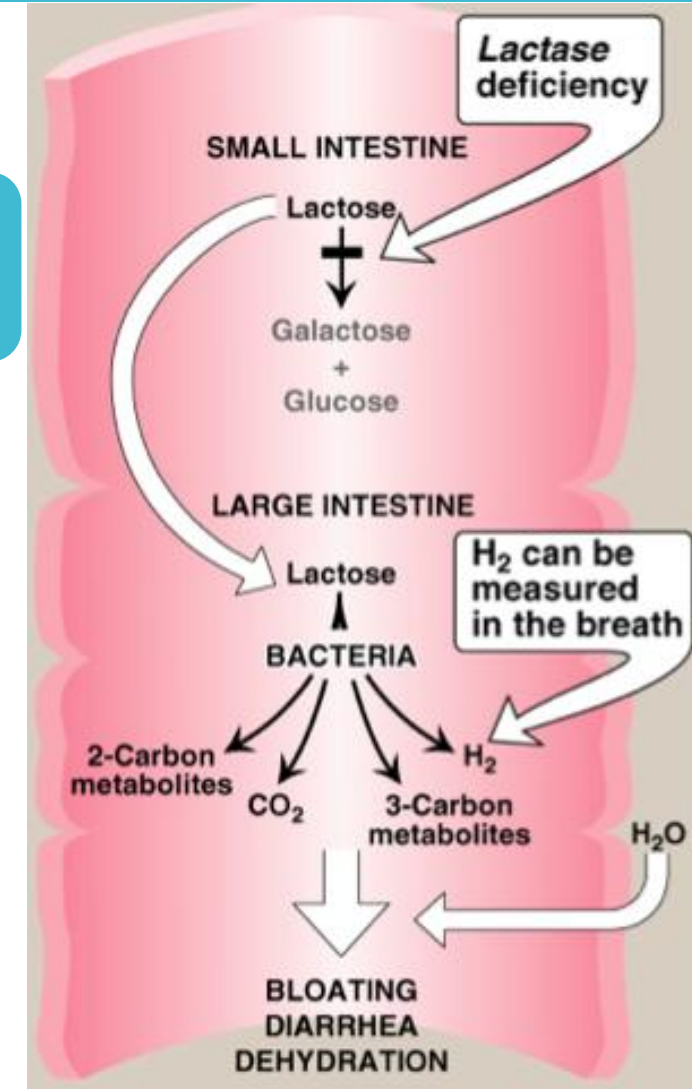
Osmotic diarrhea (osmotic dragging)

Bacterial fermentation of undigested compounds in the large intestine

CO₂, H₂ gas

Abdominal cramping, diarrhea, distention and flatulence

*Normally, no amount of lactose reaches the large intestines as its already been digested and absorbed. In lactose deficiency, it persists undigested until it is fermented by the bacteria in the large intestine producing gases, hydrogen and other unnaturally occurring substances that result in osmotic dragging and subsequent diarrhea.





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Summary

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Digestion of dietary proteins

- ✓ Proteolytic enzymes responsible for digestion of dietary proteins are produced by the **stomach**, the **pancreas** & the **small intestine**.
- ✓ The digestion of proteins in the stomach is the result of the action of *HCl*, *pepsin* & *rennin* .
- ✓ Pancreatic proteases are, like pepsin, synthesized and secreted as **inactive** zymogens .

- ✓ The intestinal digestion of proteins occurs in the small intestine's lumen, on the luminal surface of the small intestine, and is completed intracellularly to produce free amino acids .
- ✓ In pancreatic insufficiency, the digestion and absorption of fat & protein is incomplete → steatorrhea & appearance of undigested proteins in the feces .



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Summary

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Digestion of dietary carbohydrates

- Salivary α -amylase acts on dietary glycogen & starch in the **mouth**.
- Pancreatic α -amylase continues the process of polysaccharide digestion in small intestine.
- The final digestive processes of carbohydrates into *monosaccharides* occur at the mucosal lining of the small intestine by **disaccharidases & $\alpha(1,6)$ glucosidase** .

- Dietary cellulose cannot be digested due to the absence of enzyme that can cleave β (1-4) bonds, so it passes through the GIT largely intact. Despite that, it has several beneficial effects.
- Absorption of the monosaccharides requires specific transporters (GLUTs).
- Lactose intolerance is due to deficiency of lactase enzyme and causes abdominal cramps, diarrhea & flatulence.

Test your knowledge ...!

Q1/ The gastric juice contains 3 components important for protein digestion , Except :

- A) Hydrochloric acid
- B) Trypsin
- C) Pepsin
- D) Rennin

Q2/ Most of active Pancreatic enzymes that digest proteins are endopeptidase , Except :

- A) Chymotrypsin
- B) Trypsin
- C) Carboxypeptidases
- D) Elastase

Q3/ Which carbohydrate cannot be digested and also excreted as is :

- A) Sucrose
- B) cellulose
- C) Isomaltose
- D) lactose

Answers :
1- B
2- C
3- B



**Biochemistry
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If you find any mistake, please contact us:)

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**Biochemistry team leaders:
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Thank you

