# Biochemical Aspects of Digestion of Proteins and Carbohydrates

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Editing File

# Objectives:

- Understand the overall process of dietary proteins' and carbohydrates' digestion, the organs involved, the enzymes required, and the end products

- Implement the basic science knowledge of the process of proteins & carbohydrates digestion to understand the clinical manifestations of diseases that involve defective proteins' or carbohydrates' digestion &/or absorption.

# Protein Digestion:

- Dietary protein constitute 70-100 g/day.

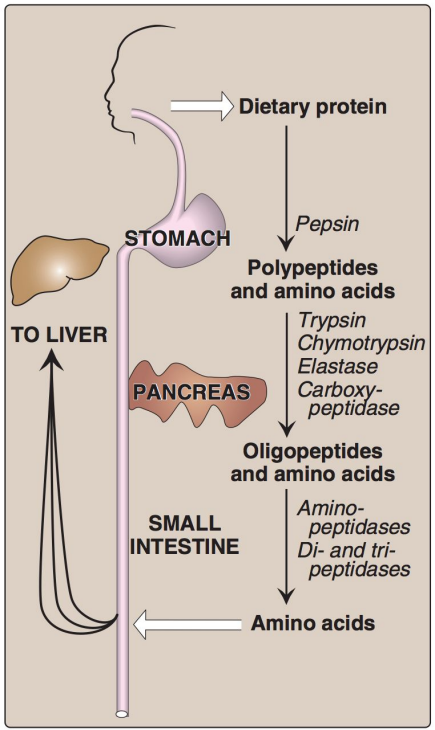
- Protein are too large to be absorbed by the intestine. Small intestine only absorb amino acids

- They must be hydrolyzed to their constituent amino acids to be absorbed

Dr notes: so proteins have to be degraded except maternal antibodies they are directly absorbed found in breast milk

# The Source of Proteolytic Enzymes Responsible for Degrading Dietary Proteins

- The stomach
- The pancreas
- The small intestine




HCL is responsible for the denaturation of The proteins.

Protein digestion starts in the stomach and ends in the small intestine

Denaturation is: Return the ready structure protein into it primary structure by breaking all the bonds except the peptide and some of the disulfide bonds.

# 1- Digestion of Proteins By Gastric Secretion

The gastric juice contains 2 components important for protein digestion:

1. Hydrochloric acid.
2. Pepsin.

| Digesting agent | Description |
|---|---|
| Hydrochloric acid | 1. Kills some bacteria<br>2. Denatures protein → denatured proteins are more susceptible to hydrolysis by proteases.<br>3. it activates pepsin enzyme by converting pepsinogen to pepsin |
| Pepsin | • Acid-stable<br>• Endopeptidase<br>• Secreted as inactive zymogen (pepsinogen)<br>• Pepsinogen is activated by:<br>1. hydrochloric acid<br>2. pepsin, i.e. autocatalysis<br>• Protein digestion by stomach → Polypeptides + few free amino acids |

It's very important to know the enzymes that are Endo/Exopeptidase.
Endopeptidase: Enzyme that catalyze the bonds that located in the middle.
Exopeptidase: Enzyme that catalyze the terminal C-N bonds.

# 2- Digestion of Proteins in Small Intestine

1- By pancreatic enzymes

2- By intestinal aminopeptidase

- The digestion in small intestine is hormonally controlled.
- Two small peptide hormones are released from cells of the upper part of small intestine:

**1. Cholecystokinin (CCK)**

**2. Secretin**

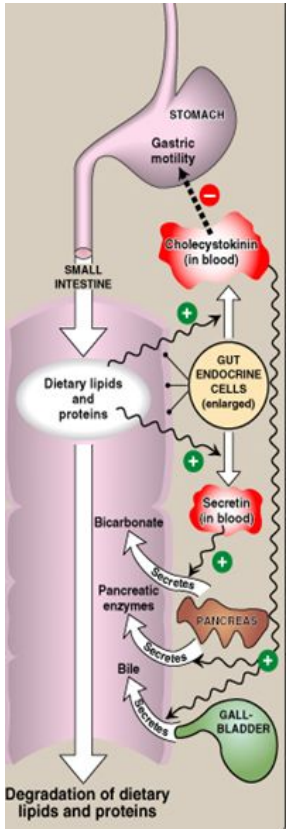
# Hormonal Control of Digestion in Small Intestine:

**1** **Cholecystokinin (CCK)**

1. Secretion of pancreatic enzymes.
2. Bile secretion.
3. Slow release of gastric contents.

**2** **Secretin**

Release of watery solution rich in bicarbonate by pancreas.




Further details in the next slide.

# The Gut Hormones ★

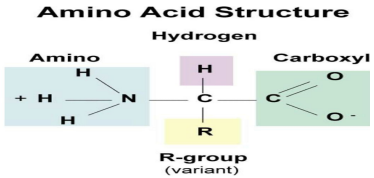
| The gut hormones | Stimulus for secretion | Effects |
|---|---|---|
| **Cholecystokinin (CCK)** | The presence of partially digested proteins (& lipids) in the upper small intestine. | 1. Stimulates the release of pancreatic digestive enzymes<br><br>2. Stimulates the contraction of the gallbladder & release of bile (bile is used for lipids)<br><br>3. Decreases gastric motility → slower release of gastric contents into the small intestine (to give more time for the digestion) |
| **Secretine** | 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) |

# Pancreatic enzymes for digestion of proteins

A. Digestion by pancreatic enzymes:

1. The pancreatic secretion contains a group of pancreatic proteases
2. Each of these enzymes has different specificity for the cleavage sites
   Ex:trypsin always cleaves after arginine and lysine
3. These proteases are synthesized and secreted as inactive zymogens

In proteins, we have two terminals:
1) N-terminals: containing amino acids.
2) C-terminals: containing carboxyl group.
-Carboxypeptidases break the C-terminals and has two types A,B; they differ by amino acid they prefer to break
-aminopeptidase break N-terminal




# Pancreatic enzymes:

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

# Pancreatic enzymes continued

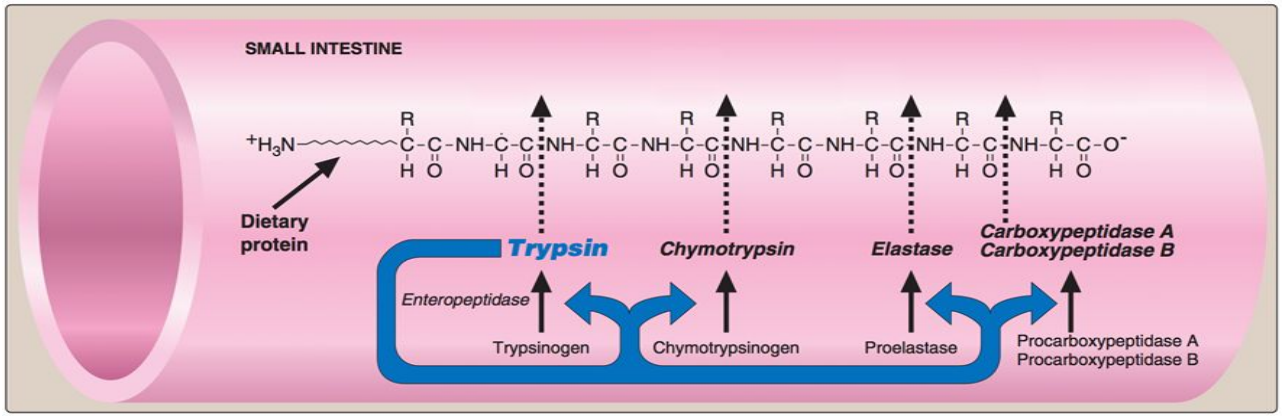
**Enteropeptidase:** Converts trypsinogen to trypsin

(The conversion is initiated by this enzyme)

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

(So two enzymes form by autocatalysis: pepsin,trypsin)

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



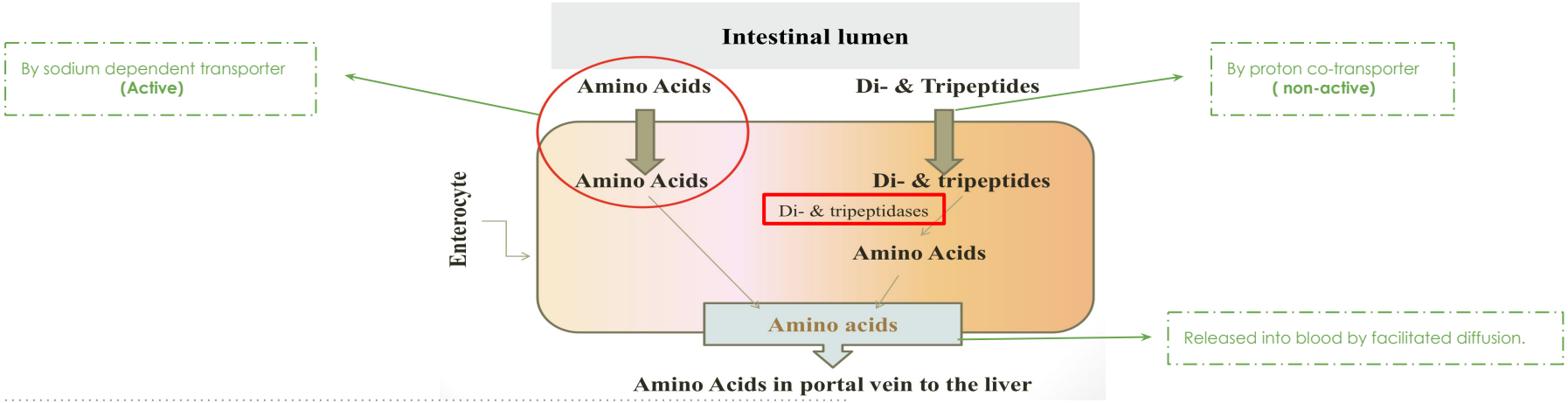

Trypsin starts a cascade because it can activate all other pancreatic enzymes. Every protease is specific for different active site, polypeptides are their substrates and their products are oligopeptides and amino acids.

# 2- Digestion of Proteins in Small Intestine: *Continued…*

B. Digestion by **intestinal aminopeptidase**, which break the N-terminals of proteins → giving a lot of amino acids.

Oligopeptides that result from the action of pancreatic proteases are cleaved into free amino acids and smaller peptides (di- & tri- peptides)
by **intestinal aminopeptidase** (an exopeptidase on the luminal surface of the intestine)

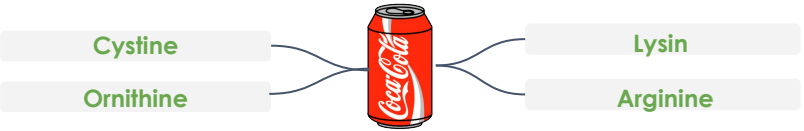
## Absorption of digested proteins




Di & tripeptidase is an enzyme that converts the di and tri amino acids → mono amino acid

# Genetic Errors in Amino Acids Transport

| Cystinuria | |
|---|---|
| About the disease: | Is one of the most common genetic error of amino acid transport |
| Example of: | Inherited disorder in the transport of certain amino acids |
| Affects: | The transport of Cystine and dibasic amino acids (COLA) |
| Organs affected: | Small intestine and the kidney |
| Clinically: | Cystine and dibasic amino acids appear in the urine |
| | There is kidney stones formation because they're not absorbed |
| Treatment: | Oral hydration (drinking lots of water) is an important part of Treatment (to prevent kidney stones formation) |




Remember:cystine is made up of dimer of 2 cysteine by a disulfide bond

# Abnormalities of Protein Digestion

**1** Pancreatic insufficiency, e.g., chronic pancreatitis, cystic fibrosis, surgical removal of the pancreas.

**2** Incomplete digestion & absorption of lipids & proteins

**3** Abnormal appearance of lipids (steatorrhea) & undigested proteins in the feces

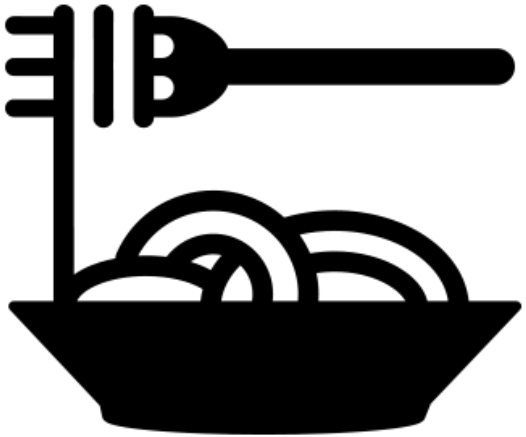
# Celiac Disease (Celiac sprue)

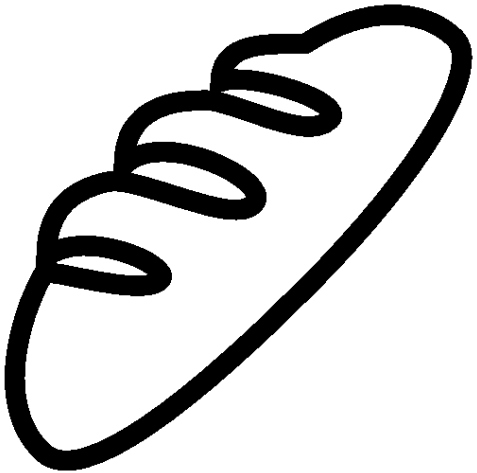
**Definition:** A disease of malabsorption resulting from immune-mediated damage to the villi of the small intestine in response to ingestion of gluten.

mechanism of celiac disease: when gluten is degraded it forms gliadin, so the antibodies attack the gliadin causing inflammatory responses causing damage to the villi

A protein found in wheat, rye, and barley


# Biochemical Aspects of Digestion of Dietary Carbohydrates





# Carbohydrates Digestion

Carbohydrates digestion is **rapid**:
Generally completed by the time the gastric contents reach the junction of the duodenum & jejunum.

Sites for digestion of dietary carbohydrates:

- Mouth
- Intestinal lumen

## Dietary Carbohydrates Mainly:

**Polysaccharides**: (Digested by breaking the glycosidic bonds)

- **Starch** from plant origin
  - Contain α (1→4) & α (1→6) bonds( the branch form)
- **Glycogen** from animal origin
- **Cellulose** from plant origin
  - Contains β (1→4) bonds(humans don't have the enzyme to break the bond,so cellulose is not digested)

**Disaccharides**:

1- Sucrose=glu+fru
2- Lactose=glu+galact
3- Maltose=glu+glu

**Oligosaccharides**

**Monosaccharides**: Little amounts

# Enzymes for Digestion of Dietary Carbohydrates

**α-amylase** (Both salivary & pancreatic*).
- Substrate: **Polysaccharides**

**Disaccharidases** (Intestinal)
- Substrate: **Disaccharides**

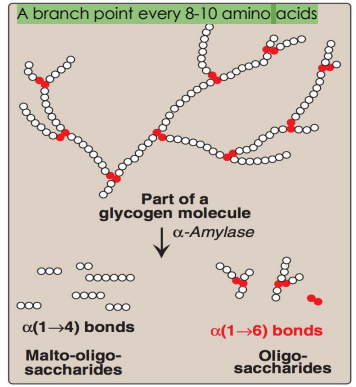
**Isomaltase & α(1,6) glucosidase** (Intestinal)
- Substrate: Branch points of **oligo**- and **di-saccharides**

- **No dietary carbohydrate digestion occurs in the stomach.** (the high acidity of the stomach inactivates the salivary a–amylase)
- **Pancreatic a–amylase continues the process of starch & glycogen digestion in the small intestine.** (Secreted by pancreas and works in small intestine)

*In blood both,but salivary is so low so it's referred as pancreatic

## Effects of a-amylase on Glycogen

| | |
|---|---|
| Hydrolysis of: | α(1,4) glycosidic bonds |
| Products: | - Mixture of short oligosaccharides (both branched & unbranched)<br>- Disaccharides: Maltose and isomaltose |



# Serum level of α-amylases

Normal level in serum: **25 -125 U/L** Units/L

The clinical significance of rising circulating levels of a-amylase activity:

Its level starts to **rise** within few hours.

Reaches a **peak** within 12-72 hours.

Then returns to normal within few days. Usually 5 days

Diagnosis of **acute pancreatitis**:
(damage of pancreatic cells ⟶ release & activation of the intracellular enzymes into the blood)

**The significant in using serum a-amylase level test:**
1)cheap;lipase is more expensive
2)easy
3)has certain pattern

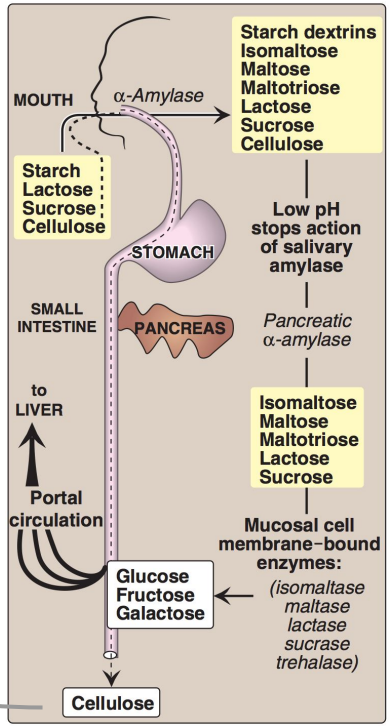
# Final Digestion of Carbohydrates By Intestinal Enzymes in The Small Intestine

| Enzyme | Source | Location of their action |
|---|---|---|
| Disaccharidases | Secreted by & remain associated with the luminal side of the brush border membranes of the intestinal mucosal cells | the mucosal lining of the jejunum. |
| α(1,6) Glucosidase (for branched oligosaccharides) | | |

## Intestinal Disaccharidases:

| Enzyme | Substrate | Product |
|---|---|---|
| Isomaltase | Isomaltose | 2 Glucose |
| Maltase | Maltose | 2 Glucose |
| Sucrase | Sucrose | Glucose & Fructose |
| Lactase (β-galactosidase) | Lactose (From milk) | Glucose & Galactose |

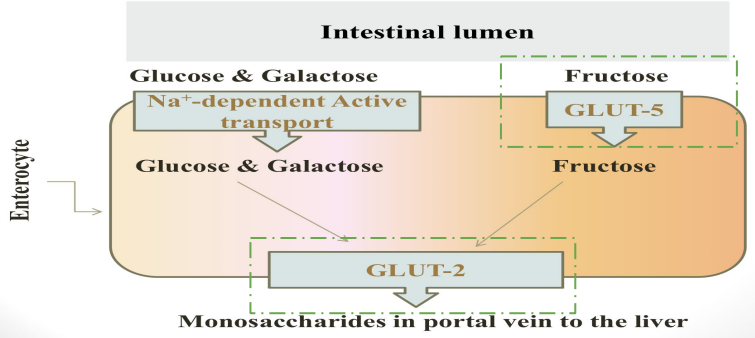
Dietary cellulose cannot be digested due to the absence of enzyme that can cleave β(1-4) bonds. It passes through the GIT largely intact.
Despite that, it has several beneficial effects.
(increases motility and treat constipation)



# Absorption of Monosaccharides by Intestinal Mucosal Cells

- **Location**: Duodenum & upper jejunum.
- **Insulin**: is NOT required for the uptake of glucose by intestinal cells.
- **Different monosaccharides have different mechanisms of absorption:**
  - 1. Facilitated diffusion (GLUT-mediated)
    - Sodium independent
  - Active transport (Energy-dependent): Co-transport with $Na^+$
    - Sodium dependent

## Absorption of Digested Carbohydrates




GLUT : Transports all monosaccharides into the bloodstream. Fructose enters the enterocytes by GLUT-5

Example of cells that need insulin for uptake of glucose is muscle cells

# Abnormal Digestion of Disaccharides (e.g. of lactose)

**Lactose intolerance (Lactase deficiency)**

Lactase (β-galactosidase) deficiency

↓

Undigested carbohydrate in large intestine

↓

Osmotic diarrhea.

Bacterial fermentation of the undigested compounds in the large intestine

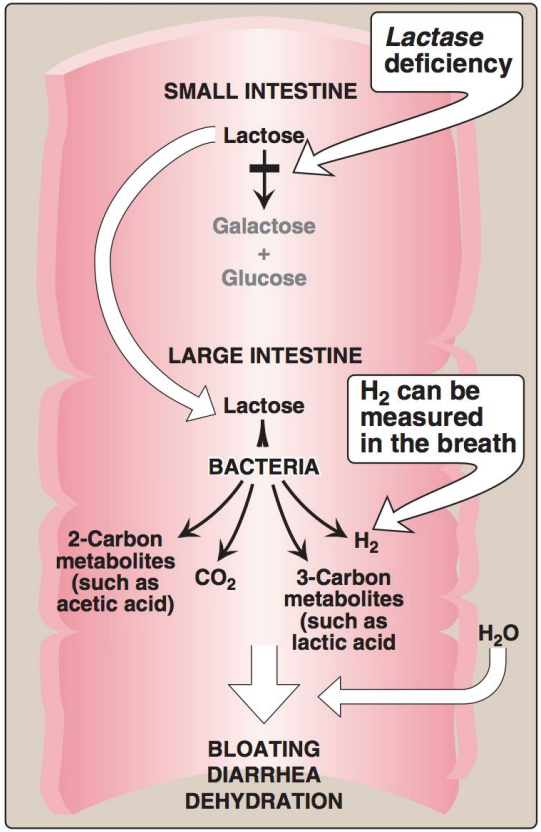
↓

$CO_2$, $H_2$ gas

↓

Abdominal cramps, diarrhea & distension (flatulence)

Summary:when there is lactase deficiency lactose will accumulate in the large intestine and the normal bacteria in the large intestine will feed on lactose causing release of carbon dioxide and carbon metabolites and water will enter the large intestine causing osmotic diarrhea



# Take Home Messages
# 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 and pepsin.**
- **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.**

# Take Home Messages
# Digestion of Dietary Carbohydrates

- Salivary a-amylase acts on dietary glycogen & starch in the mouth.
- Pancreatic a-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 & α(1,6) glucosidase.
- Dietary cellulose cannot be digested due to the absence of enzyme that can cleaveβ (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

# Summary

## Diseases related to protein digestion

| Genetic errors of amino acid transport | Abnormalities of protein digestion | |
|---|---|---|
| Cystinuria | Pancreatic insufficiency | Celiac disease |
| 1. Most common genetic error of amino acid transport.<br>2. Inherited disorder.<br>3. Affects the transport of Cystine and dibasic amino acids.<br>4. Affects kidney and small intestine.<br>5. Cystine and dibasic appear in the urine.<br>6. Kidney stones formation.<br>7. Kidney stones formation treated by hydration.<br>8. Oral hydration is an important of treatment. | 1. Such as in: chronic pancreatitis, cystic fibrosis, and removal of pancreas.<br>2. Leads to Incomplete digestion and absorption of lipids and proteins because of lack of pancreatic enzymes .<br>3. Which lead to Abnormal appearance of lipids (steatorrhea) & undigested proteins in feces. | 1. It is a disease of malabsorption resulting from immune-mediated damage to the villi of the small intestine in response to ingestion of gluten.<br>2. Gluten is a protein found in wheat, rye, and barley. |

# Summary

Lactose intolerance (Lactase deficiency): Lactase (β-galactosidase) deficiency → Undigested carbohydrate in large intestine → osmotic diarrhea.
Bacterial fermentation of the undigested compounds in the large intestine → $CO_2$, $H_2$ gas → abdominal cramps, diarrhea & distension (flatulence)

## Intestinal Disaccharides

| Enzyme | Substrate | Product |
|---|---|---|
| Isomaltase | Isomaltose | 2 glucose |
| Maltase | Maltose | 2 glucose |
| Sucrase | Sucrose | Glucose and fructose |
| Lactase | Lactose | Glucose and galactose |

Absorption of monosaccharides:

- Occurs in duodenum and jejunum.
- No insulin required for re-uptake of glucose by intestinal cells
- Two Mechanisms of absorption:

1. Facilitated diffusion (GLUT-mediated). such as in fructose.
2. Active transport (Energy-dependent): Co-transport with Na+. such as in glucose and galactose.

# Quiz

## MCQs :

**Q1: Which one of the following considered as a normal level of a-amylases in serum?**

**a)** 5 U/L **b)** 50 U/L **c)** 500 U/L **d)** 5000 U/L

**Q2: Lactose considered as?**

**a)** Polysaccharides **b)** Oligosaccharides
**c)** Disaccharides **d)** Monosaccharides

**Q3: a-amylase works which one of the following?**

**a)** Polysaccharides **b)** Oligosaccharides
**c)** Disaccharides **d)** Monosaccharides

**Q4: Which of the following is not an endopeptidase?**

**a)** Trypsin **b)** Chymotrypsin
**c)** Elastase **d)** Enteropeptidase

**Q5: Which of the following is not wrong about Secretin?**

**a)** Contract the gallbladder **b)** Release a watery solution
**c)** Slow the release of gastric contents **d)** A&B

**Q6: Which of the following is an genetic error in amino acid transport?**

**a)** Cystinuria **b)** Chronic pancreatitis
**c)** Celiac sprue **d)** Lactose intolerance

## SAQs :

**Q1: What is the Sites for digestion of dietary carbohydrates?**

**Q2: What are the deficient amino acids in cystinuria?**

**Q3: Where does the absorption of monosaccharides occur?**

**Q4: Mention two hormones that control the digestion of proteins in small intestine.**

★ **MCQs Answer key:**

1) B 2) C 3) A 4) D 5) B 6) A

★ **SAQs Answer key:**

1) The mouth, The intestinal lumen

2) 1- Cystine 2- Ornithine 3- Lysine 4- Arginine

3) Duodenum & Upper jejunum

4) 1- Cholecystokinin (CCK), 2- Secretin

# Team members

## Girls Team:

- Ajeed Al-Rashoud
- Alwateen Albalawi
- Amira AlDakhilallah
- Arwa Al Emam
- Deema Almaziad
- Ghaliah Alnufaei
- Haifa Alwaily
- **Leena Alnassar**
- Lama Aldakhil
- Lamiss Alzahrani
- Nouf Alhumaidhi
- Noura Alturki
- Sarah Alkhalife
- Shahd Alsalamah
- Taif Alotaibi

## Boys Team:

- Abdulrahman Bedaiwi
- Alkassem Binobaid
- Khayyal Alderaan
- Mashal Abaalkhail
- Naif Alsolais
- Omar Alyabis
- **Omar Saeed**
- Omar Odeh
- **Rayyan Almousa**
- Yazen Bajeaifer

# Team Leaders

Lina Alosaimi

Mohannad Alqarni

★ Persistence is very important. you should not give up UNLESS you are forced to give up.

Elon Musk.

438 BIOCHEMISTRY TEAM

We hear you