Digestion of proteins and Carbohydrates.

The source of proteolytic enzymes responsible for degrading dietary proteins:
1-The stomach 2-The pancreas 3-The small intestine

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.

1-Digestion of proteins in Stomach:

- **The digestion of proteins begins in the stomach which secrets gastric juice.**
- **A unique solution containing 2 components important for protein digestion:**
  - **Hydrochloric acid (HCl).**
  - **Pepsin.**

Digesting agent	Description
Hydrochloric Acid (HCl)	▪ kills some bacteria ▪ **Denatures proteins** → denatured proteins are more susceptible to hydrolysis by proteases.
Pepsin	▪ Acid-stable. ▪ Endopeptidase. "meaning was explained in first lecture". ▪ Secreted as **inactive zymogen** (**pepsinogen**) ▪ Pepsinogen is then activated by: 1. **hydrochloric acid.** 2. **pepsin** that have already been formed (autocatalysis). ▪ Protein digestion by stomach → **Polypeptides** + **few free amino acids**.

2-Digestion of proteins in Small intestine:

A. digestion by pancreatic enzymes.
B. digestion 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:**

Hormone	Stimulus	Effects
1- Cholecystokinin (CCK)	The presence of **partially digested** proteins and lipids in the upper small intestine.	▪ Stimulates the **release of pancreatic digestive** enzymes ▪ Stimulates the contraction of the gall bladder and release of bile "**Bile secretion**". ▪ 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).

Digestion of proteins in Small intestine:

A. digestion by pancreatic enzymes.

- **The pancreatic secretion contains a group of pancreatic proteases.**
- **Each of these enzymes has different specificity for the cleavage sites.**

Pancreatic enzymes are very specific. For instance, trypsin will cut only if there is arginine or lysine.

- **These proteases are synthesized and secreted as inactive zymogens.**

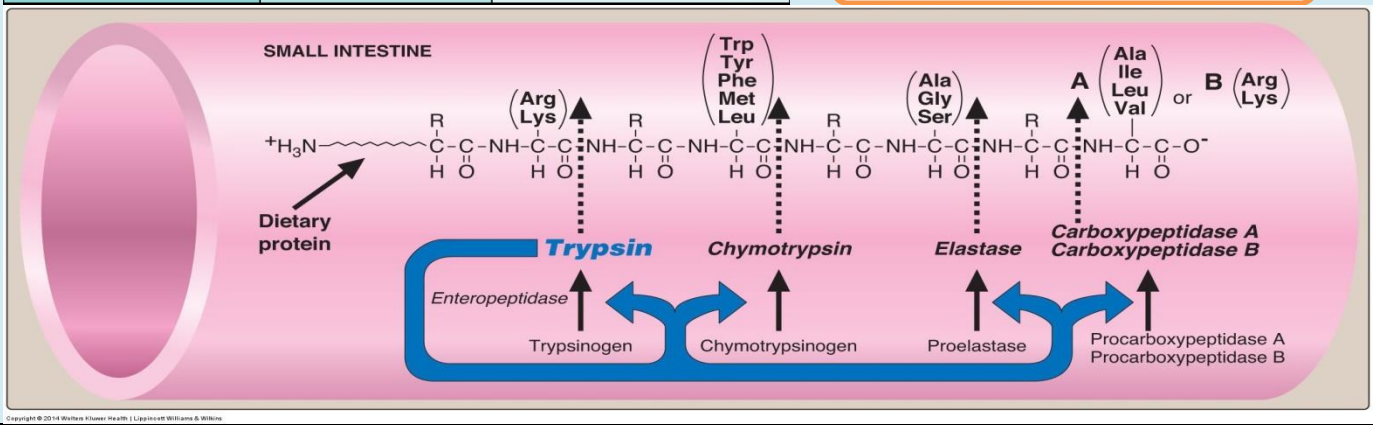
In this step the polypeptide is broken into oligopeptides + amino acids by specific enzymes.

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

Enteropeptidase:
An enzyme synthesized by and present on the luminal surface of intestinal mucosal cells of the brush border membrane

converts **trypsinogen** to **trypsin**

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



Digestion of proteins in Small intestine:

B. digestion by intestinal aminopeptidase.

- What is Aminopeptidase? an **exopeptidase** on the luminal surface of the intestine.
- Function \ role: cleaves Oligopeptides that result from the action of pancreatic proteases into free amino acids and smaller peptides (di and tri-peptides).

Genetic errors in amino acids transport

Cystinuria

- **one of the most common genetic error of amino acid transport.**
  - **It is an example of inherited disorder in the transport of certain amino acids.**
  - **It affects the transport of Cystine and dibasic amino acids.**
- **Affected organs: the small intestine and the kidney.**
- **Urine features: Cystine and dibasic amino acids appear in the urine.**
- **Clinically: there is kidney stones formation Flank pain , blood in urine.**

Treatment: Oral hydration (drinking lots of water) is an important part of treatment (to prevent kidney stones formation).

Abnormalities of protein digestion:

- Pancreatic insufficiency.

e.g. Chronic pancreatitis , cystic fibrosis, surgical removal of the pancreas

- incomplete digestion & absorption of lipids & protein
- abnormal appearance of lipids (steatorrhea) & undigested protiens in the feces

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:
  - The mouth.
  - The intestinal lumen. (mainly the duodenum & jejunum).

Dietary Carbohydrates:

1-Polysaccharides: 1.Starch from plant origin
2.Glycogen from animal origin Contain α (1→4) & α (1→6) bonds (both 1,2)
3.Cellulose from plant origin Contains β (1→4) bonds

2- Oligosaccharides

3- Disaccharides: Sucrose - Lactose - Maltose

4- Monosaccharides: Little amounts

Enzymes	α-amylase	Disaccharidases	Isomaltase & α(1,6) glucosidase
Substrate	Polysaccharides	Disaccharides	Branch points of oligo- and di-saccharides
Type	Both salivary & pancreatic	Intestinal	

Effects of α-amylase on Glycogen

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

✓ No dietary carbohydrate digestion occurs in the stomach.
- the high acidity of the stomach inactivates the salivary α–amylase.

✓ Pancreatic α–amylase continues the process of starch & glycogen digestion in the small intestine
- Secreted by pancreas and works in small intestine.

Serum level of α-amylases (25 -125 U/L)

❖ The clinical significance of rising circulating levels of α-amylase activity:
- Diagnosis of acute pancreatitis.

Damage of pancreatic cells → Release & activation of the intracellular enzymes into the blood.

Measurement:
- Its level starts to rise within few hours.
- Reaches a peak within 12- 72 hours.
- Then returns to normal within few days.

Final digestion of carbohydrates by intestinal enzymes in the small intestine

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

Intestinal disaccharidases

Enzyme	Substrate	Product
Isomaltase	isomaltose	2 Glucose
Maltase	maltose	2 Glucose
Sucrase	sucrose	Glucose & fructose
Lactase (β-galactosidase)	lactose	Glucose & galactose

Digestion of Carbohydrates:

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.

Absorption of Monosaccharaides 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)
2. Active transport (Energy-dependent): Co-transport with Na+(against the conc.)

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

Lactose intolerance(lactase deficiency)