



# Digestion and absorption of proteins

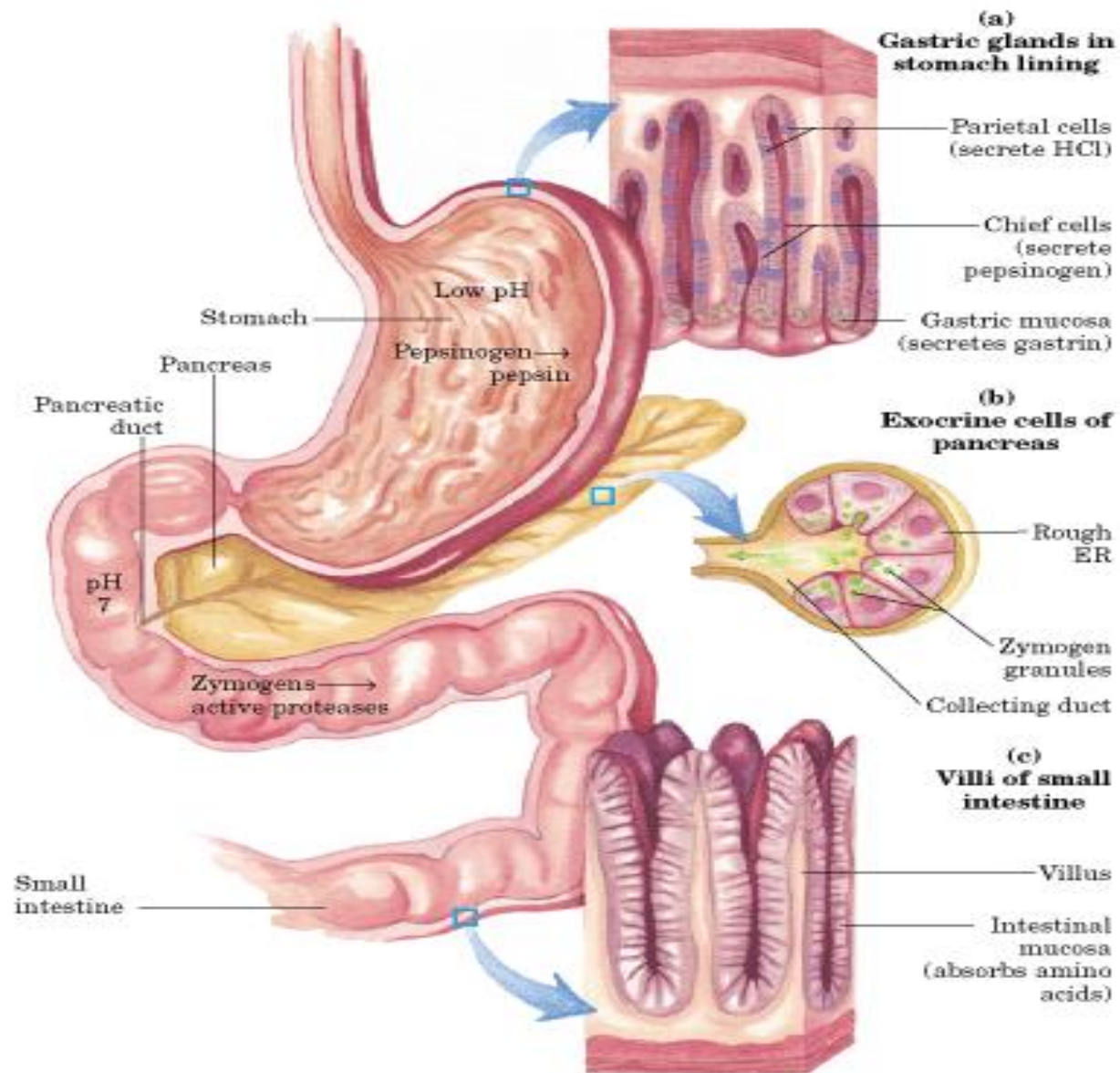
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# Digestion and absorption

From oral cavity until intestine absorption

- Mechanic homogenization of food, mixing of solid food with liquid which secreted from glands in GIT
- Secretion of digestive enzymes which hydrolyze macromolecules in oligomers, dimers and monomers
- Secretion of electrolytes, acids, bases to get optimal conditions for enzyme activity
- Secretion of bile acids as detergents for resolving of lipids and to facilitate absorption of lipids
- Hydrolyzing of oligomers and dimers from food with enzymes from small intestine
- Transport of molecules and electrolytes from lumen of small intestine through epithelium into a blood and lymph

# Digestion and absorption of proteins



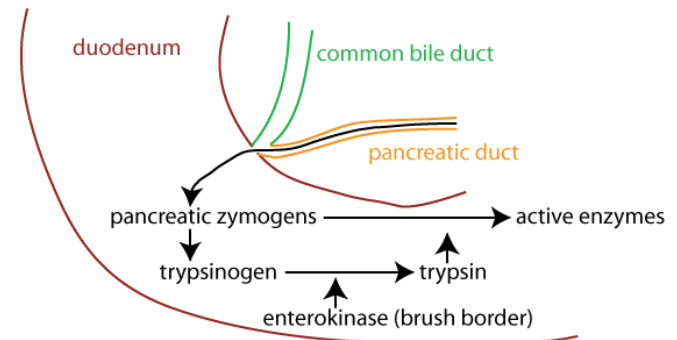
Gastrin

CCK-PZ

Hormon	Enzyme	Conditions	Substrate	Product
<b>Stomach glands:</b> Chief cells and parietal cells secrete gastric juice in response reflex stimulation and hormone <b>gastrin</b>	Pepsin	Pepsinogen converts to active pepsin , pH 1,5-2	Protein	Peptides
	----- <i>Renin</i>	----- Calcium, pH 4	----- Casein of milk	----- Coagulates milk
<b>Pancreas:</b> Presence of acid chyme from the stomach activates duodenum to produce (1) <b>secretin</b> , which hormonally stimulates flow of pancreatic juice; (2) <b>cholecystokinin</b> , which stimulates the production of enzymes.	Trypsin	Trypsinogen converted to active trypsin by enteropeptidase of intestine at pH 5.2-6.0. Autocatalytic at 7.9	Protein Peptides	Polypeptides Dipeptides
	----- Chymotrypsin	----- Secreted as chymotrypsinogen and converted to active form by trypsin	----- Protein Peptides	----- Polypeptides Dipeptides
	----- Elastase	----- Secreted as pro-elastase and converted to active form by trypsin	----- Protein Peptides	----- Polypeptides Dipeptides
	----- Carboxypeptidase	----- Secreted as pro-carboxypeptidase and converted to active form by trypsin	----- Polypeptides at the free carboxyl end of the chain	----- Lower peptides and amino acids
<b>Small intestine:</b> Secretion of Brunner,s glands of the duodenum and glands of Lieberkuhn	Aminopeptidase		Polypeptides at the free amino end of the chain	Lower peptides, free amino acids
	----- Dipeptidases		----- Dipeptides	----- Amino acids

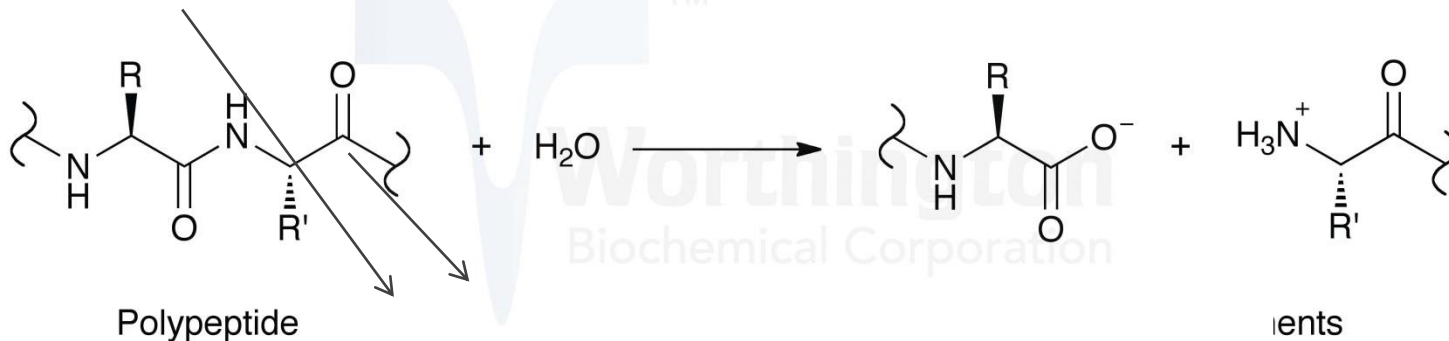
# *Pepsin*-endopeptidase

- Hydrolyzes central peptide bond
- cleaves peptides on the C-terminal side in which amino group belongs to aromatic amino acids ie. Phe, Tyr, Trp



<http://courses.washington.edu/conj/bess/zymogens/zymogens.html>

## Pepsin



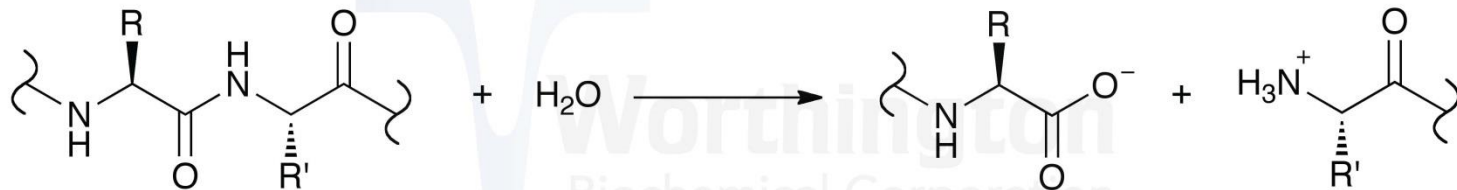
R and R' = Leu, Phe, Trp, and Tyr (preferred); also hydrolyzes esters

<http://www.worthington-biochem.com/>

# *Trypsin*-endopeptidase

- hydrolyzes at lysine and arginine
- Zymogen is activated by enterokinases

## Trypsin



Polypeptide

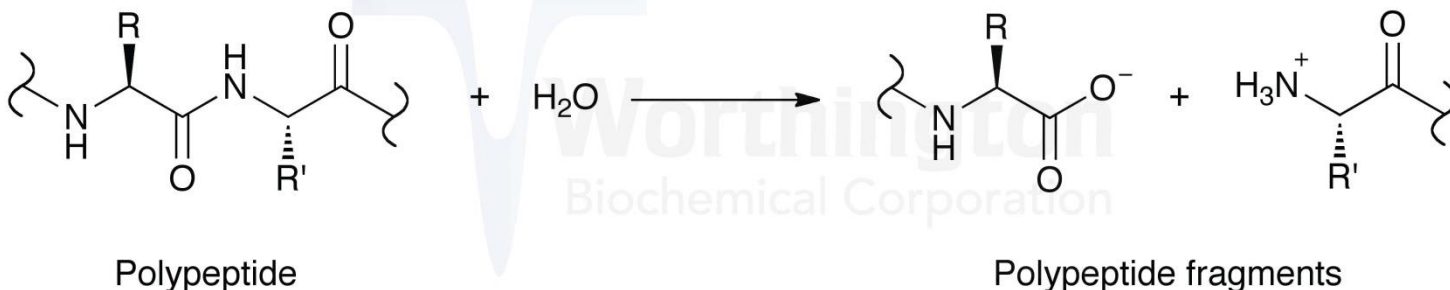
R = Arg and Lys

Polypeptide fragments

# *Chymotrypsin*-endopeptidase

- serine endopeptidase produced by the acinar cells of the pancreas.
- It is activated after proteolysis of chymotrypsinogen by trypsin.
- selectively cleaves peptide bonds formed by aromatic residues (Tyr, Phe, Trp)

## Chymotrypsin



Polypeptide

Polypeptide fragments

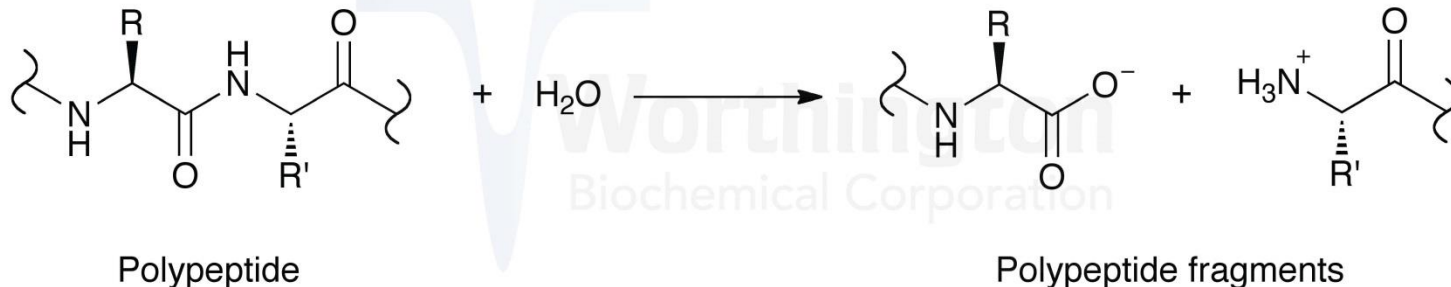
R = Phe, Trp, and Tyr; R' ≠ Pro

<http://www.worthington-biochem.com/chy/default.html>

# *Elastase*-endopeptidase

- Hydrolyzes after carboxy-term of small uncharged amino-acids
- produced in the pancreas as an inactive zymogen, and activated in the duodenum by trypsin

## Elastase



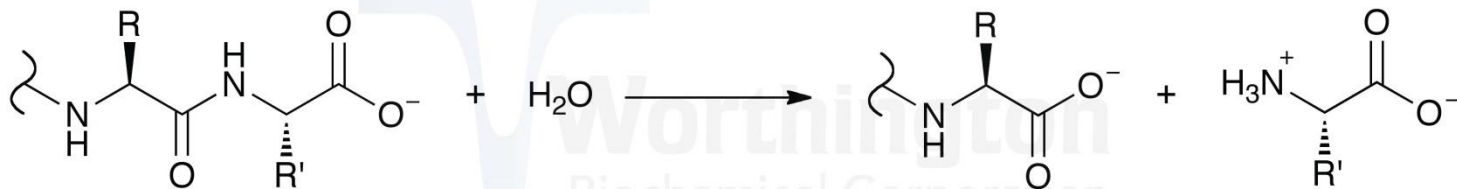
R = Ala, Gly, and Val; also hydrolyzes amides and esters



# *Carboxypeptidase*-exopeptidase

- catalyzes the hydrolysis of the basic amino acids, lysine, arginine, and ornithine from the C-terminal position of polypeptides

## Carboxypeptidase B



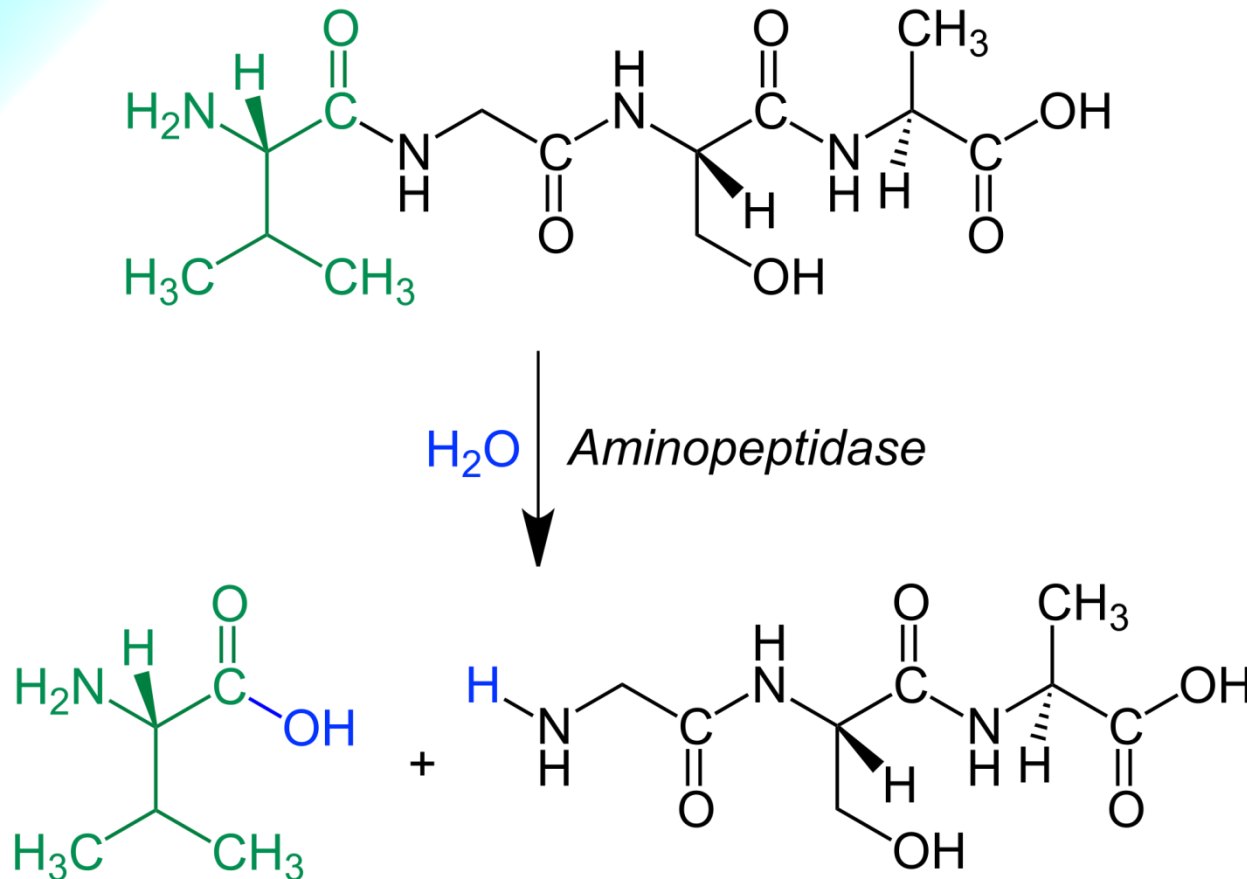
Polypeptide ( $n$  residues)

Polypeptide ( $n-1$  residues)

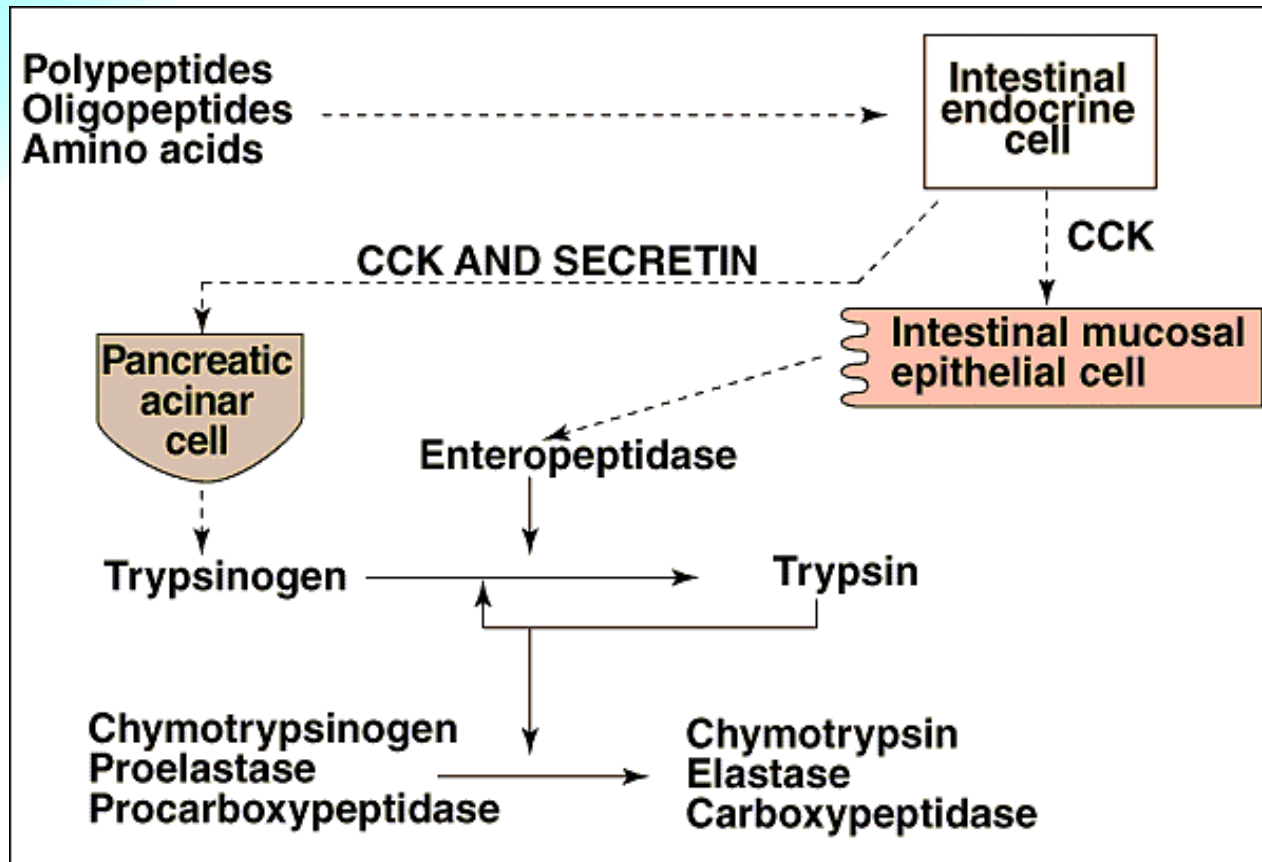
Amino Acid

$R' = \text{Arg, Lys, and ornithine}$

# *Amino*peptidase-exopeptidase



# Activation of proteinases



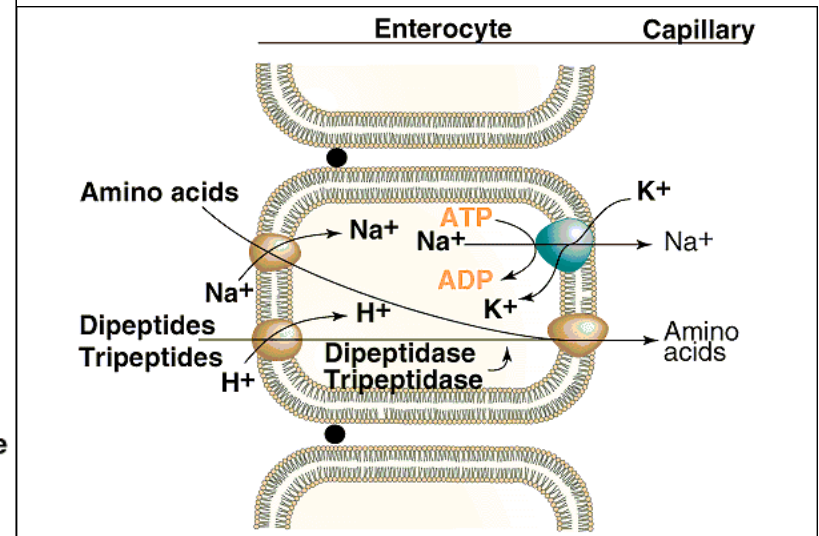
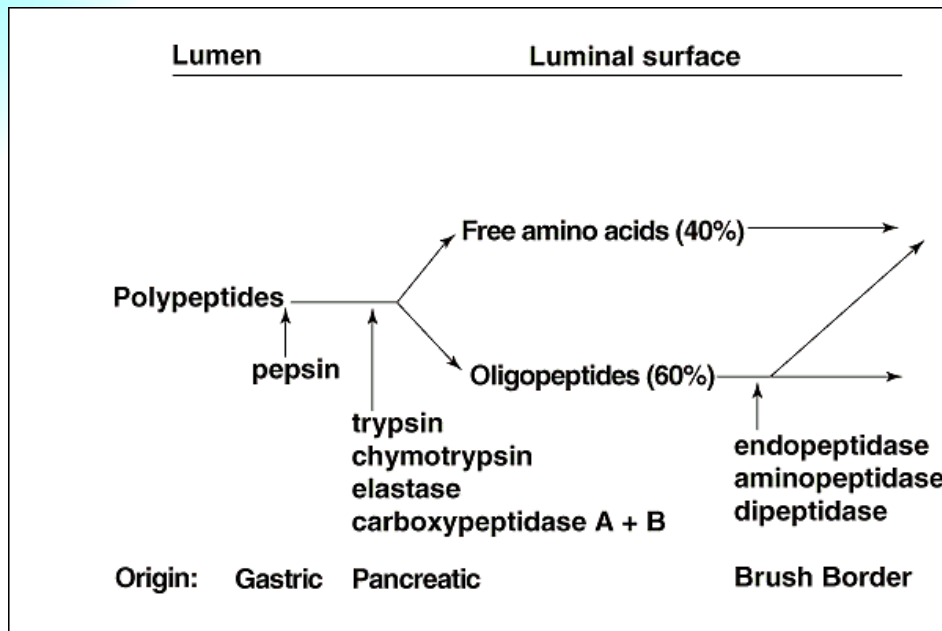
# Absorption of proteins in small intestine

The products of protein digestion are absorbed as individual amino acids. This absorption is energy dependent. Natural <L-isomers are actively transported across the intestine from mucosa to serosa.

-vitaminB6 (pyridoxal phosphate may be involved in this transfer

-Amino Acids are transported through the brush border by multiplicity of carriers, many having Na<sup>+</sup>-dependent mechanisms similar to the glucose carrier system, that include neutral AA-carrier, Phe-Met-carrier, iminoAA-carrier (for Pro and Hyp). Na-independent-carriers are specializing in the transport of neutral and lipophilic AAs(Phe, Ile), cationic AAs (Lys).

Some dipeptides and tripeptides could enter the enterocytes and then undergo hydrolysis by dipeptidases and tripeptidases.



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# Recycling of proteins

## Intracellular protein degradation

-***different from digestion*** of dietary proteins in two main aspects:

- (1) the proteins that are degraded are the same that were synthesized by the organism
- (2) this degradation occurs within the cells by energy requiring processes

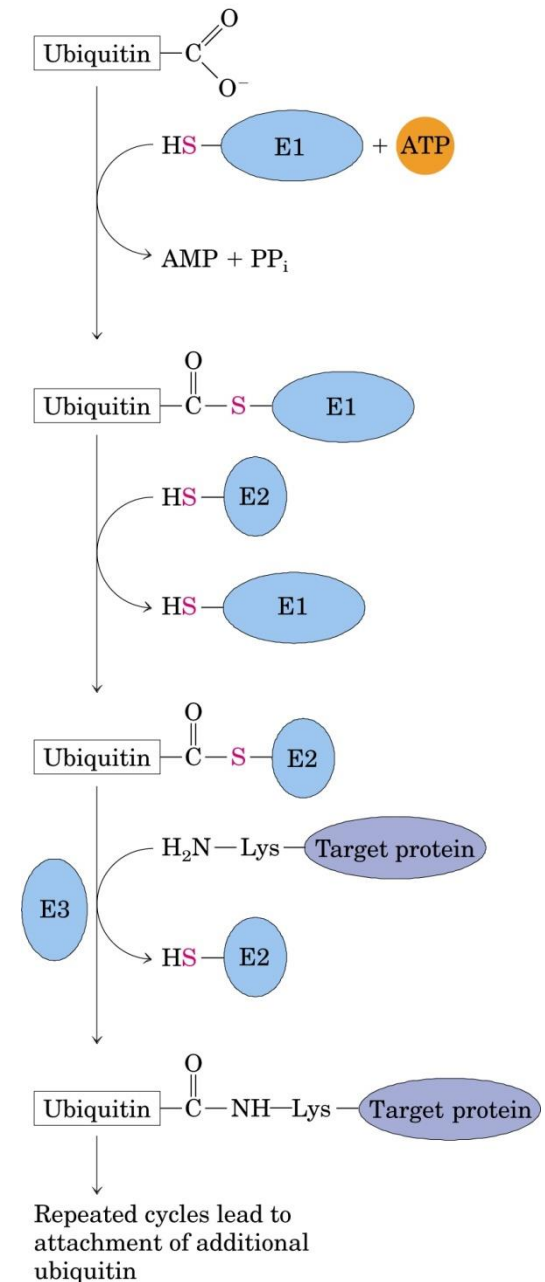
Intracellular proteins have their own turnover and could be affected by intracellular protein degradation. This is totally different process and it serves for degradation of endogenous cellular proteins.

# Intracellular protein degradation

Protein turnover- 30 s to many days

## Two main ways of degradations

- 1. Lysosomes
  - the final destination for endocytic, autophagic, and secretory molecules targeted for destruction or modification by a variety of acidic hydrolases, including numerous peptidases, called **cathepsins**
  - Mechanisms: **endocytosis**, **crinophagy** (**fusion with secretory vesicles**) and the various autophagy (degradation of its own cytosolic proteins)
- 2. Proteasomes (rapid degradation)
  - -major non-lysosomal degradation
  - -position: nucleus and cytosol
    - Ubiquitin-targets the attached protein for destruction in eukaryotes
  - Proteasome- proteolytic ATP-dependent system



# Quiz

1. Which cell secretes pepsinogen?
2. Pepsinogen is partially activated by \_\_\_\_\_.
3. Name the brush border enzyme responsible for activating trypsinogen.
4. Which hormones are involved in digestion process?
5. Explain shortly the mechanism of amino acid absorption?
6. What are the specifics of intracellular protein degradation?

# Sources of figures

- T. E. Devlin: Textbook of Biochemistry with Clinical Correlations, John Wiley and Sons Inc., 2002
- Nelson D.L. and Cox M. M.: Lehninger Principles of Biochemistry. Worth Publishers, 3<sup>rd</sup> Ed., 2000
- R. K. Murray i sur.: Harper's Illustrated Biochemistry, prijevod 28th Edition, New York , McGraw Hill