

## Amino acid Metabolism

The main role of amino acids **is in the synthesis of structural and functional proteins**. Unlike carbohydrates and fats, there is no storage form of proteins in the body. A 70 kg man has an average protein turnover rate of 400 g per day (same amount synthesized and same amount broken down). The non-essential amino acids are either derived from the diet or synthesized in the body. The **essential amino acids are obtained from the diet**. Even if one is deficient, protein synthesis cannot take place. The body amino acid pool is always in a dynamic steady state. In an adult, the rate of synthesis of proteins balances the rate of degradation, so that nitrogen balance is maintained

## Digestion and Absorption of Proteins

### Digestion of Protein

Dietary proteins (from animal source or vegetable source) are very large complex molecules that cannot be absorbed from the intestine. To be absorbed, dietary proteins must be digested to small simple molecules (amino acids), which are easily absorbed from the intestine.

The dietary proteins are denatured on cooking and therefore more easily digested. All these enzymes are hydrolases (class 3 enzymes) in nature. Proteolytic enzymes are secreted as inactive **zymogens** which are converted to their active form in the intestinal lumen. The proteolytic enzymes include:

**1. Endopeptidases:** They act on peptide bonds inside the protein molecule, so that the protein becomes successively smaller and smaller units. This group includes Pepsin, Trypsin, Chymotrypsin and Elastase.

**2. Exopeptidases:** Which act only on the peptide bond located at the ends of the polypeptide chain. This group includes:

a. **Carboxypeptidase**, which acts only on the peptide bond at the carboxyl terminal end of the chain.

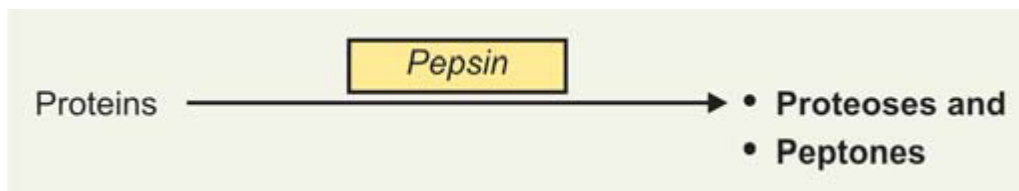
b. **Amino peptidase**, which acts only on the peptide bond at the amino terminal end of the chain. The digestion of protein is effected by enzymes in: Stomach, Pancreas, and Intestinal cells

## Gastric Digestion of Proteins

In the stomach, hydrochloric acid is secreted. It makes the pH optimum for the action of pepsin and also activates pepsin. The acid also denatures the proteins

### *Pepsin*

It is secreted by the chief cells of stomach as inactive **pepsinogen**. The conversion of pepsinogen to pepsin is brought about by removal of 44 amino acids from the N-terminal end, by the hydrochloric acid. The optimum pH for activity of pepsin is **around 2**. Pepsin is an endopeptidase, Pepsin catalyzes hydrolysis of the bonds formed by carboxyl groups of Phe, Tyr, Trp and Met. By the action of pepsin, proteins are broken into proteoses and peptones.



### *Rennin*

Rennin otherwise called **Chymosin**, is active in infants and is involved in the curdling of milk. It is absent in adults. It is secreted as prorennin, which is activated in the stomach to form active rennin. Milk protein, casein is converted to paracasein by the action of rennin. This denatured protein is easily digested further by pepsin.

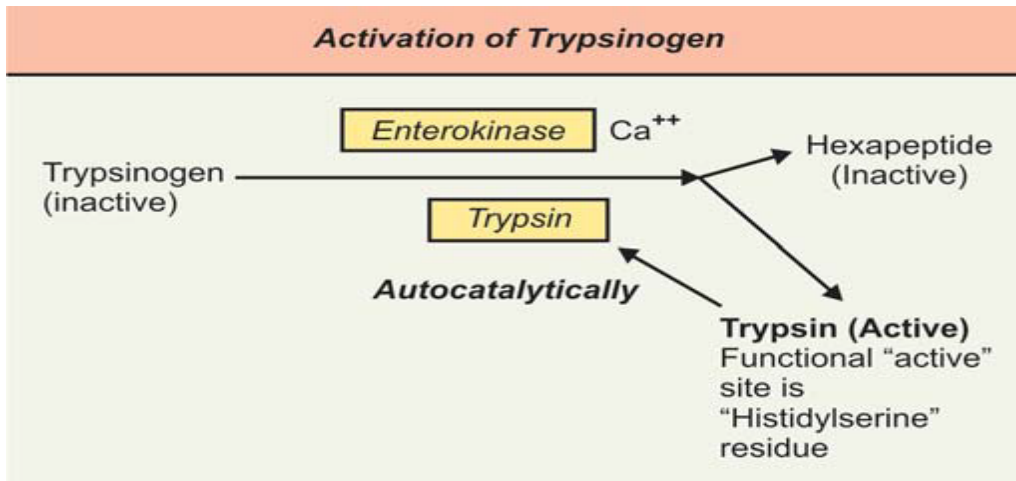
## Pancreatic Digestion of Proteins

The optimum pH for the activity of pancreatic enzymes (pH 8) is provided by the alkaline bile and pancreatic juice. The secretion of pancreatic juice is stimulated by the peptide hormones, **Cholecystokinin** also called **Pancreozymin**. Pancreatic juice contains the important endopeptidases, namely **Trypsin**, **Chymotrypsin**, **Elastase** and **Carboxypeptidase**. These enzymes are also secreted as zymogens (trypsinogen, chymotrypsinogen and proelastase).

### *Trypsin*

Trypsinogen is activated by **enterokinase** (enteropeptidase) present on the intestinal microvillus membranes. Once activated, the trypsin activates other enzyme molecules. Trypsin is activated by the removal of a hexapeptide from N-terminal

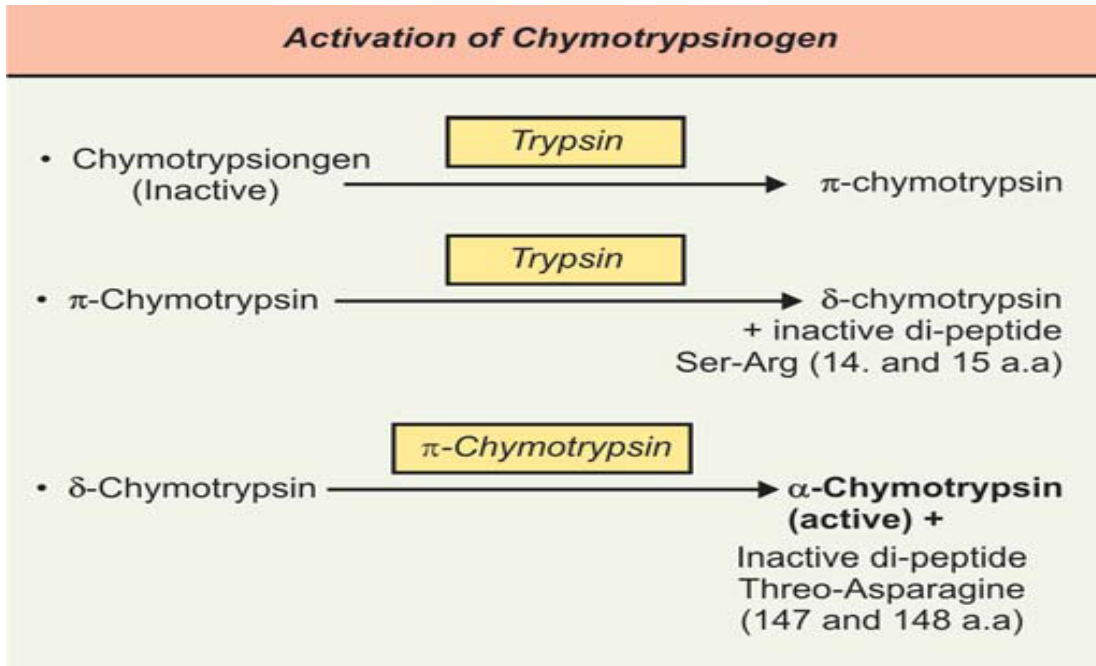
end. Trypsin catalyzes hydrolysis of the bonds formed by carboxyl groups belongs to basic amino acids e.g. arginine, lysine and histidine.



**Acute pancreatitis:** Premature activation of trypsinogen inside the pancreas itself, will result in the autodigestion of pancreatic cells. The result is acute pancreatitis. It is a life threatening condition.

### Chymotrypsin

It is an endopeptidase that hydrolyzes central peptide bond in which the carboxyl group belongs to aromatic amino acids. It is secreted in an inactive form called chymotrypsinogen, activated by trypsin, and completed by chymotrypsinogen, which acts autocatalytically.  $\alpha$ -Chymotrypsin is the active form, optimum pH(7-8), it converts the proteoses, peptones and peptides to smaller peptides and amino acids.



### Elastase

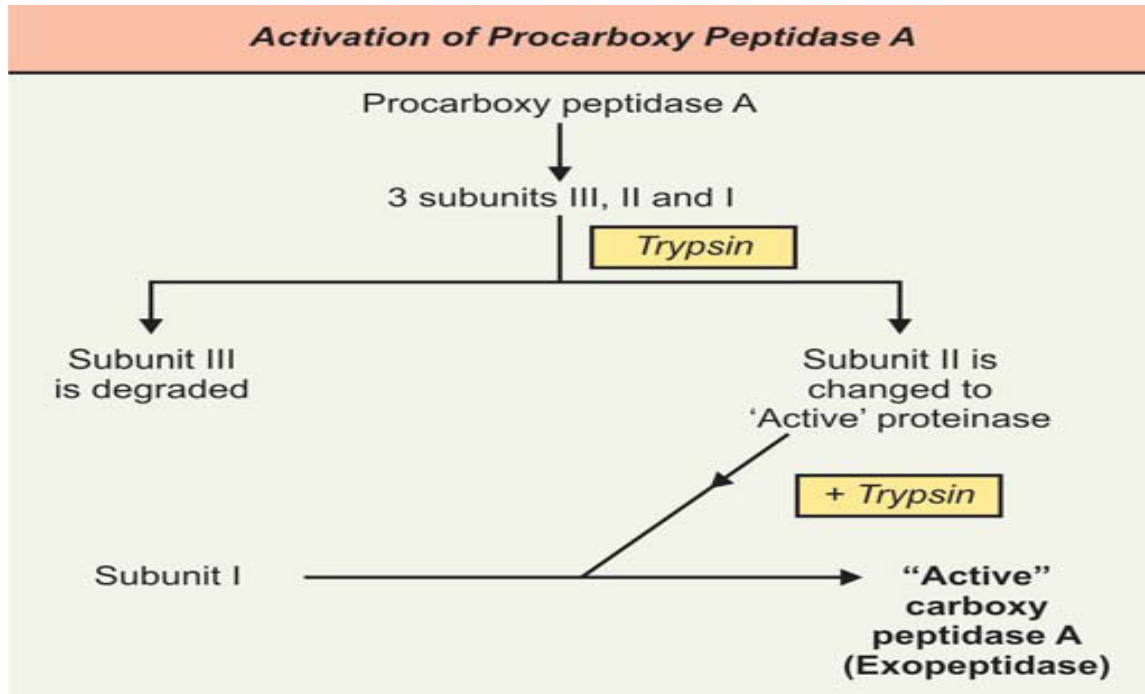
It is an endopeptidase acting in pH= 8 on peptide bonds formed by glycine, alanine and serine. It is secreted in an inactive form called proelastase, and activated by trypsin. It digests elastin and collagen.

### Carboxypeptidases

Trypsin and chymotrypsin degrade the proteins into small peptides; these are further hydrolyzed into dipeptides and tripeptides by **carboxypeptidases** present in the pancreatic juice. It is an exopeptidase that hydrolyzes the terminal (peripheral) peptide bond at the carboxyl terminus (end) of the polypeptide chain. Its two types carboxypeptidase A and B. It is secreted in an inactive form called procarboxypeptidase which is activated by trypsin. They are metalloenzymes requiring zinc

Carboxypeptidase A: it is an exopeptidase that cleaves aromatic amino acids from the C-terminal end of peptides.

Carboxypeptidase B: is also an exopeptidase cleaves the basic amino acids, lysine and arginine, from the C-terminal end of peptides.



### Intestinal Digestion of Proteins

Complete digestion of the small peptides to the level of amino acids is brought about by enzymes present in intestinal juice. The luminal surface of intestinal epithelial cells contains the following enzymes:

#### Aminopeptidase

It is an exopeptidase that acts on the terminal peptide bond at the amino terminus of the polypeptide chain. It releases a single amino acid can't hydrolyze a dipeptide. It requires presence of  $Zn^{++}$ ,  $Mn^{++}$  and  $Mg^{++}$ .

#### Prolidase

It's an exopeptidase and can hydrolyze a proline peptide of collagen molecule, liberating a proline molecule.

#### Tri and Dipeptidase

Tri-peptidase acts on tri-peptide and produces a di-peptide and free a. a.

Di-peptidase hydrolyzes a di-peptide to produce two molecules of a. a.

They requires the presence of  $Zn^{++}$ ,  $Mn^{++}$  and  $Co^{++}$  as cofactors for their activity.

## Food Allergy

Dipeptides and tripeptides can enter the brush border of mucosal cells; they are immediately hydrolyzed into single amino acids. They are then transported into portal vein. Rarely, larger molecules may pass paracellularly (between epithelial cells) and enter blood stream. These are immunogenic, causing antibody reaction, leading to food allergy.

*The end products of protein digestion in the small intestine are amino acids*

