Digestion and absorption of protein (CC4, unit 2)

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Digestion of dietary proteins

Digestion is the disintegration of complex nutrients into simple, soluble and assimilable form. Most of the nitrogen in the diet is consumed in the form of proteins. Proteins are too large to be absorbed. The dietary proteins are hydrolyzed to amino acids by proteolytic enzymes, which can be easily absorbed. Proteolytic enzymes responsible for degrading proteins are produced by three different organs; The stomach, pancreas and the small intestine.

Characteristics of proteolytic enzymes

1)The y are hydrolases.

2)Secreted in the zymogen (Inactive) form, converted to active form in the intestinal lumen. The active site of the enzyme is masked by a small region of the peptide chain that is removed by hydrolysis of a specific peptide bond.

3) They may be Exopeptidases or Endopeptidases.

Exopeptidases catalyze the hydrolysis of peptide bonds, one at a time, from the ends of peptides. Endopeptidases hydrolyze peptide bonds between specific amino acids throughout the molecule. They are the first enzymes to act, yielding a larger number of smaller fragments.

Digestion in the oral cavity

There are no proteolytic enzymes present in the saliva. The function of the saliva is to lubricate the food, this helps in making food soluble for the action of proteolytic enzymes. After mastication and chewing, the bolus of food enters stomach where it is acted upon by gastric juice.

Digestion by gastric juice

Gastric juice contains HCL and 4 proteolytic enzymes:

Pepsin, Rennin, Gastriscin and Gelatinase.

Functions of HCL

-Too dilute to hydrolyze but can cause denaturation of dietary proteins

-Required for activation of inactive proteolytic enzymes secreted by the gastric mucosa.

-Has a strong bacteriostatic action.

Functions of Proteolytic enzymes
Pepsin

-Secreted in the form of pepsinogen, activated by HCL and pepsin itself (Autocatalysis)

-Acid stable endopeptidase, optimum pH lies between 1.6-2.5 ; becomes inactive if the pH is > 5.0

-Active for a peptide bond where amino group is contributed by aromatic amino acids like Phenyl Alanine, Tyrosine and Tryptophan.

-Has a strong action on milk protein casein.

-Hydrolyzes proteins to proteoses, peptones and small peptides.

Functions of proteolytic enzymes

Rennin

-Present in infants but absent in adult gastric juice.

- Secreted as pro-rennin

-Optimum p H 4.0

-Action is similar to pepsin

-Acts on casein of milk and is involved in the curdling of milk

-Commercially, 'rennet' tablets are used in the making of cheese.

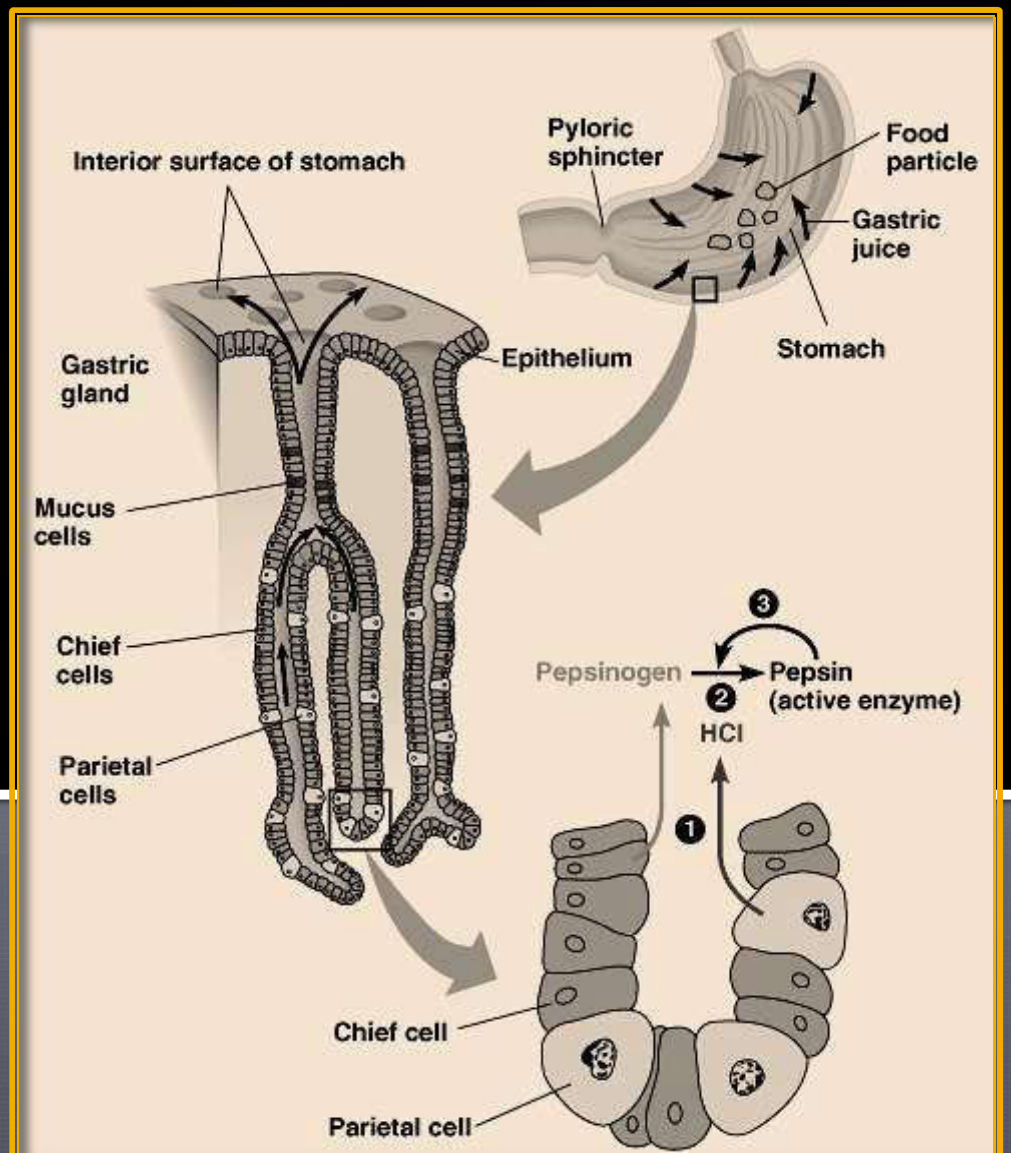
Functions of proteolytic enzymes

Gastriscin and Gelatinase

-Both are secreted in zymogen form and are acid-stable. Activated in the presence of HCL.

-Gelatinase acts on Gelatin to hydrolyze it to short peptides.

Digestion by gastric juice- Over view



Digestion by Pancreatic Juice

The bolus of food after leaving stomach reaches duodenum and is acted upon by the pancreatic juice. All the enzymes are active only in the alkaline medium and alkalinity is provided by Bile juice and bicarbonates present in pancreatic juice. The proteolytic enzymes present in pancreatic juice are:

-Trypsin

-Chymotrypsin

-Elastase

-Collagenase

- Carboxypeptidases

Role of Trypsin

-Secreted in the zymogen form (Trypsinogen)and activation is brought about by Enterokinase (secreted by the intestinal mucosa) and by Trypsin itself. Trypsin is specific for cleaving peptide bonds contributed by basic amino acids.

- Required for activation of Chymotrypsin
- Required for conversion of pro-elastase to elastase
- It is required for conversion of fibrinogen to fibrin
- It has weak action on casein

Role of Chymotrypsin

-Activated by Trypsin and

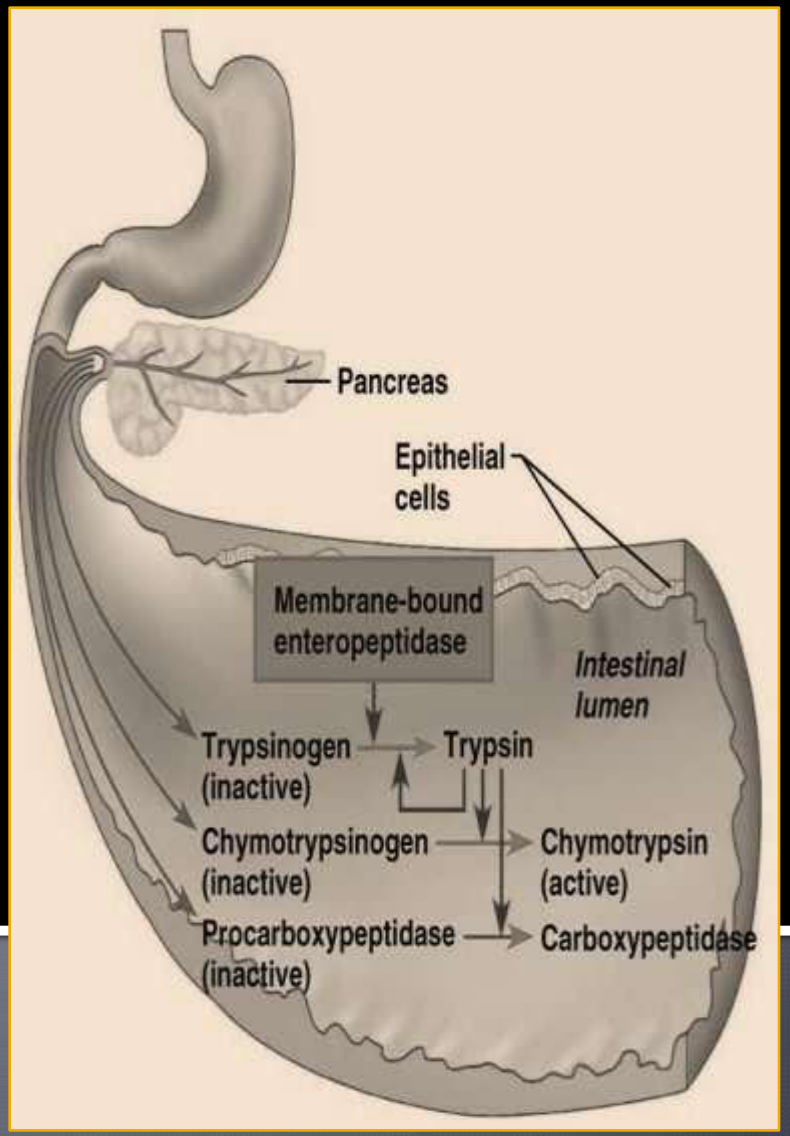
Chymotrypsin itself

(auto catalytically)

-Cleaves peptide bonds contributed

by aromatic amino acids.

- Can hydrolyze milk protein.



Role of Carboxy-peptidases

Two types of Carboxypeptidase are there

Carboxypeptidase A:Metalloenzyme , contains Zinc, Activation brought about by Trypsin and auto catalytically by itself, Exopeptidase, Hydrolyzes the terminal peptide bond connected to an end amino acid (Aromatic) bearing free carboxyl group

Carboxypeptidase B: Also an Exopeptidase, hydrolyzes terminal peptide bonds connected by basic amino acids

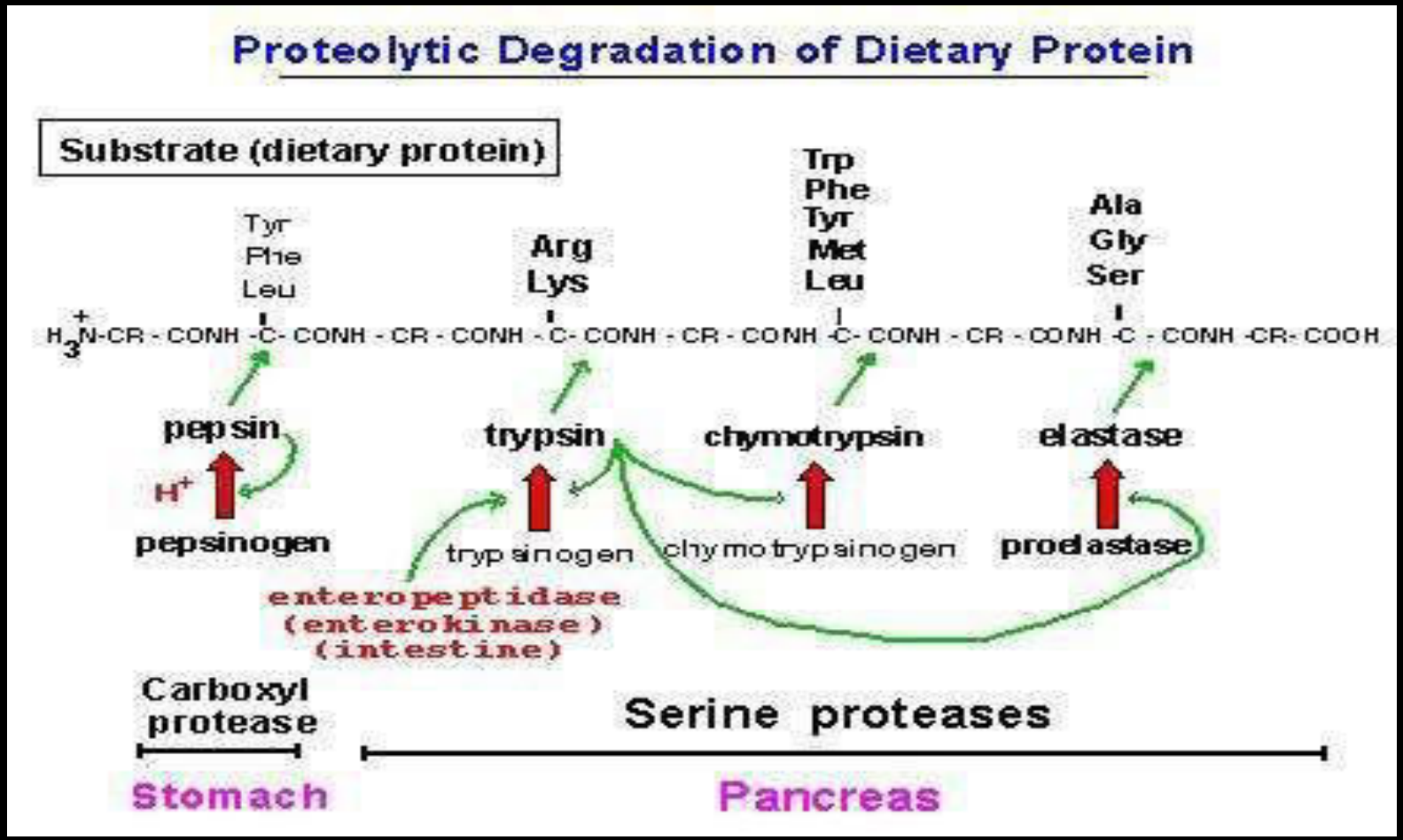
Role of Elastase and Collagenase

Elastase-

Activated by Trypsin

Has maximum activity on peptide bonds contributed by carbonyl groups of neutral aliphatic amino acids- Alanine, Glycine, Serine etc.

Collagenase- Acts on Collagen


Proteolytic Degradation of Dietary Protein
Substrate (dietary protein)
Tyr
Phe
Leu
Arg
Lys
Trp
Phe
Tyr
Met
Leu
Ala
Gly
Ser
pepsin
trypsin
chymotrypsin
elastase
H+
pepsinogen
trypsinogen
chymotrypsinogen
proelastase
enteropeptidase
(enterokinase)
(intestine)
Carboxyl
protease
Serine proteases
Stomach
Pancreas

Digestion by intestinal Juice

Enzymes present in intestinal juice are:

-Enterokinase

-Amino peptidases

-Prolidase

-Di and Tri peptidases

Functions of the Intestinal enzymes

Enterokinase - required for activation of Trypsin, also called Enteropeptidase, present in the epithelial cells of brush border of duodenal mucosa. Bile salts help in its liberation in to intestinal lumen.

Amino peptidases – are exopeptidases, remove the amino acid one by one from amino terminal end of peptide chains.

Prolidase - also an exopeptidase, removes proline residues from terminal end of peptide chains.

Functions of Intestinal enzyme(Contd.)

Di and Tripeptidases - Digestion of di and tri peptides is brought about by di and tri peptidases present in brush border membrane of epithelial cells as well as present in the interior of the cell.

Tripeptidases convert tripeptides into a dipeptide and a free amino acid, then dipeptidases convert dipeptides to free amino acids.

Diseases associated with digestion of proteins

Acute Pancreatitis

Premature activation of pancreatic proteolytic enzymes in the pancreas itself causes digestion of the secretory mucosa causing Acute pancreatitis. It is a life-threatening condition.

Steatorrhea

In conditions of deficient pancreatic secretions like cystic Fibrosis, chronic pancreatitis or surgical removal of pancreas, the digestion and absorption of fats and proteins is left incomplete with the resultant appearance of lipids and undigested proteins in the feces. This condition is called Steatorrhea

Absorption of amino acids

Proteins are completely digested to constituent amino acids. But some amounts of oligopeptides may remain undigested.

The products of digestion are rapidly absorbed.

Site of Absorption- Oligopeptides are absorbed from duodenum. and proximal Jejunum, while amino acids are absorbed from ileum and distal jejunum .

Absorption of amino acids

Mechanism of Absorption-

The absorption takes place by active transport (same as that of glucose). Natural L-amino acids are actively transported.

D- amino acids are absorbed by simple diffusion.

Vitamin B6 is involved in the active transfer of amino acids.

Energy requiring process, ATP is required as a source of energy

A carrier protein is also required which may be Na+ dependent or independent.

Different carrier proteins are there specific for different amino acids.

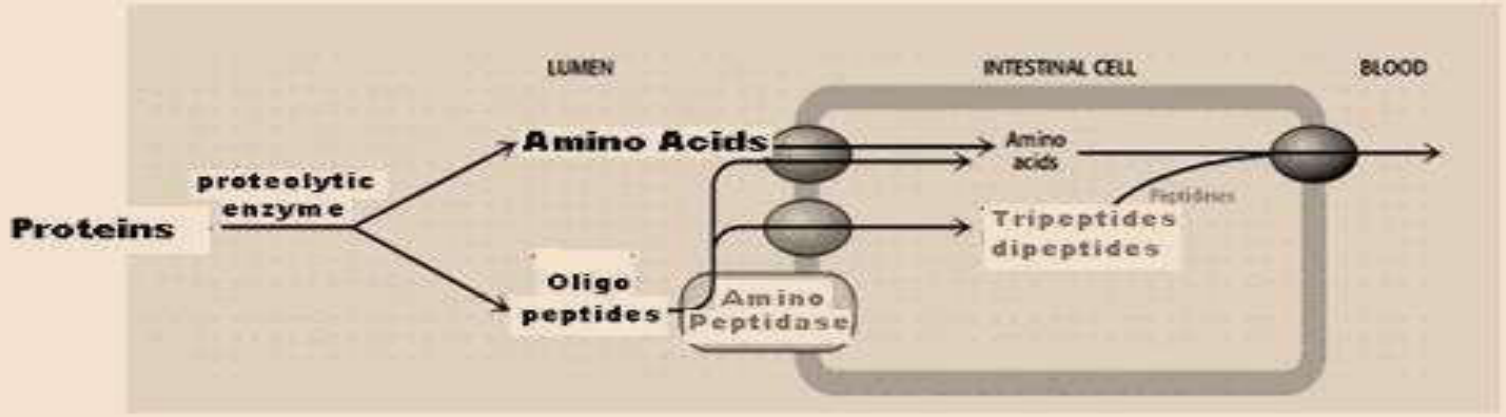
Absorption of Oligopeptides

Absorbed by active transport

Intracellular peptidases hydrolyze them to amino acids

Hydrolysis is rapid to keep peptide concentration low in the cell

Transport mechanism is independent of L- amino acids



Role of glutathione

Glutathione participates in the Active group translocation of L- amino acids in to the cells of small intestine, kidneys, seminal vesicles, epididymis and brain. A cyclic pathway, operates in which Glutathione is regenerated again, it is named as Gamma Glutamyl Cycle or Meister cycle(Based on the name of Scientist).

Meister cycle

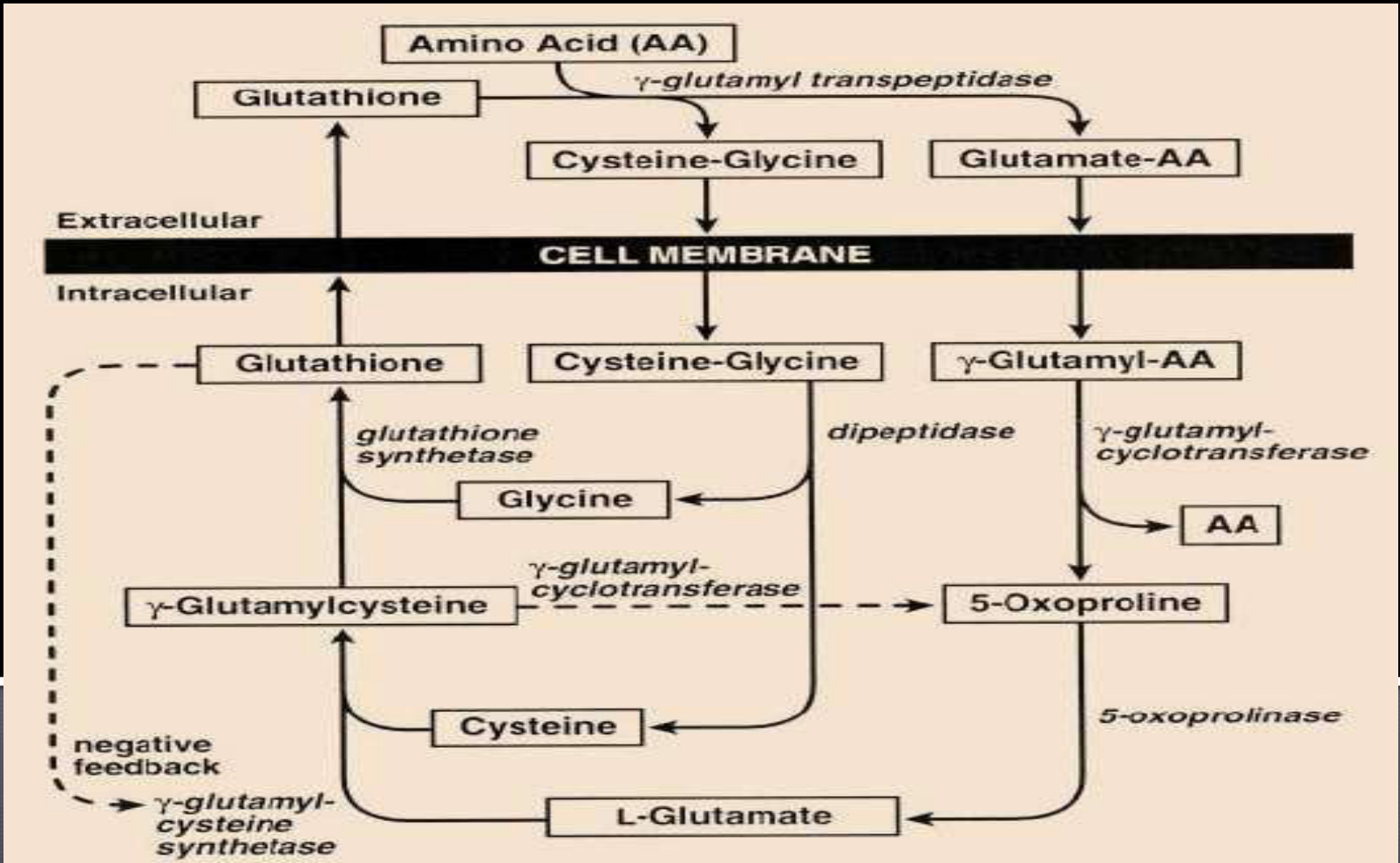


Figure 1. The γ-glutamyl cycle.

Clinical Significance

Cystinuria-Common transporter for cystine, ornithine, arginine and lysine(COAL) is present in gut and renal tubules. Deficiency of transporter results in loss of these amino acids in the feces and urine.

Hart- Nup Disease-There is deficiency of transporter for tryptophan and neutral amino acid. no absorption of tryptophan takes place ,tryptophan deficiency produce neurological and skin manifestation (pellagra-like rashes).

Food Allergies

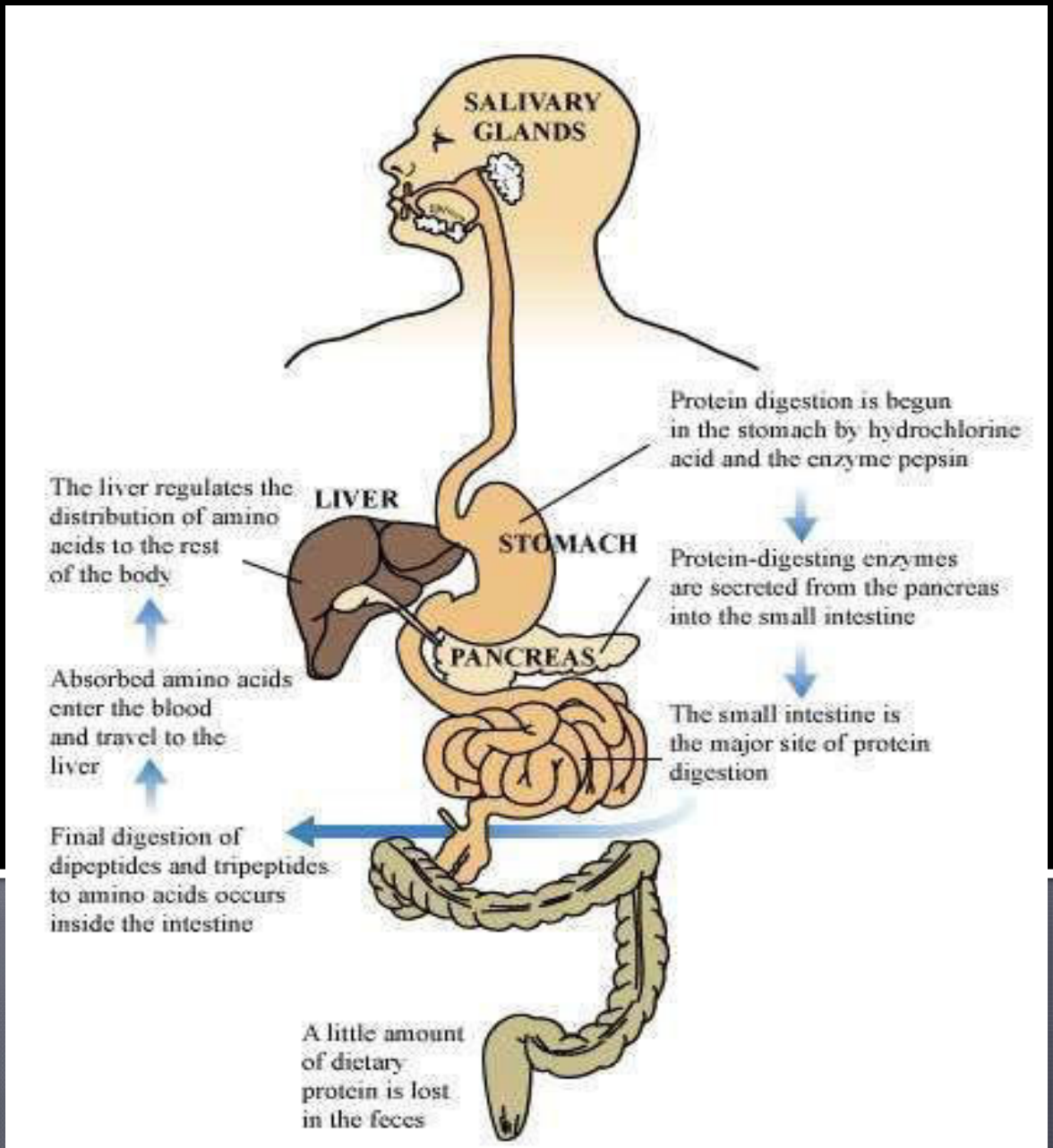
Food allergies are due to absorption of undigested peptides by pinocytosis. The immune response may be local or systemic .

Examples- Gluten induced enteropathy
Fish allergies or egg allergies

Clinical Manifestations may be due to –
local damage in the intestine in the form of nausea, vomiting, diarrhea, abdominal cramps: or

Systemic manifestations - cutaneous rashes, running nose, facial flushing, broncho-constriction or anaphylactic shock in severe cases

Summary


SALIVARY GLANDS
Protein digestion is begun in the stomach by hydrochlorine acid and the enzyme pepsin
The liver regulates the distribution of amino acids to the rest of the body
LIVER
STOMACH
Protein-digesting enzymes are secreted from the pancreas into the small intestine
PANCREAS
Absorbed amino acids enter the blood and travel to the liver
The small intestine is the major site of protein digestion
Final digestion of dipeptides and tripeptides to amino acids occurs inside the intestine
A little amount of dietary protein is lost in the feces