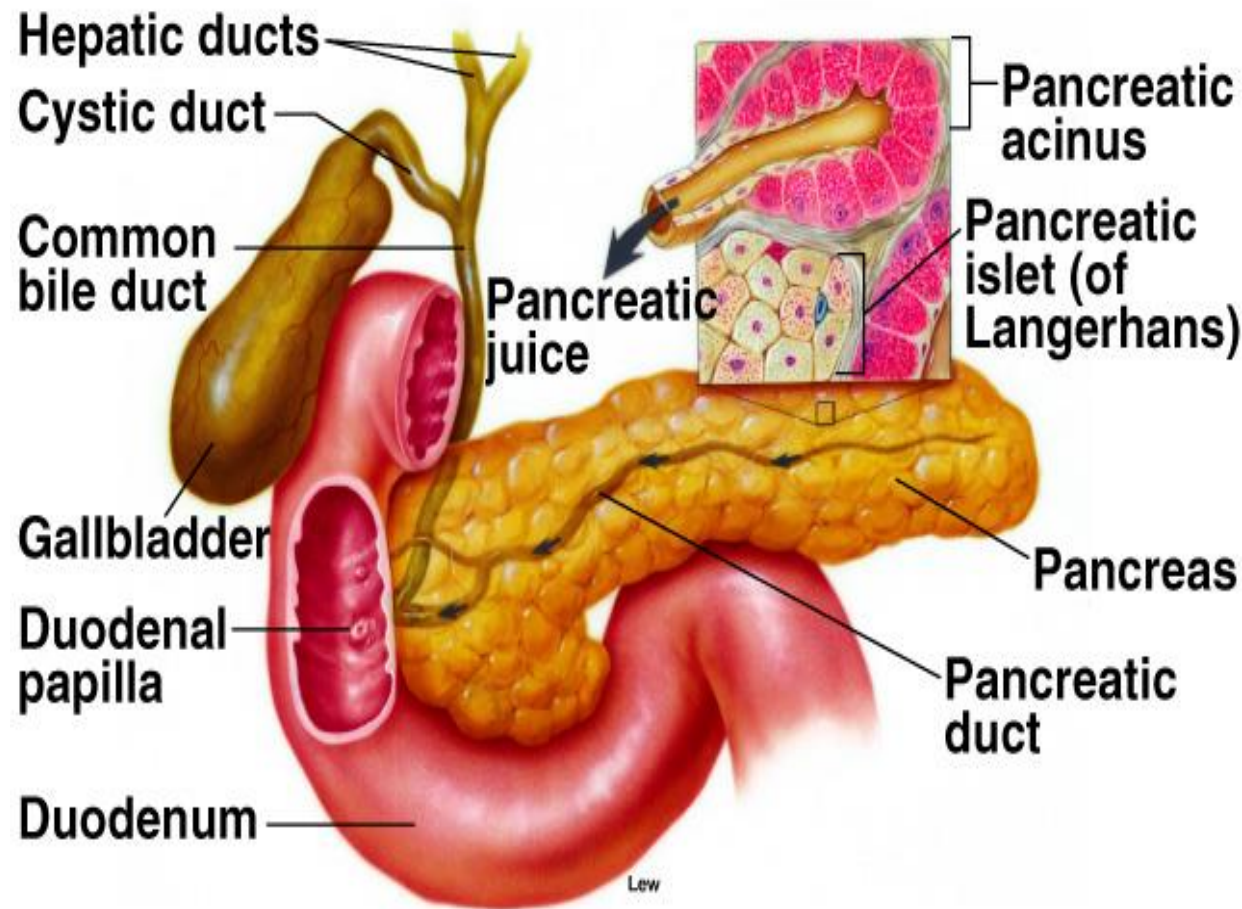


Pancreas

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- **Exocrine:**
 - **Acini:**
- **Secrete pancreatic juice.**
- **Endocrine:**
 - **Islets of Langerhans:**
- **Secrete insulin and glucagon.**



5-Pancreatic Secretion

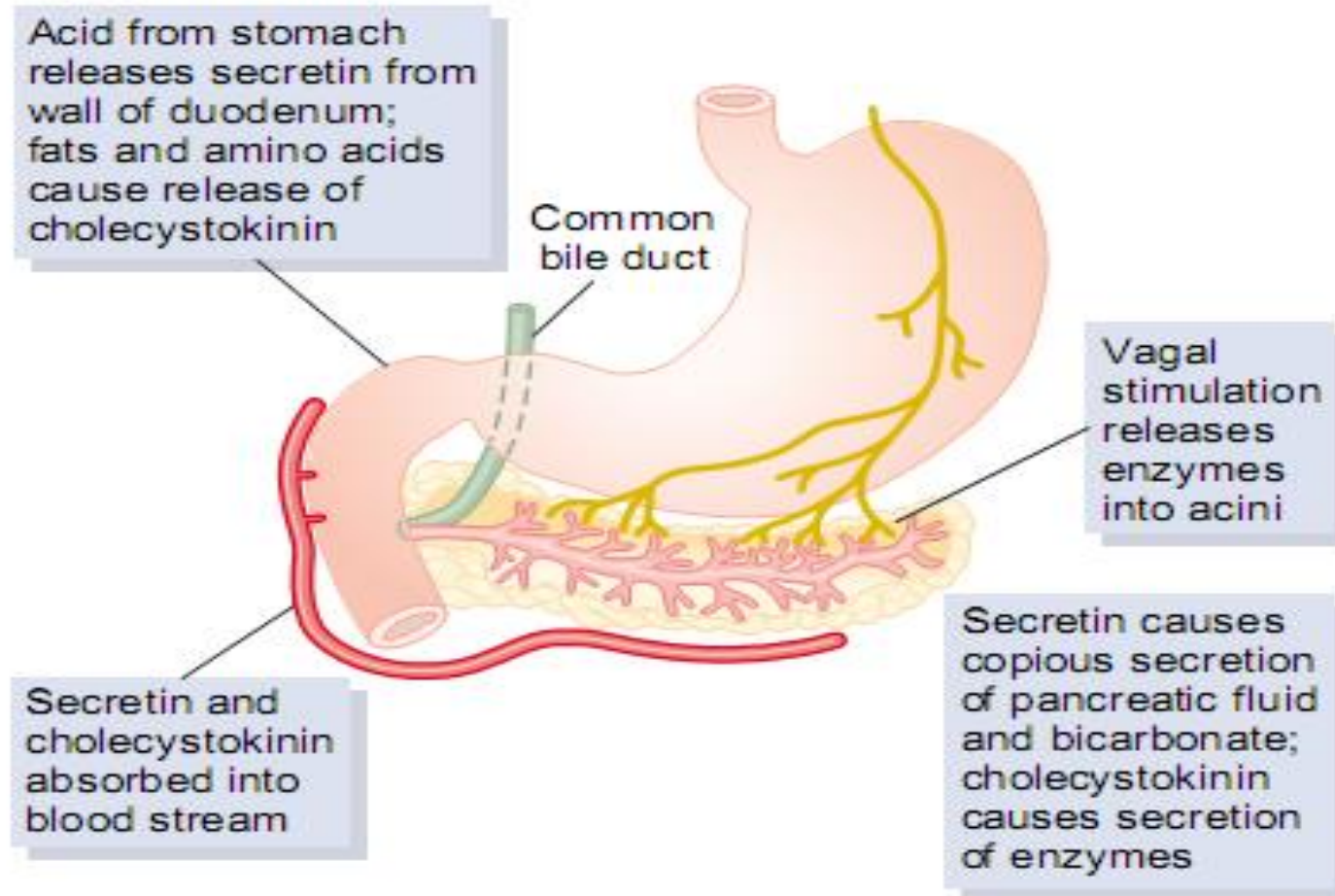
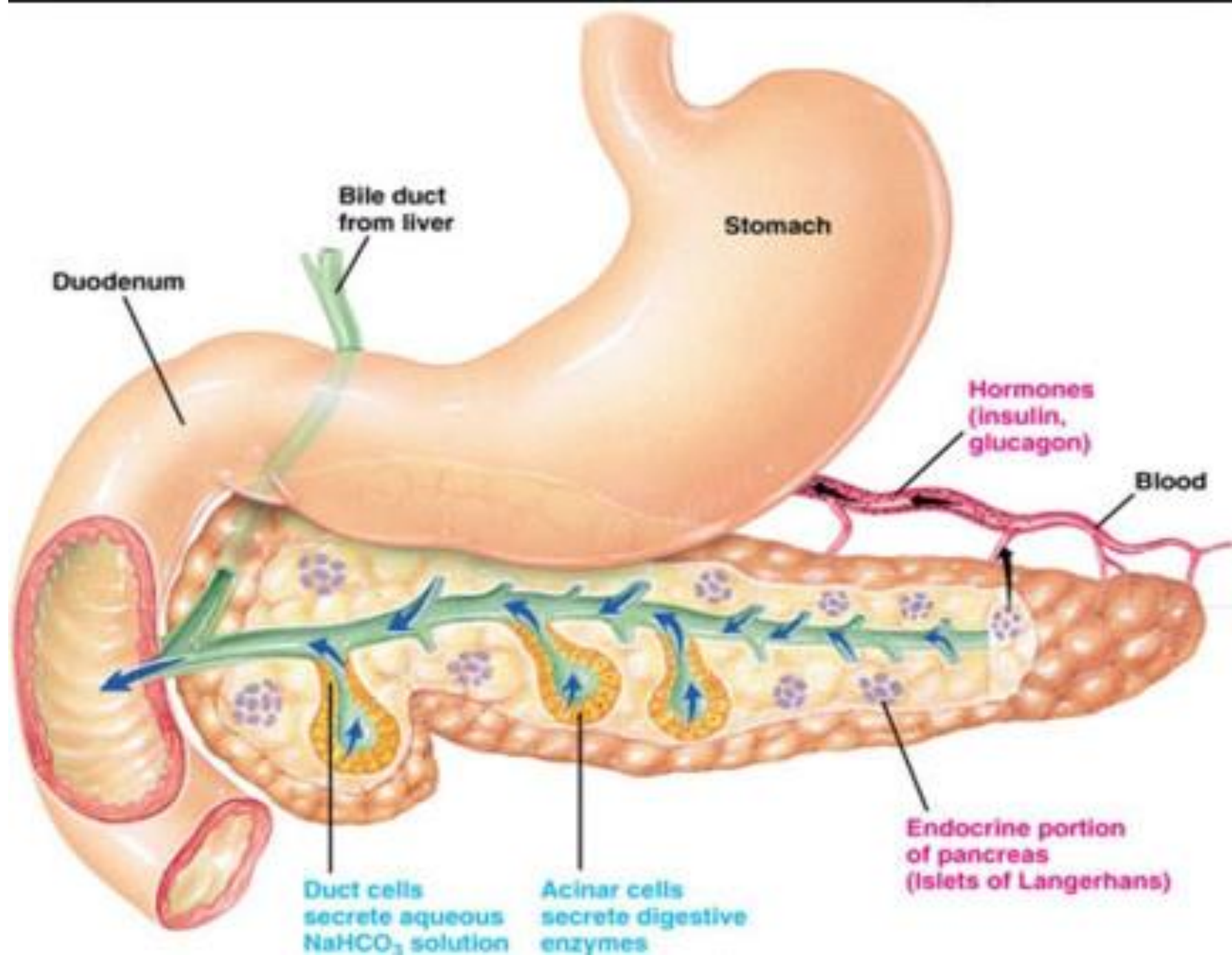


Figure 64-10

Regulation of pancreatic secretion.





Pancreatic secretion contains multiple enzymes for digesting all of the three major types of food: proteins, carbohydrates, and fats. It also contains large quantities of bicarbonate ions, which play an important role in neutralizing the acidity of the chyme emptied from the stomach into the duodenum.

- Pancreatic enzymes for digesting **Proteins** are *Trypsin, Chymotrypsin, and Carboxypolypeptidase*. By far the most abundant of these is trypsin.
- The pancreatic enzyme for digesting **Carbohydrates** is *pancreatic Amylase*, which hydrolyzes starches, glycogen, and most other carbohydrates (except cellulose) to form mostly disaccharides and a few trisaccharides.

- ◎ The main enzymes for **Fat digestion** are:
 - (1) ***Pancreatic lipase***, which is capable of hydrolyzing neutral fat into fatty acids and monoglycerides
 - (2) ***Cholesterol esterase***, which causes hydrolysis of cholesterol esters
 - (3) ***Phospholipase***, which splits fatty acids from phospholipids.

Pancreas

◎ Pancreatic juice

- 1.0-1.2 L/day
- Mostly water some salts, bicarbonate, enzymes
- Alkaline, pH 7.1-8.2.
- Buffers acidic gastric juice, stops pepsin activity, creates proper alkaline pH for enzymes acting in the intestine.
- Enzymes include:
 - ◆ Pancreatic amylase
 - ◆ Trypsinogen, Chymotrypsinogen, Procarboxypeptidase (inactive zymogens)
 - ◆ Pancreatic lipase
 - ◆ Ribonuclease and deoxyribonuclease

A-aqueous Pancreatic

Secretion

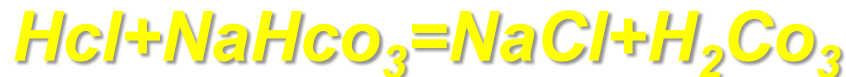
Composition;

- Water
- HCO_3^-
- Poor in enzymes.

Secretion; Actively by epithelial cells of pancreatic Ducts
It is stimulated by secretin & VIP.

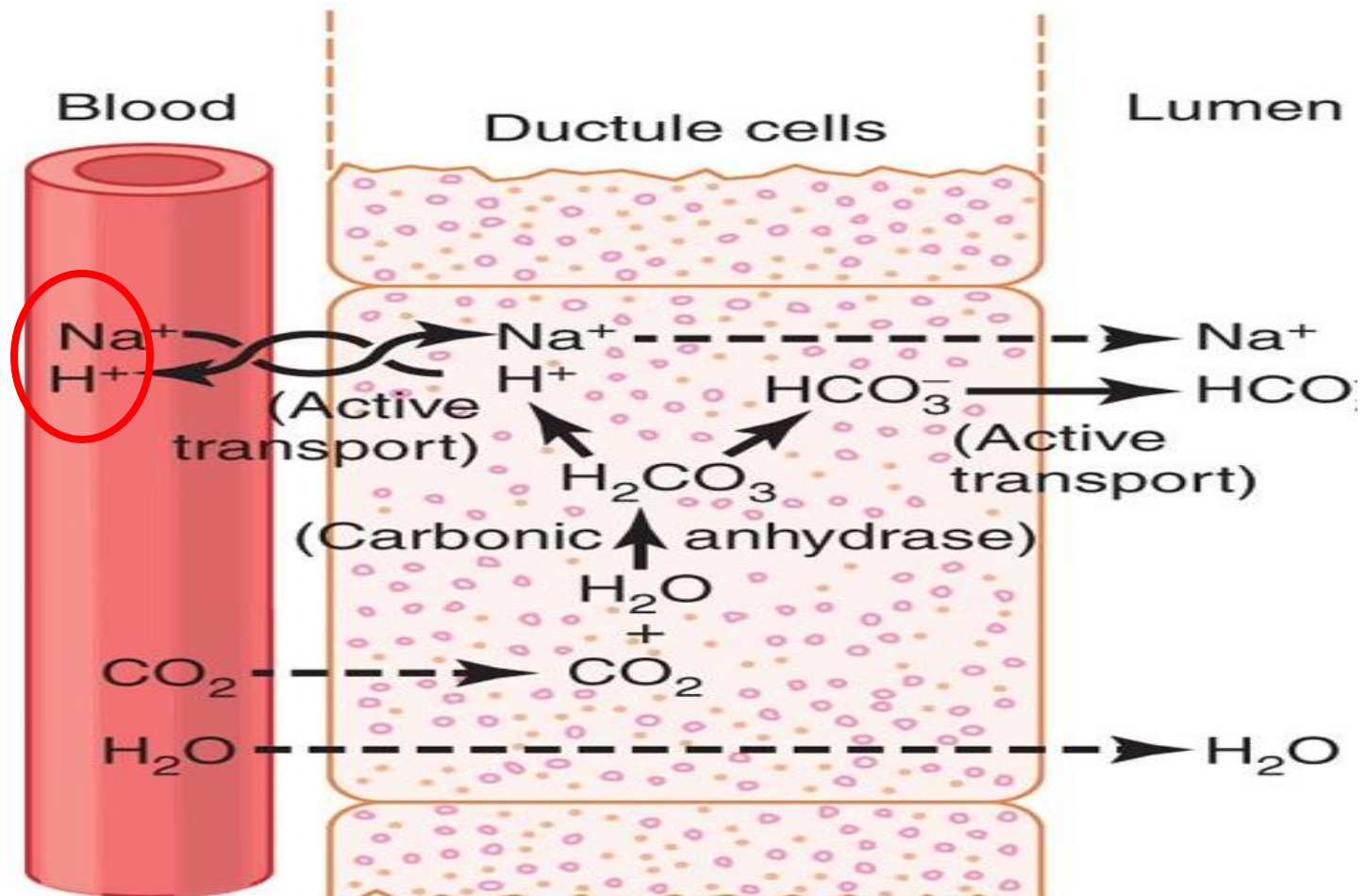
Function;

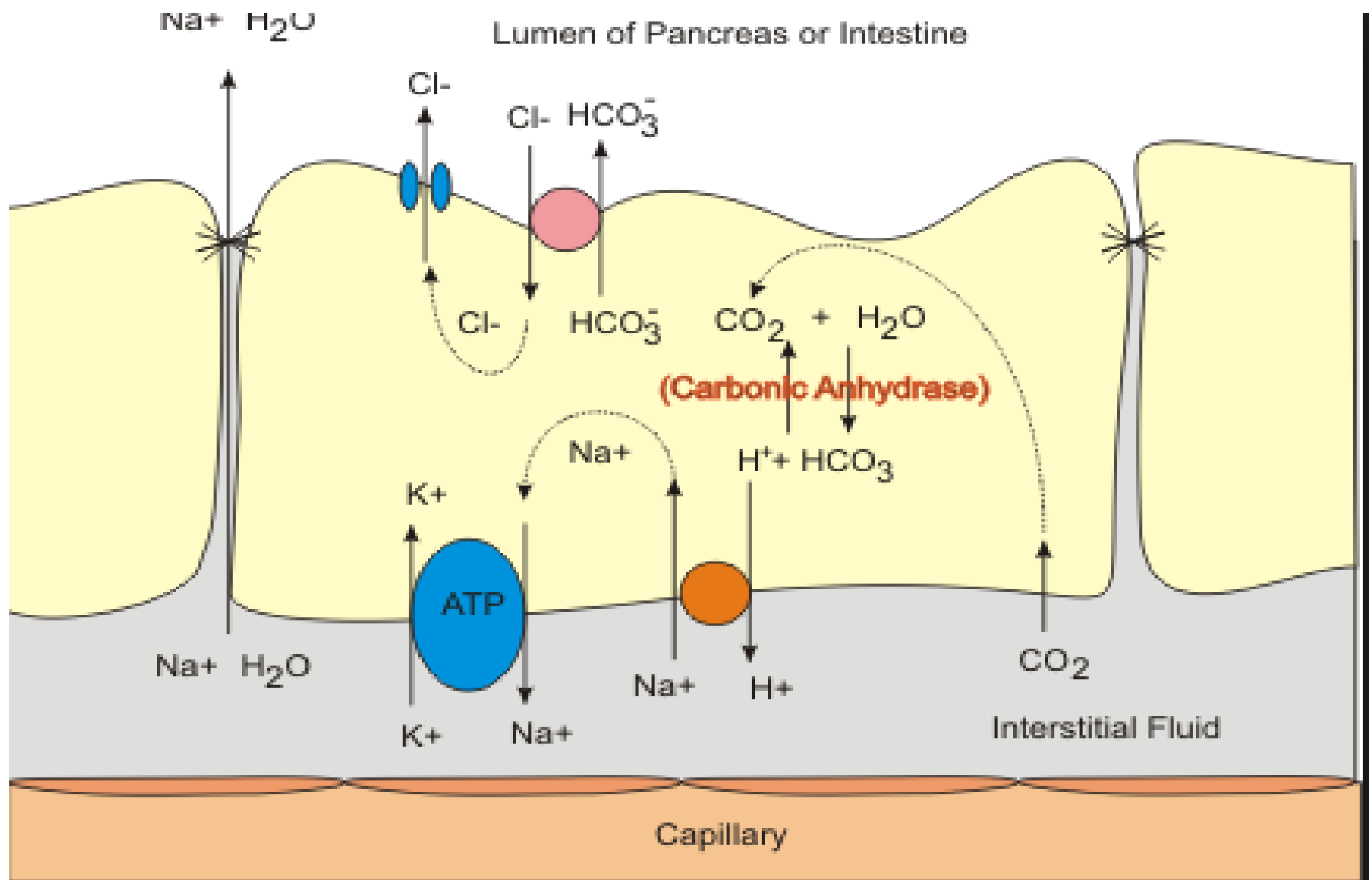
- *Neutralize the acid chyme emptied by the stomach into the duodenum to protect the delicate duodenal mucosa from harmful effect of acidity & pepsin.*



- *Provide the alkaline pH optimum for the action of pancreatic & intestinal enzymes .*

Mechanism of HCO_3^- secretion





Bicarbonate Secretion in Pancreas or Intestine

B-Pancreatic enzymes

- They are fully sufficient for complete digestion of food.
- They are secreted from the Acinar cells.
- The juice is small in volume, poor in HCO_3^- and **Rich** in the following enzymes:-
 - ◆ Pancreatic amylase.
 - ◆ Pancreatic lipase.
 - ◆ Pancreatic Proteolytic enzymes.

Pancreatic enzymes

1-Proteolytic:

Secreted in inactive form, become activated only in small intestine. By Enterokinase enzymes secreted by Intestinal mucosa EK in response to chyme.

- **Trypsinogen** → **Trypsin (Endopeptidase)** → peptides
Trypsin
- **Chymotrypsinogen** → **chymotrypsin (endopeptidase)** → peptides
Trypsin
- **Procarboxypeptidase** → **carboxypeptidase** → Amino acids

It is an **Exopeptidase**. It is the only Proteolytic enzyme that can release amino acids.

- **d-Proelastase** → **Elastase (acts on elastin).**

2-Lipolytic:

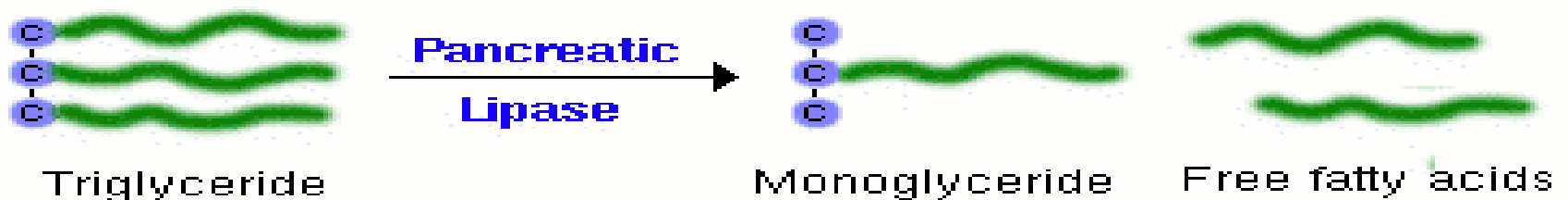
- a- **Pancreatic lipase** acts on TG → Monoglycerides and fatty acids. It is the only enzyme that accomplish fat digestion. It **needs bile salts**.
- b-**Prophospholipase A2**.
- c-**Cholesteryl ester hydrolase(cholesterol esterase)**

3- α -Amylase:

Act on starch → maltose and maltotriose & dextrans.
More potent than ptyalin.

4-Nucleases:

Act on RNA, DNA → nucleotides.



Protection Of The Pancreas From Autodigestion

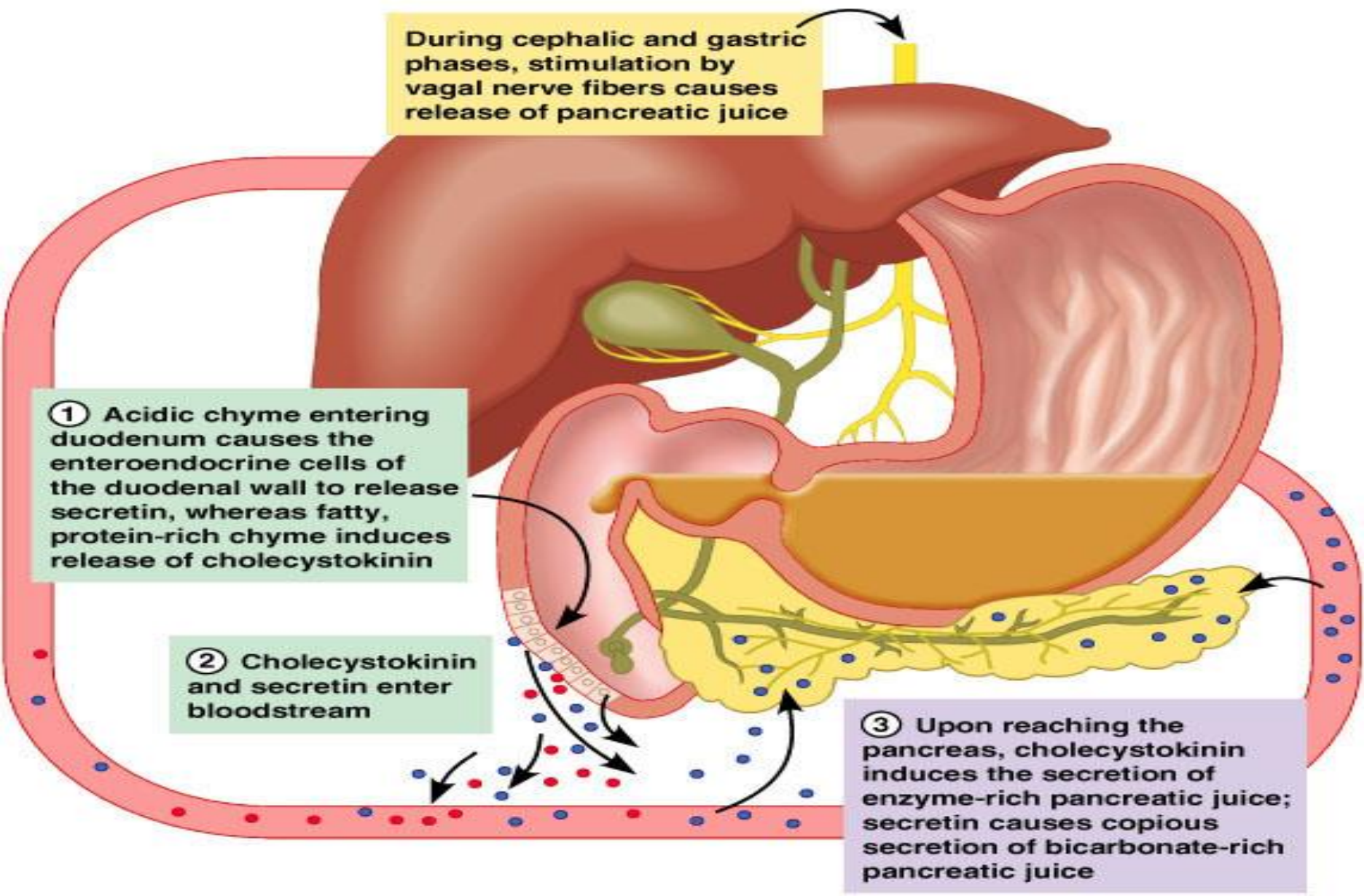
- **All Proteolytic enzymes are secreted in an inactive form to protect the pancreas against Autodigestion, and they become activated only in small intestine under the effect of Trypsin.**
 - **The pancreas also secretes a Trypsin Inhibitor that blocks any trypsin activity inside the pancreas, because normally, some trypsinogen is activated to trypsin in the pancreas.**
- Predict the mechanism of pancreatitis?**

Regulation of Pancreatic Secretion

- **Basic Stimuli That Cause Pancreatic Secretion:**
- **Acetylcholine**, which is released from the parasympathetic Vagus nerve endings and from other cholinergic nerves in the enteric nervous system
- **Cholecystokin****in**, which is secreted by the duodenal and upper jejunal mucosa when food enters the small intestine
- **Secretin**, which is also secreted by the duodenal and jejunal mucosa when highly acidic food enters the small intestine



Regulation of Pancreatic Secretion



 **Secretin**, in contrast to the first two basic stimuli, stimulates secretion of large quantities of water solution of sodium bicarbonate by the pancreatic *Ductal epithelium*.

 **Acetylcholine and Cholecystokinin**, stimulate the *Acinar cells of the pancreas*, causing production of large quantities of pancreatic digestive enzymes but relatively small quantities of water and electrolytes to go with the enzymes.

 **Secretin** is released from the mucosa of the small intestine when the pH of the duodenal contents falls below 4.5 to 5.0, and its release increases greatly as the pH falls to 3.0.

- ⦿ This immediately causes copious secretion of pancreatic juice containing large amounts of sodium bicarbonate
- ⦿ Because the mucosa of the small intestine cannot withstand the digestive action of acid gastric juice, this is an essential protective mechanism to prevent development of Duodenal ulcers.

-  **Bicarbonate ion secretion by the pancreas provides an appropriate pH for action of the pancreatic digestive enzymes, which function optimally in a slightly alkaline or neutral medium, at a pH of 7.0 to 8.0.**
-  **Fortunately, the pH of the sodium bicarbonate secretion averages 8.0.**

Regulation of secretion of pancreatic juice (Phases of Pancreatic Secretion)

1-Nervous:

During the **Cephalic 20%** (both conditioned & unconditioned reflexes) and **Gastric phase 10%** (presence of food in the stomach), there is stimulation of Vagus nerve → act on acinar cells of pancreas → pancreatic juice (secretion rich in digestive enzymes, poor in fluid).

2-Hormonal:

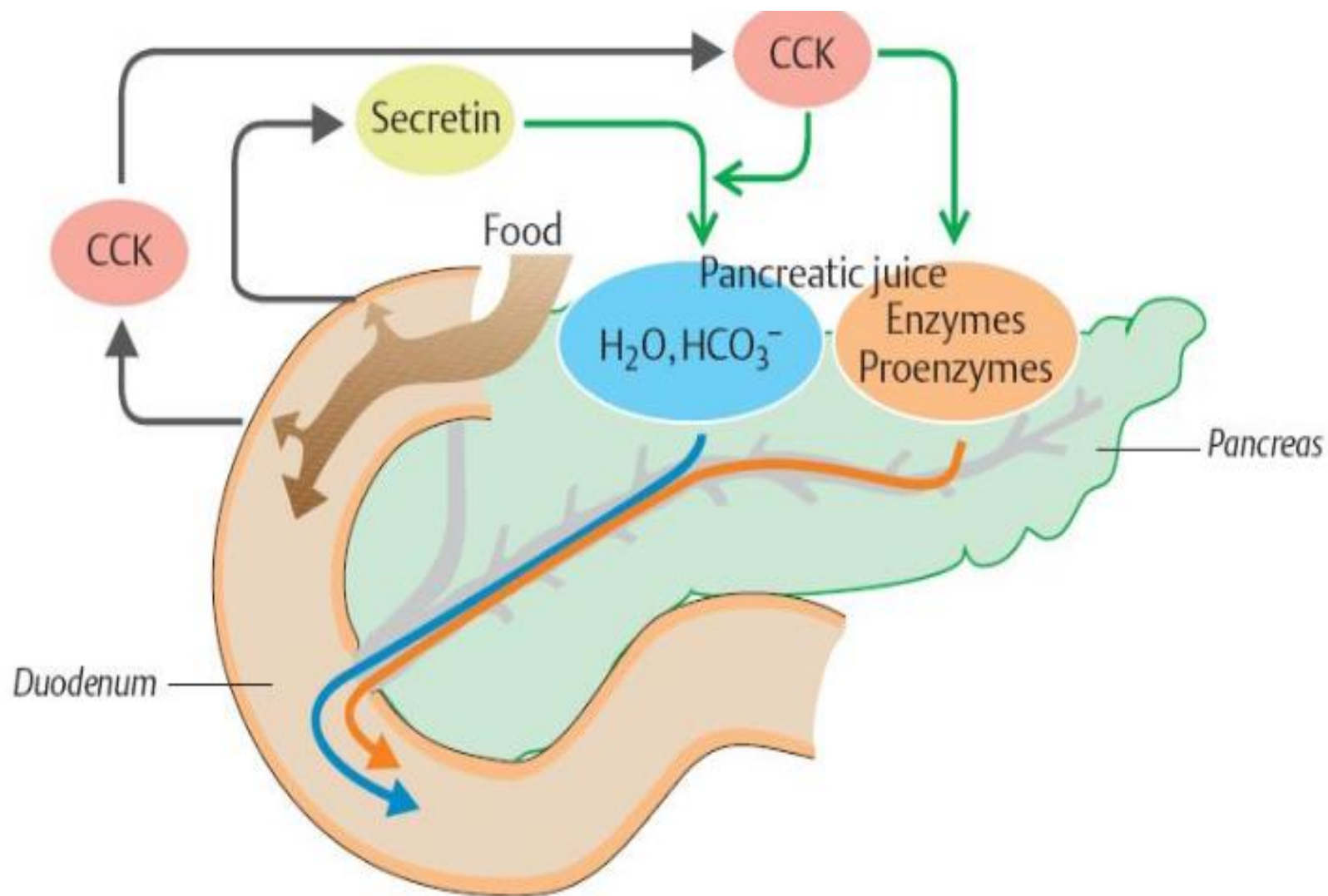
During the **Intestinal phase** of gastric secretion two important GIT hormones; secreted by duodenal mucosa stimulate the secretion of pancreatic juice:

a-Secretin hormone: It stimulates the secretion of pancreatic juice, large in volume, rich in HCO_3^- .

b-Cholecystokinin hormone (CCK): It stimulates the secretion of pancreatic juice, small in volume, rich in enzymes.

Secretin

- It is a polypeptide hormone secreted from specialized cells called **S cells** in the glands of the duodenum & jejunum contain 27 amino acid.
- It is secreted in response to:-
 - Acidic chyme in the duodenum.
 - Products of protein digestion.
- **Function:-**
 - ◆ Stimulate secretion of pancreatic juice rich in HCO_3 from pancreatic duct cells.
 - ◆ Stimulate secretion of HCO_3 from duct cells of the biliary tract which increase Bile flow (Choleretic).
 - ◆ Augment the action of CCK on pancreatic cells.
 - ◆ Inhibit gastric acid secretion & emptying.
 - ◆ Has trophic effect on exocrine pancreas.



Cholecystokinin

○ It is secreted from:-

- **I cells** in the upper small intestine contain 33 amino acid.
- Nerves in the distal ileum.

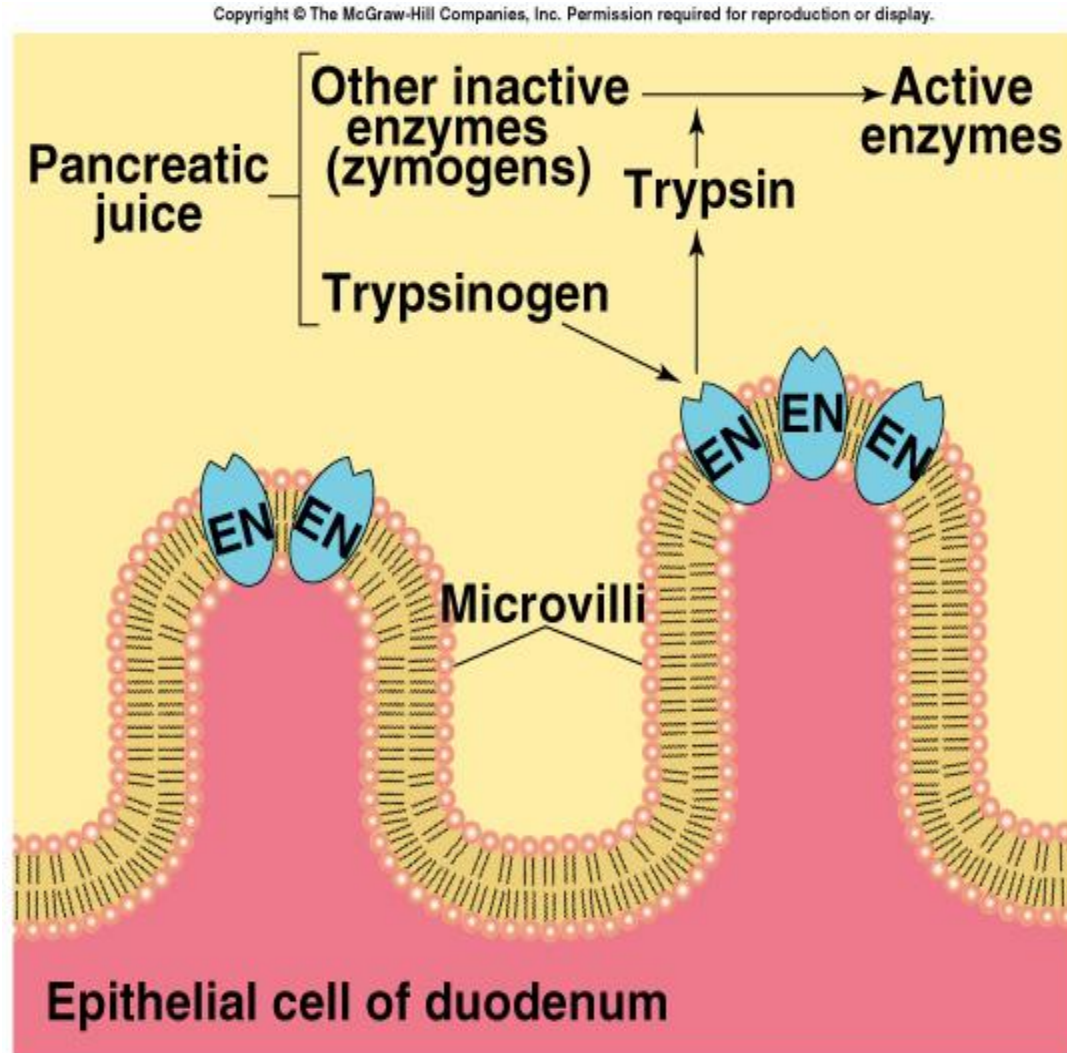
○ It is secreted in response to products of fat & protein digestion.

○ **Function:-**

- ◆ Inhibit gastric motility, emptying & secretion.
- ◆ Stimulate pancreatic acinar cell to secrete juice rich in enzymes.
- ◆ Trophic to exocrine pancreas
- ◆ Augment action of secretin.
- ◆ Stimulate gall bladder contraction (act as cholagogue).
- ◆ Involved in regulation of food intake.

Pancreatic Juice

- Complete digestion of food requires action of both Pancreatic and Brush border enzymes.
- Most pancreatic enzymes are produced as zymogens.
- Trypsin (when activated by enterokinase) triggers the activation of other pancreatic enzymes.
- Pancreatic trypsin inhibitor attaches to trypsin.
- Inhibits its activity in the pancreas.



Pancreatic Juice

- Contains H_2O , HCO_3^- and digestive enzymes.

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Table 18.4 Enzymes Contained in Pancreatic Juice

Enzyme	Zymogen	Activator	Action
Trypsin	Trypsinogen	Enterokinase	Cleaves internal peptide bonds
Chymotrypsin	Chymotrypsinogen	Trypsin	Cleaves internal peptide bonds
Elastase	Proelastase	Trypsin	Cleaves internal peptide bonds
Carboxypeptidase	Procarboxypeptidase	Trypsin	Cleaves last amino acid from carboxyl-terminal end of polypeptide
Phospholipase	Prophospholipase	Trypsin	Cleaves fatty acids from phospholipids such as lecithin
Lipase	None	None	Cleaves fatty acids from glycerol
Amylase	None	None	Digests starch to maltose and short chains of glucose molecules
Cholesterol esterase	None	None	Releases cholesterol from its bonds with other molecules
Ribonuclease	None	None	Cleaves RNA to form short chains
Deoxyribonuclease	None	None	Cleaves DNA to form short chains

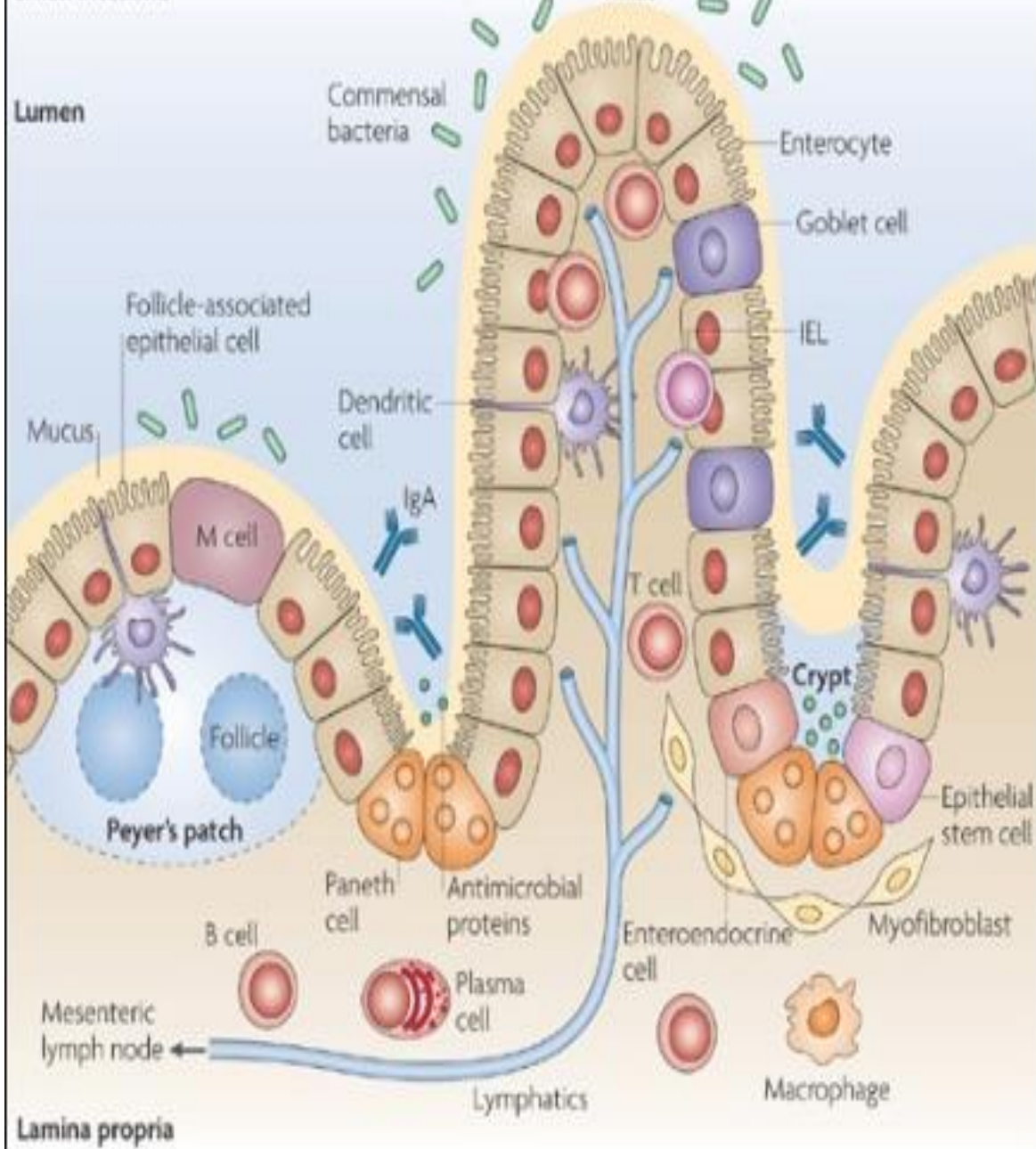
7-Secretions of the Small Intestine

- Secretion of Mucus by Brunner's Glands in the Duodenum :
- Brunner's Glands, is located mainly between the pylorus of the stomach and the ampulla of Vater. These glands secrete large amounts of alkaline mucus in response to
 - (1) Tactile or irritating stimuli on the duodenal mucosa
 - (2) Vagal stimulation, which causes increased Brunner's glands secretion concurrently with increase in stomach secretion.
 - (3) Gastrointestinal hormones, especially secretin.
- Brunner's glands are inhibited by sympathetic stimulation.

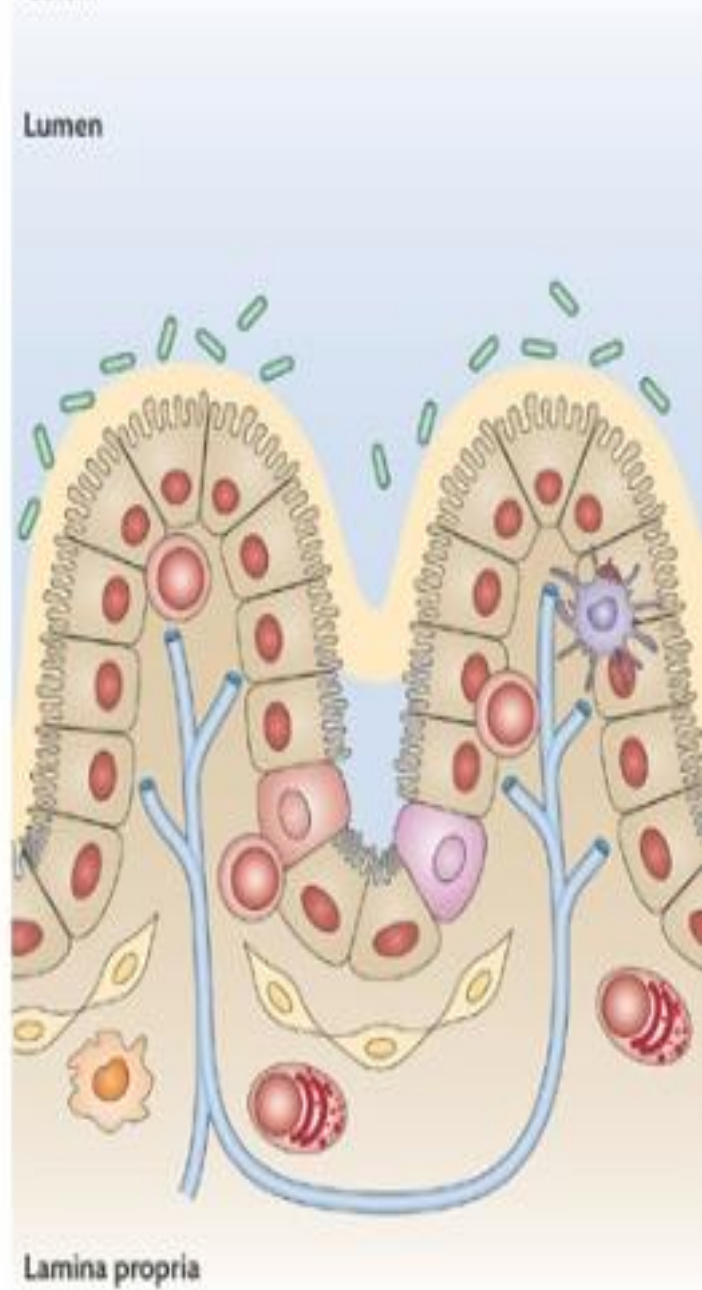
Secretion of Intestinal Digestive Juices by the Crypts of Lieberkühn

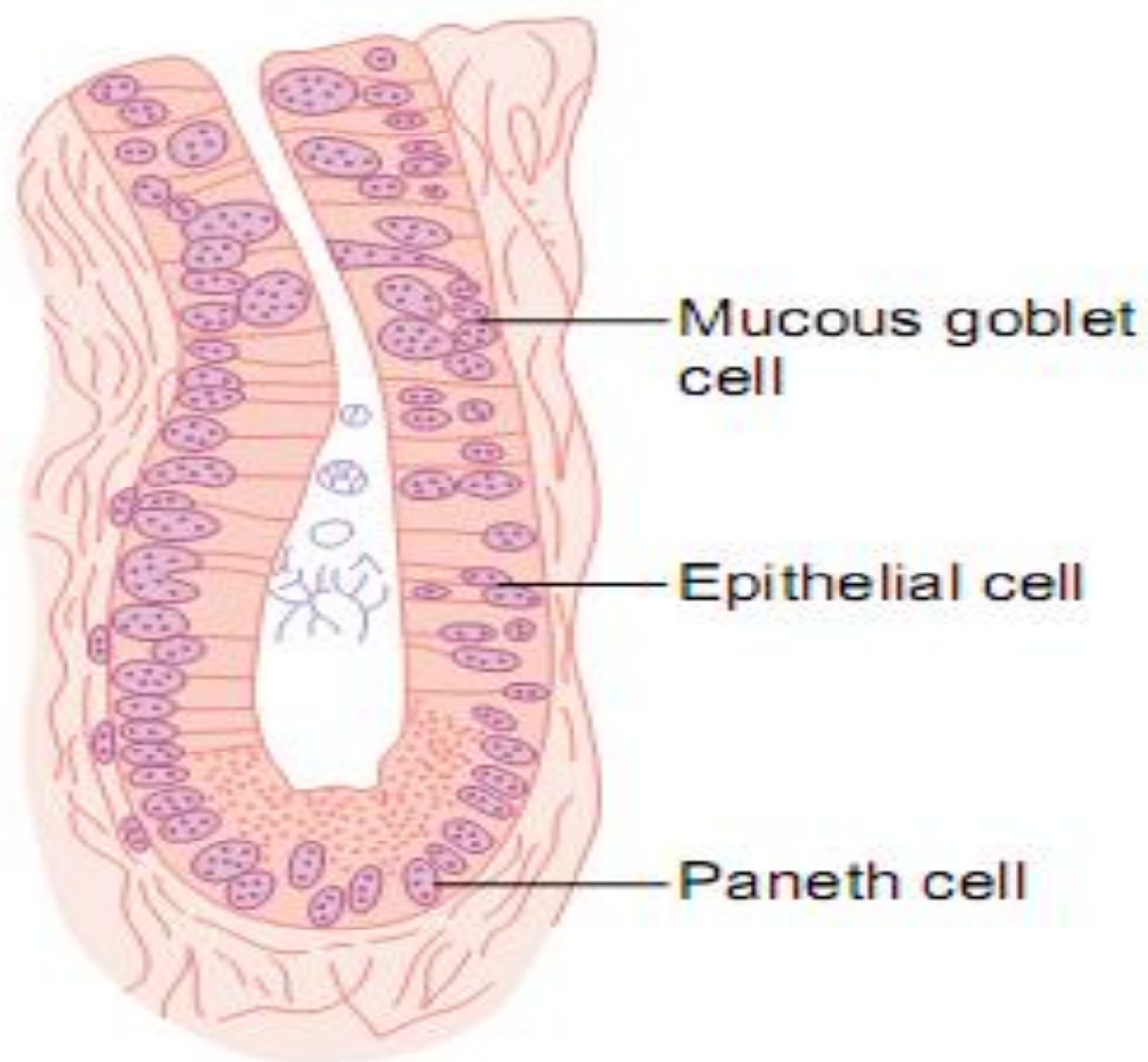
- These crypts lie between the intestinal villi
Located over the entire surface of the small intestine.
- The surfaces of both the crypts and the villi are covered by an epithelium composed of two types of cells:
- (1) Moderate number of Goblet cells, which secrete mucus that lubricates and protects the intestinal surfaces, and
- (2) Large number of Enterocytes, which, in the crypts, secrete large quantities of water and electrolytes and, over the surfaces of adjacent villi, reabsorb the water and electrolytes along with end products of digestion.

Small intestine



Colon





 ***The intestinal secretions are formed by the enterocytes of the crypts at a rate of about 1800 ml /day. These secretions are almost pure extracellular fluid and have a slightly alkaline pH in the range of 7.5 to 8.0. The secretions are also rapidly reabsorbed by the villi.***

Digestive Enzymes in the Small Intestinal Secretion

- ◎ The enterocytes of the mucosa, covering the villi, contain digestive enzymes that digest specific food substances *while they are being absorbed* through the epithelium. These enzymes are the following:
 - (1) Several peptidases: for splitting small peptides into amino acids.
 - (2) Four enzymes sucrase, maltase, isomaltase, and lactase: for splitting disaccharides into monosaccharide's.
 - (3) Small amounts of intestinal lipase: for splitting neutral fats into glycerol and fatty acids.

Regulation of Small Intestine Secretion-Local Stimuli

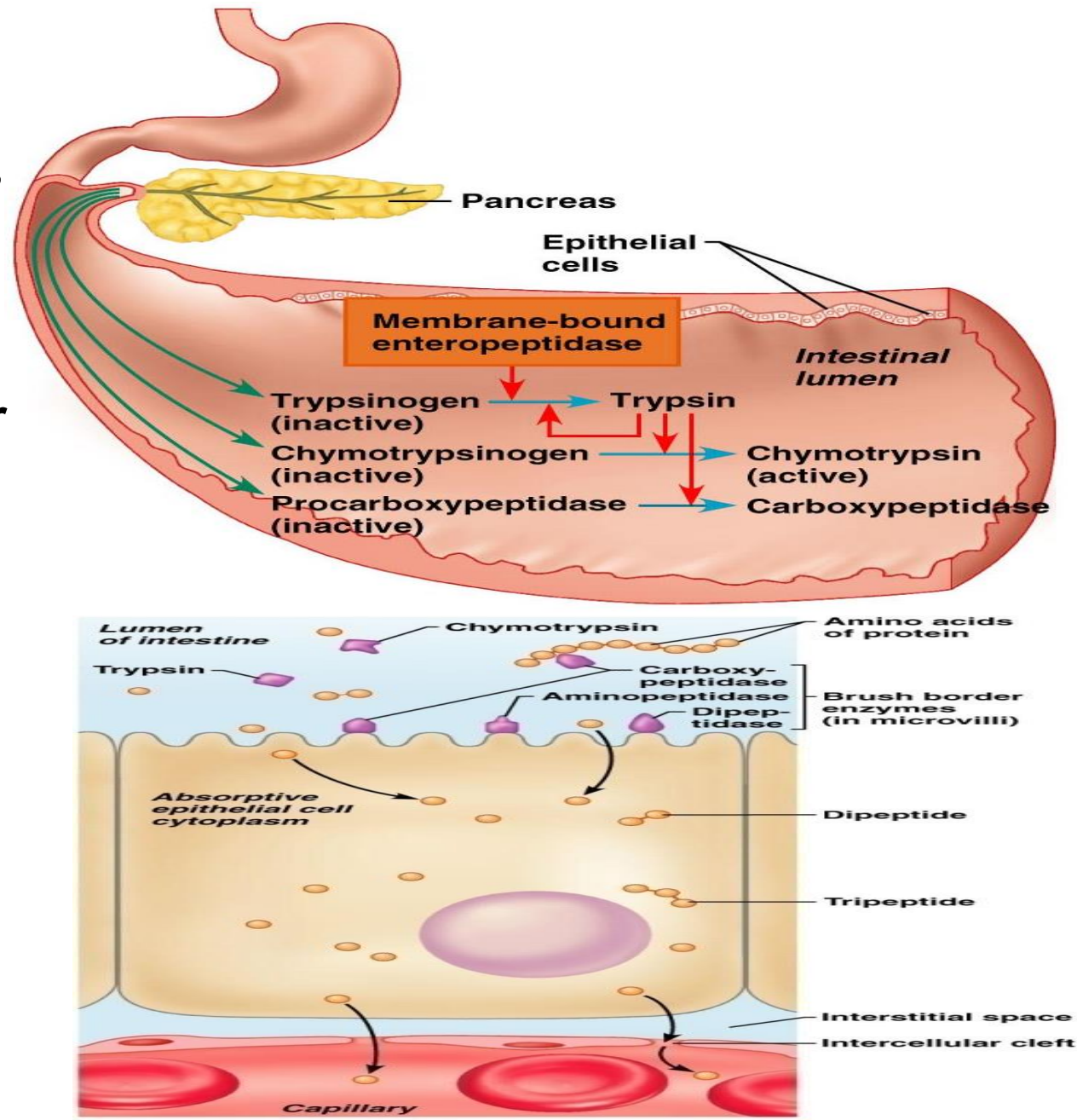
- The most important means for regulating small intestine secretion are local enteric nervous reflexes, especially reflexes initiated by tactile or irritative stimuli from the chyme in the intestines.
- The life cycle of an intestinal epithelial cell is about 5 days.

Small Intestine. Chemical Digestion

Brush border enzymes

Enteropeptidases

(Enterokinase) converts trypsinogen to trypsin
Trypsin activates other zymogens
Various other brush border enzymes complete digestion of protein and carbohydrate molecules



8-Secretion of Mucus by the Large Intestine

Mucus Secretion:

- The mucosa of the large intestine has many crypts of Lieberkühn; however, unlike the small intestine, there are no villi.
- The epithelial cells secrete almost no digestive enzymes.
- Instead, they contain mucous cells that secrete only **mucus**.
- This mucus contains moderate amounts of bicarbonate ions.