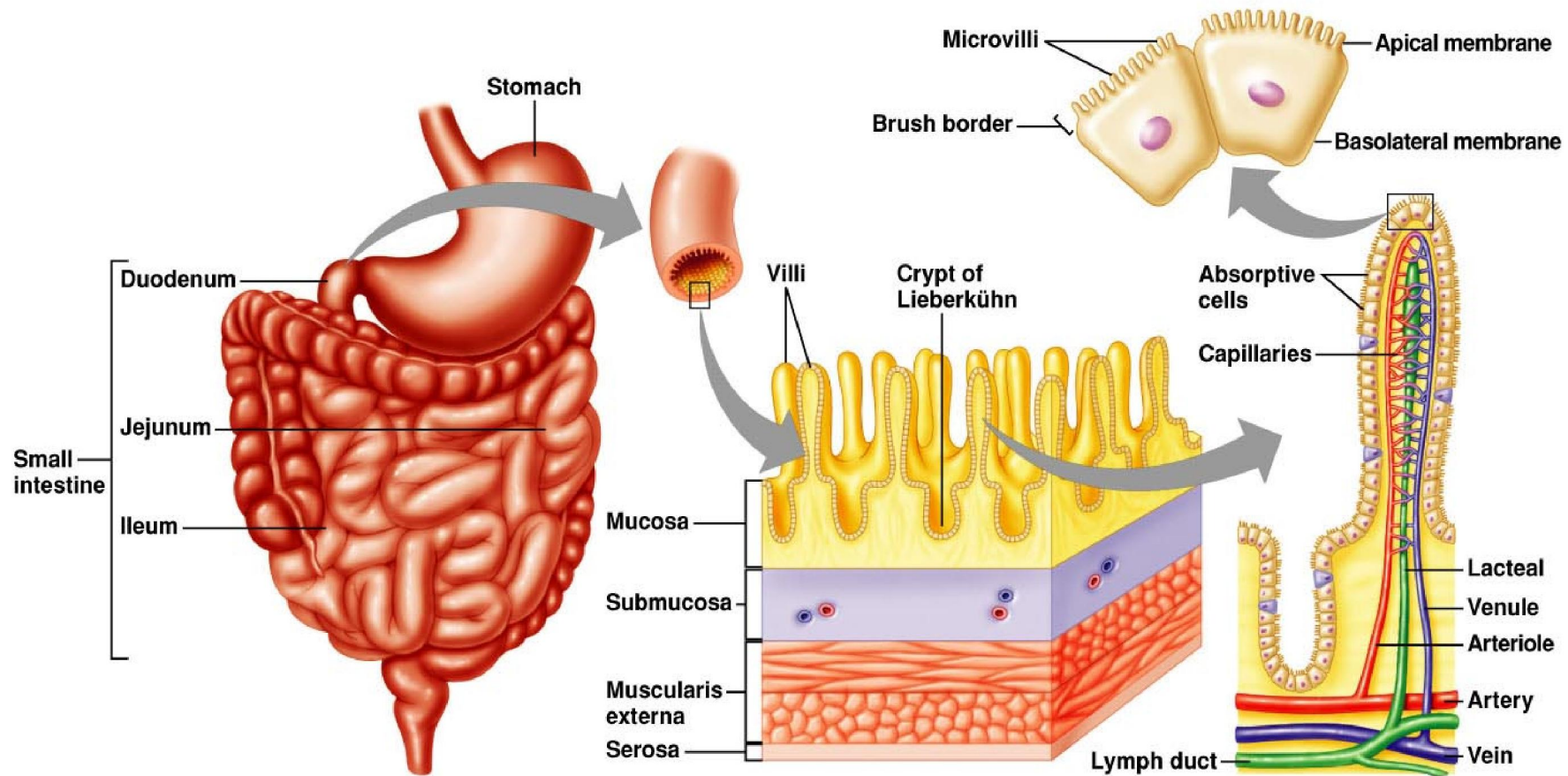


Section 3

Digestion in the Small Intestine

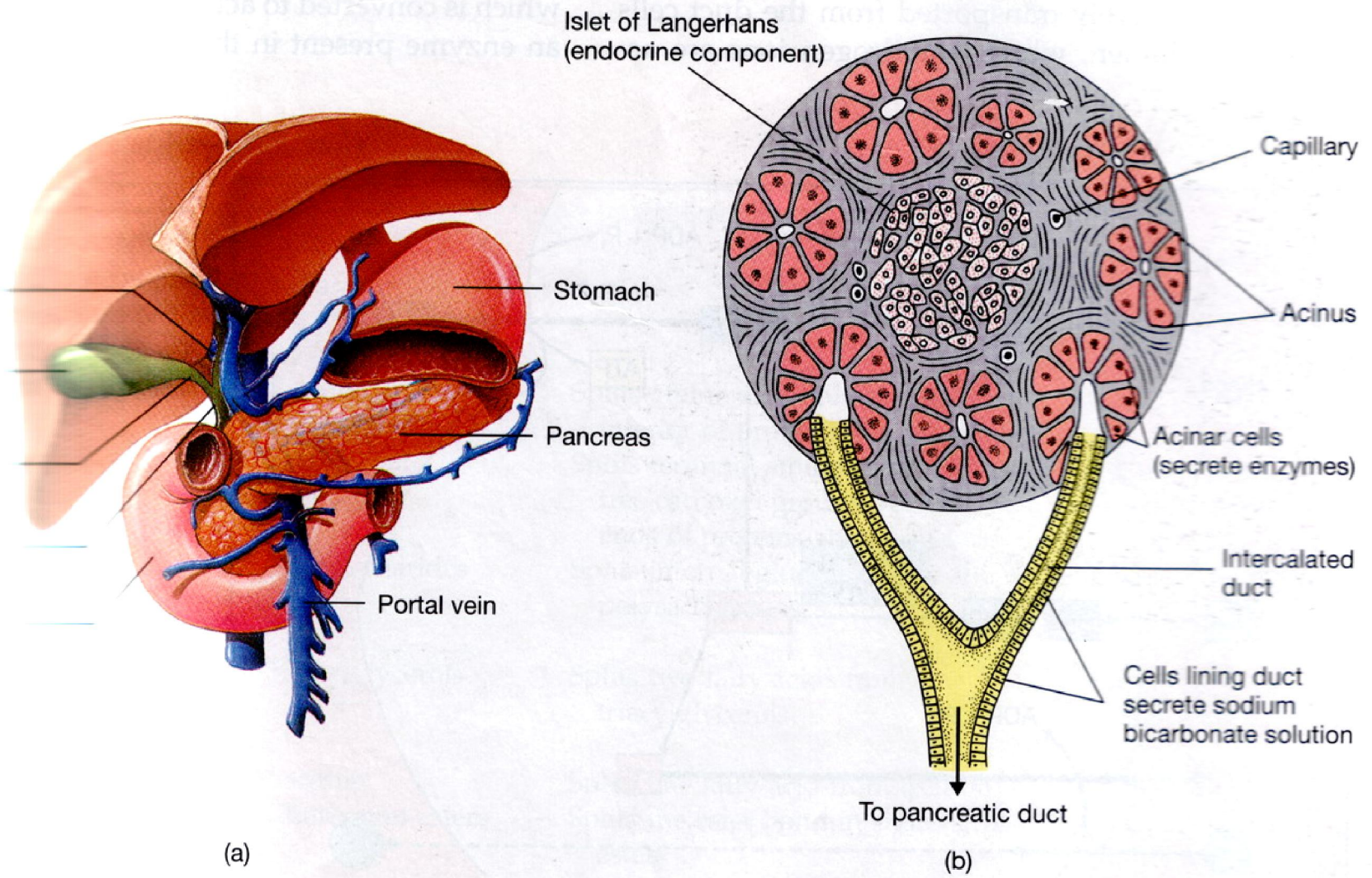




Degegestion in the small intestine

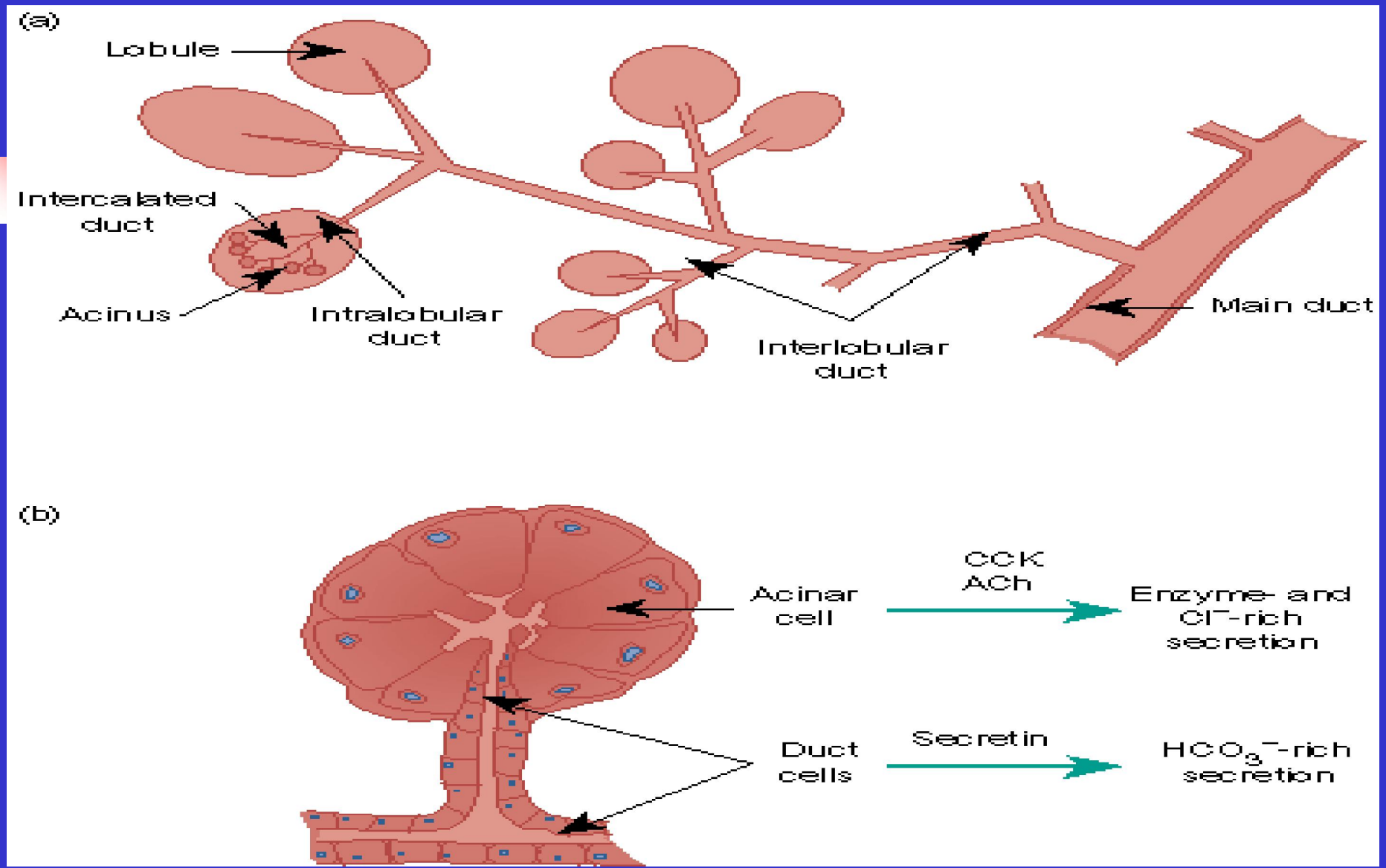
- **Pancreatic secretion**
- **Bile secretion**
- **Small intestinal secretion**
- **Digestion in brush border**
- **Motility of the small intestine**

— Pancreatic Secretion



(a)

(b)



Composition of Pancreatic juice

- A **alkaline** solution (pH: 7.8-8.4), **iso-osmotic** with plasma, 1.5L/day

- **Main composition**

- (1) A high HCO_3^- content**

- **neutralize acid emptied into the duodenum**
- **provides optimal pH for pancreatic enzymes**

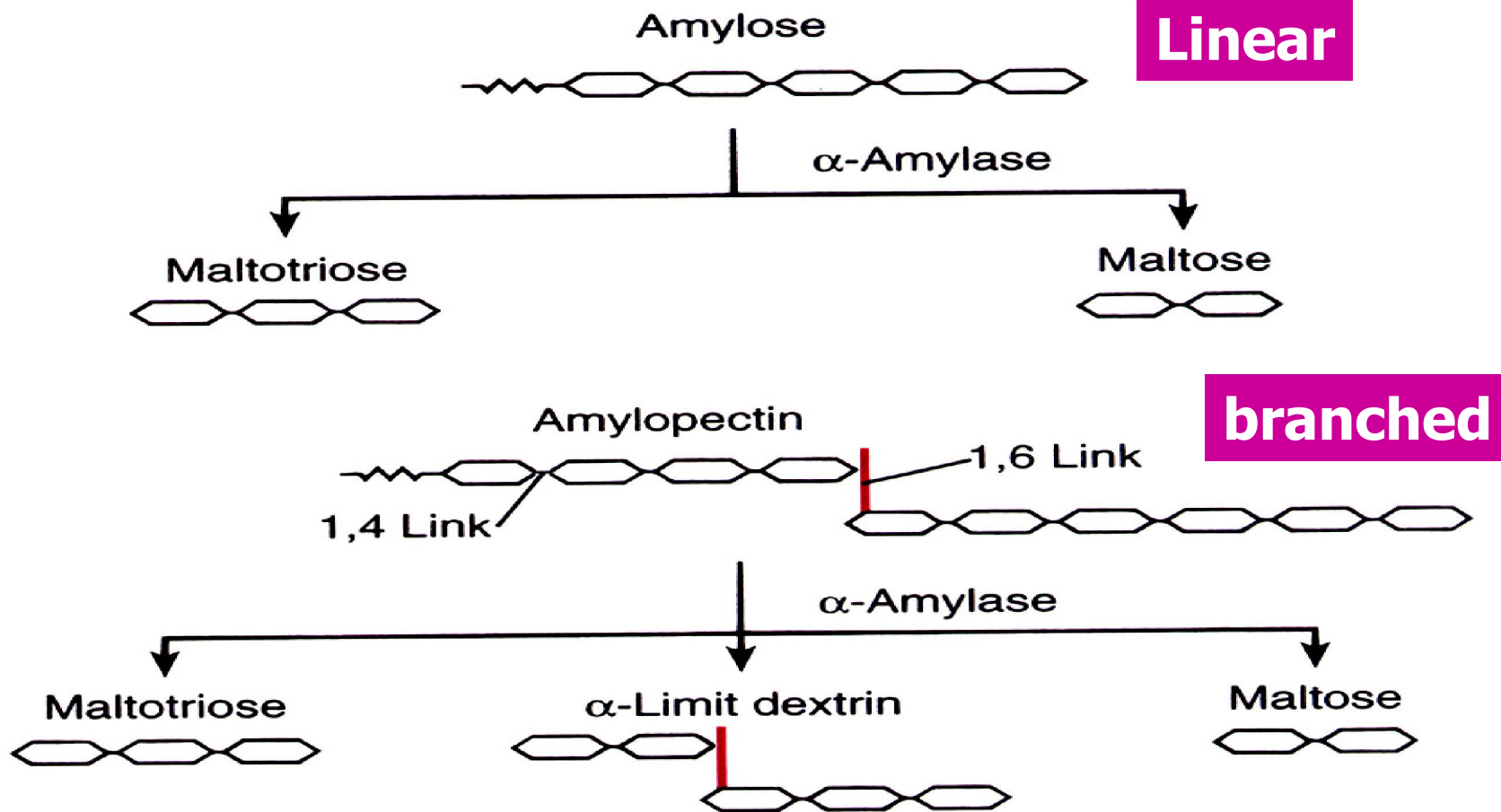
- (2) Digestive enzymes**



Pancreatic enzymes

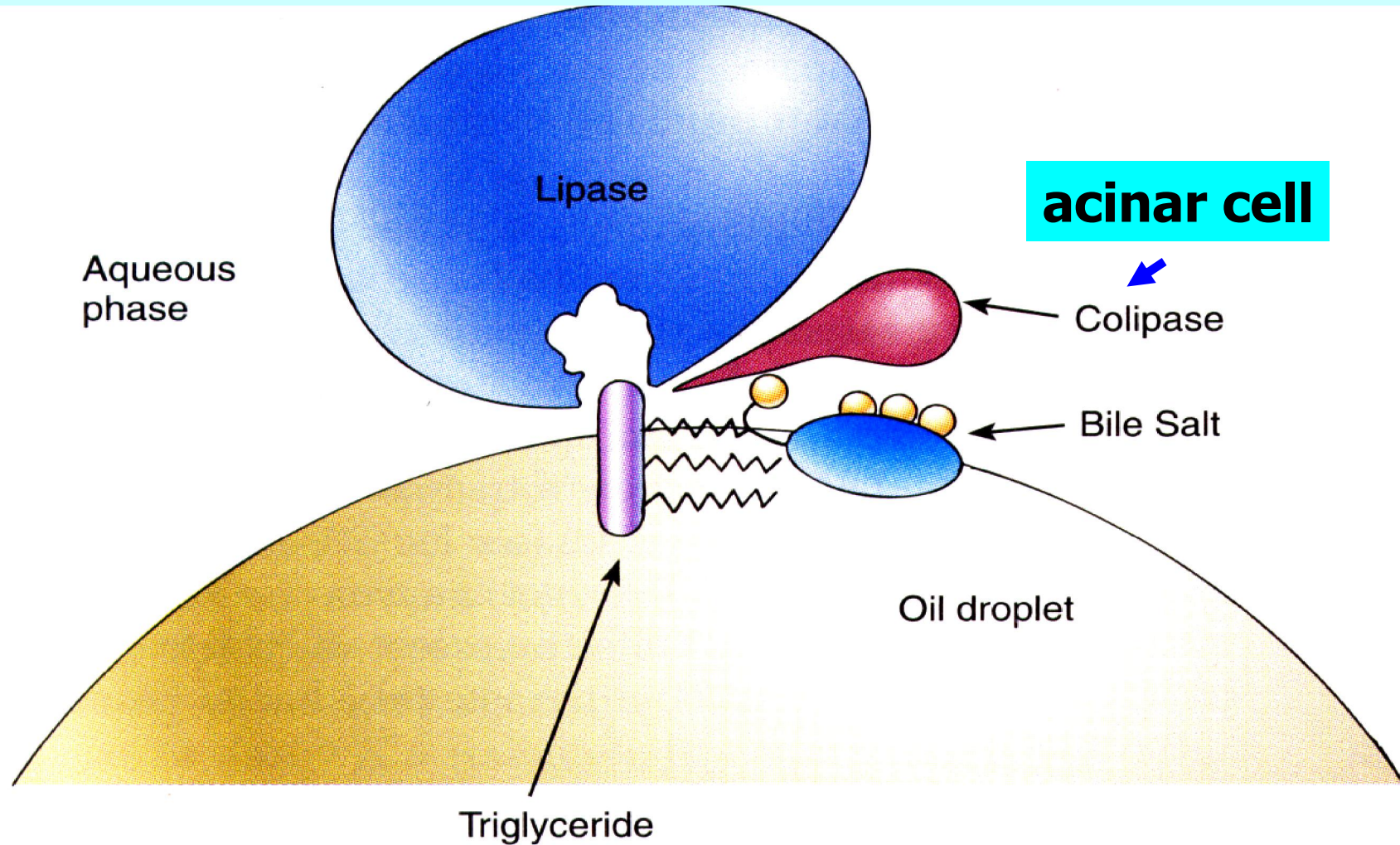
- **Pancreatic amylase**
- **Lipolytic enzymes**
 - lipase, phospholipase, cholesterol esterase**
- **Proteolytic enzymes (inactive form or zymogen)**
 - trypsin, chymotrypsin, elastase, collagenase**
 - carboxypeptidase, aminopeptidase,**
- **RNAase and DNAase**

Amylase: hydrolyze starch, glycogen and other carbohydrates into disaccharides and trisaccharides

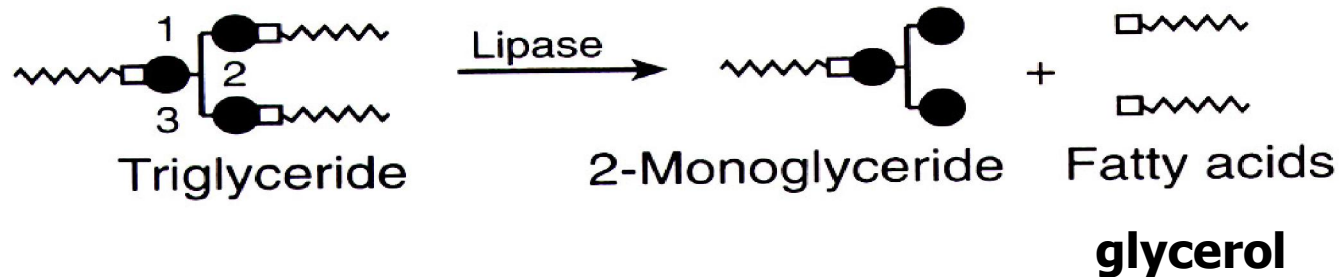


■ Lipolytic enzymes :

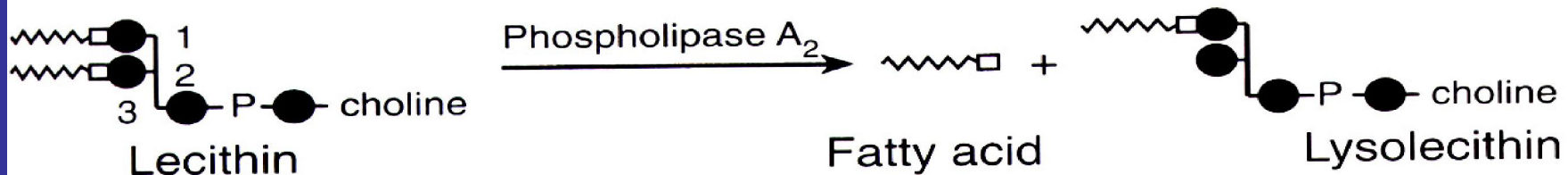
Lipase, Phospholipase, Cholesterol hydrolase



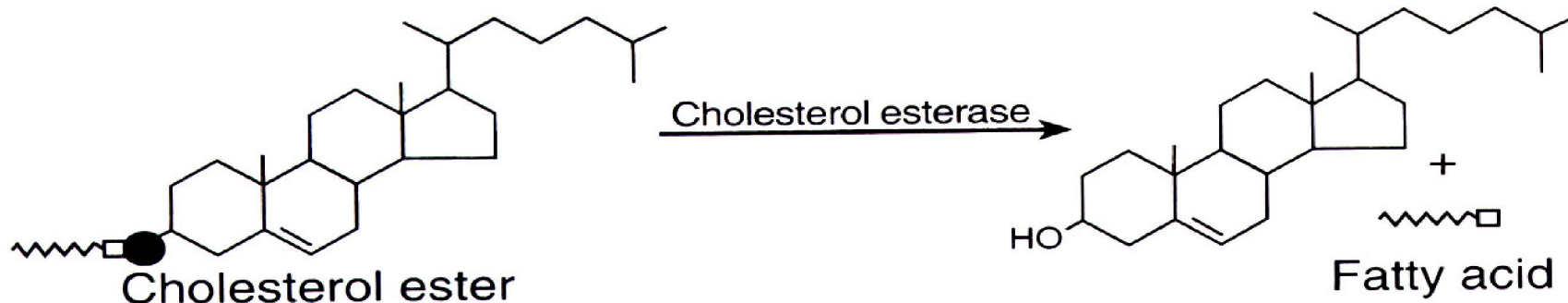
Triglyceride



Phospholipid



Cholesterol ester

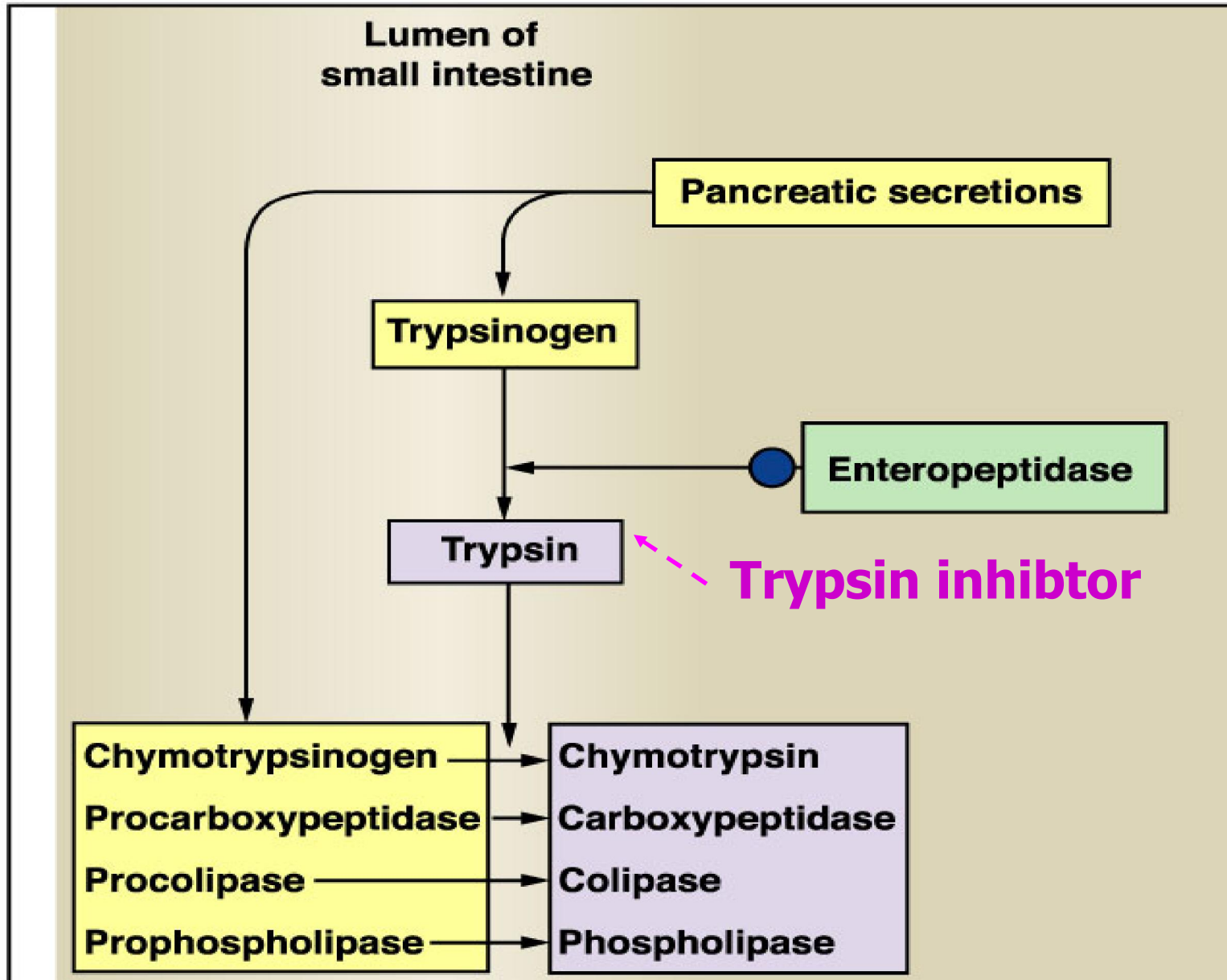


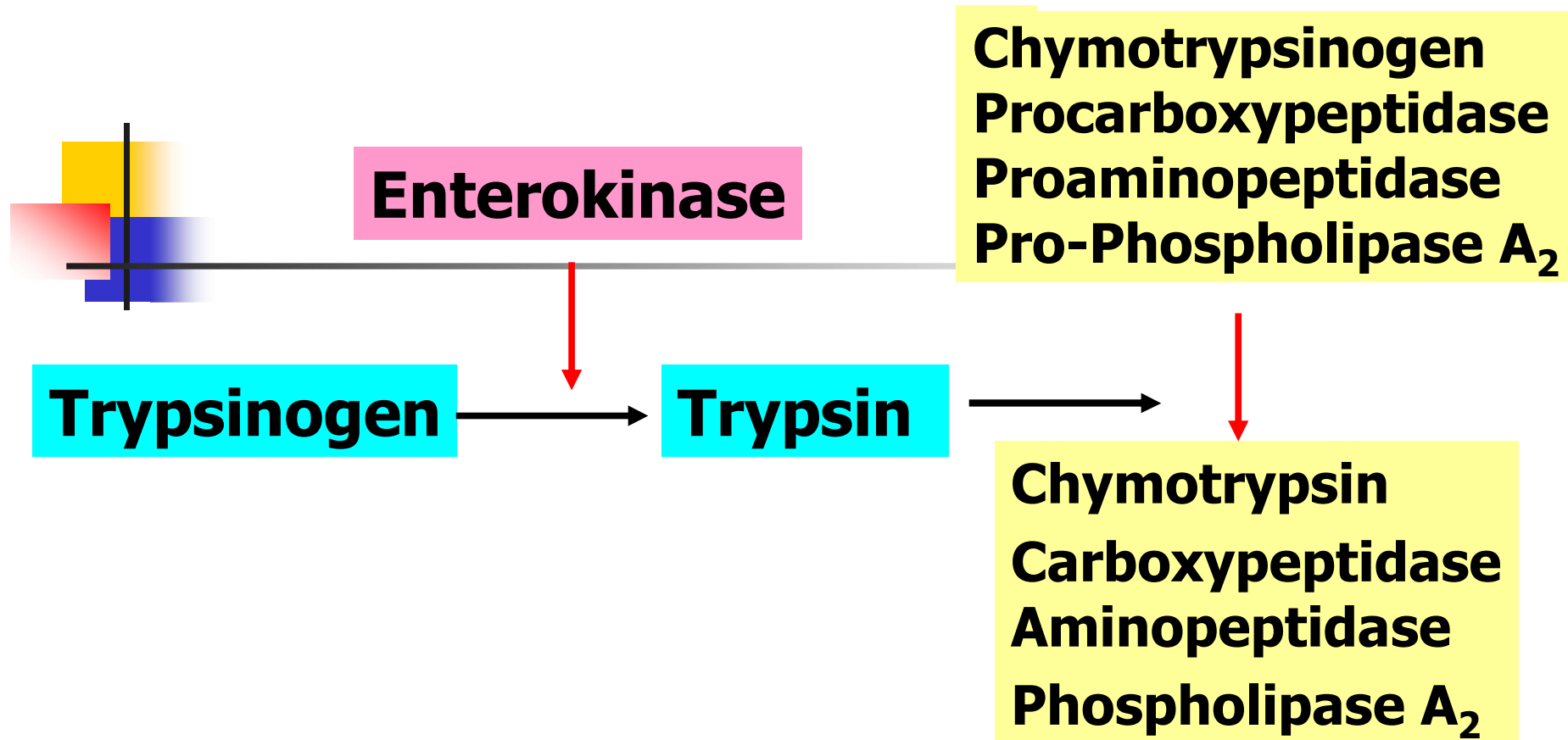


Proteolytic enzymes (zymogen)

- **Trypsinogen**
- **Chymotrypsinogen**
- **Pre-carboxypeptidase**
- **Preaminopeptidase**
- **Elastase, collagenase**

Proteolytic enzymes



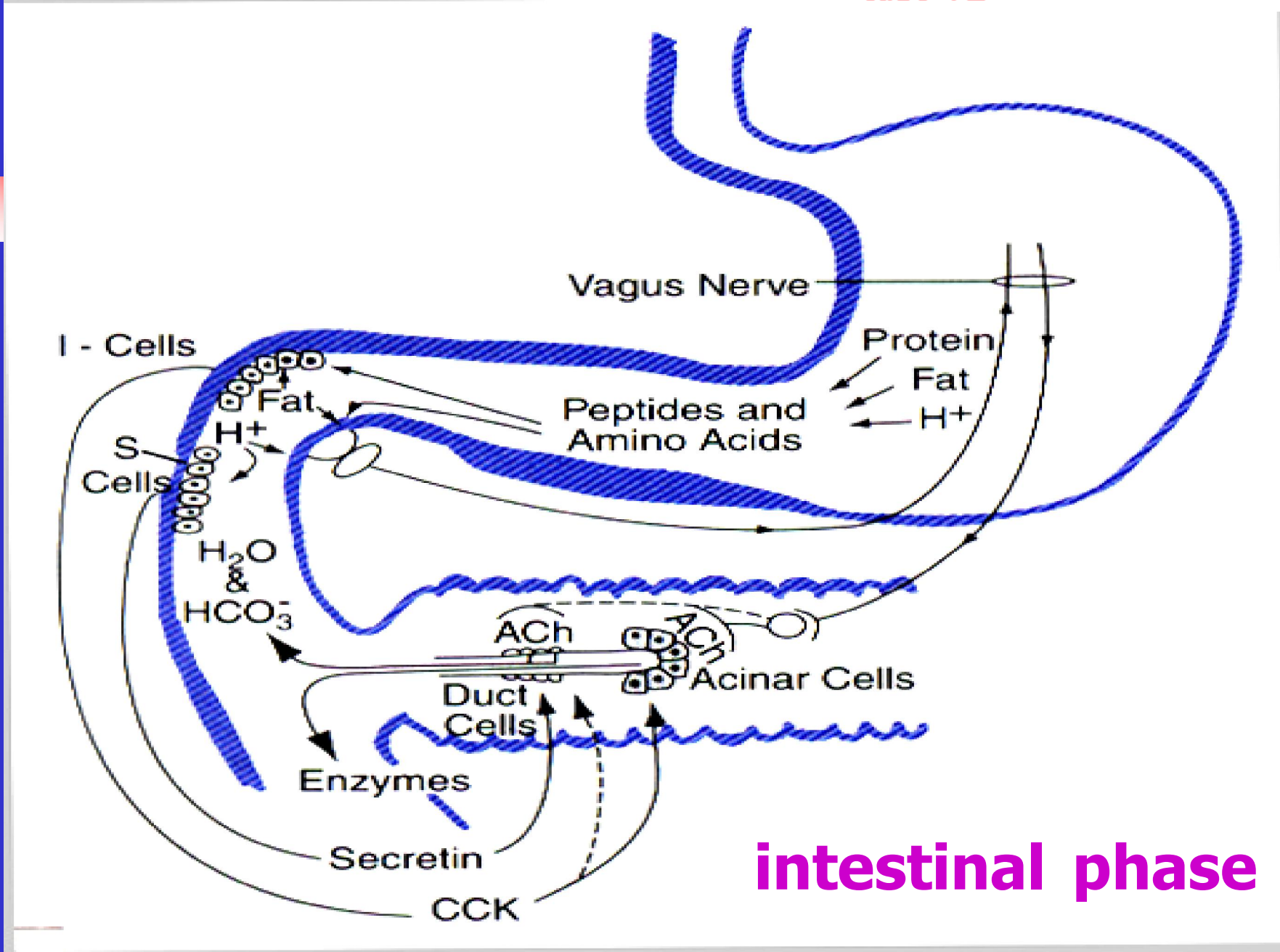


- **Trypsin and chymotrypsin** can break down proteins into peptides. **Carboxypeptidase** can split individual amino acid from the carboxyl ends of peptides
- **Trypsin inhibitor from acinar cells**

Regulation of Pancreatic Secretion



- **Cephalic phase: 20%**
 - Ach (**acinar** and ductule cells)
 - Gastrin (acinar cell)
- **Gastric phase : 5~10%**
- **Intestinal phase : 70%**
 - Secretin
 - CCK





■ Secretin (27 amino acids)

- ❖ **S cells** in upper small intestine
- ❖ **HCl (pH 4.5)** > Protein > Fatty acid
- ❖ Secretin stimulate **duct cells** to produce large volume of secretion containing high concentration of HCO_3^-



■ CCK (cholecystokinin, 33 amino acids)

- **I cells** in upper small intestine
- **proteins > fatty acid > HCl > fat**
- **CCK stimulate acinar cells to produce secretion containing abundant enzymes**

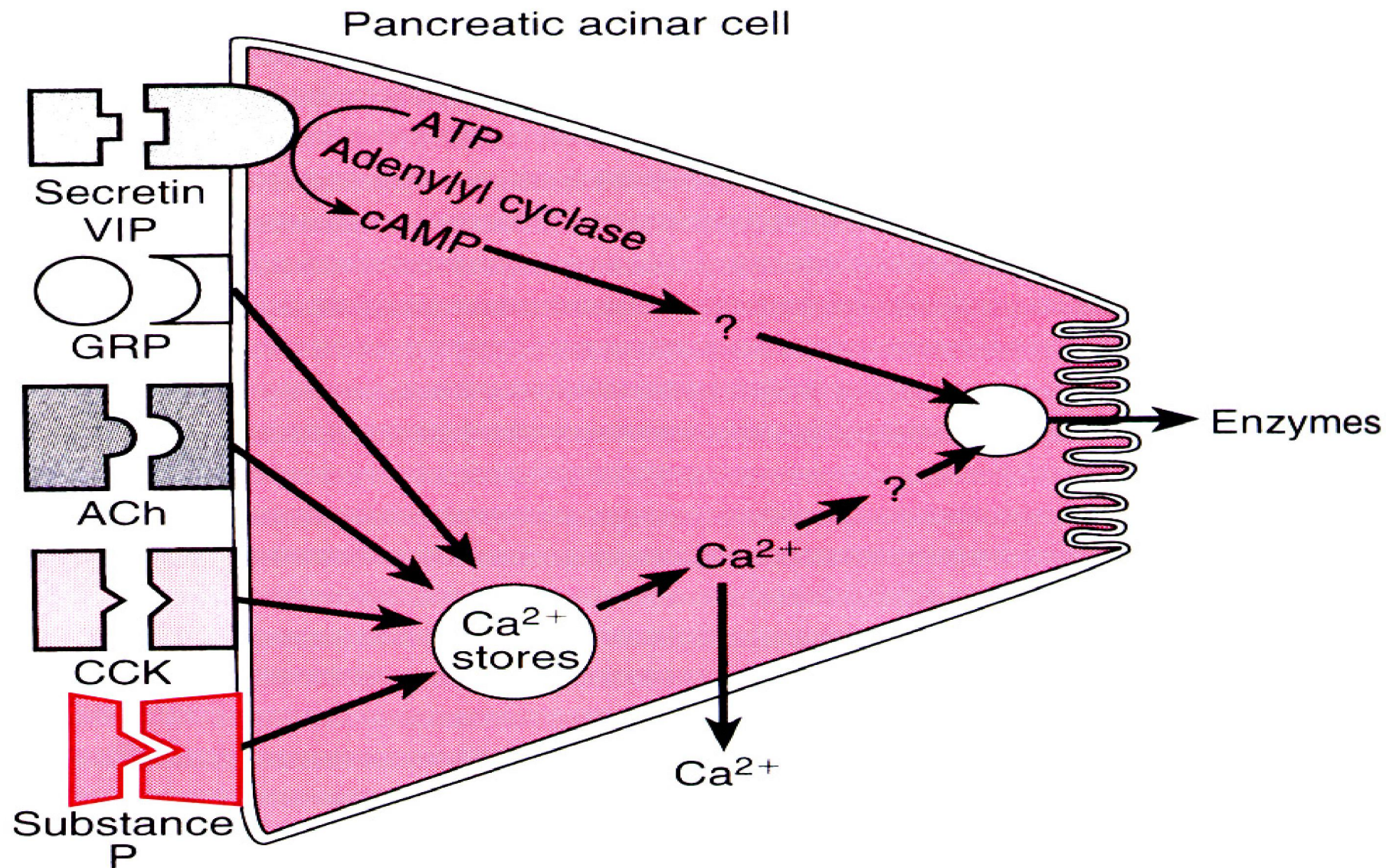
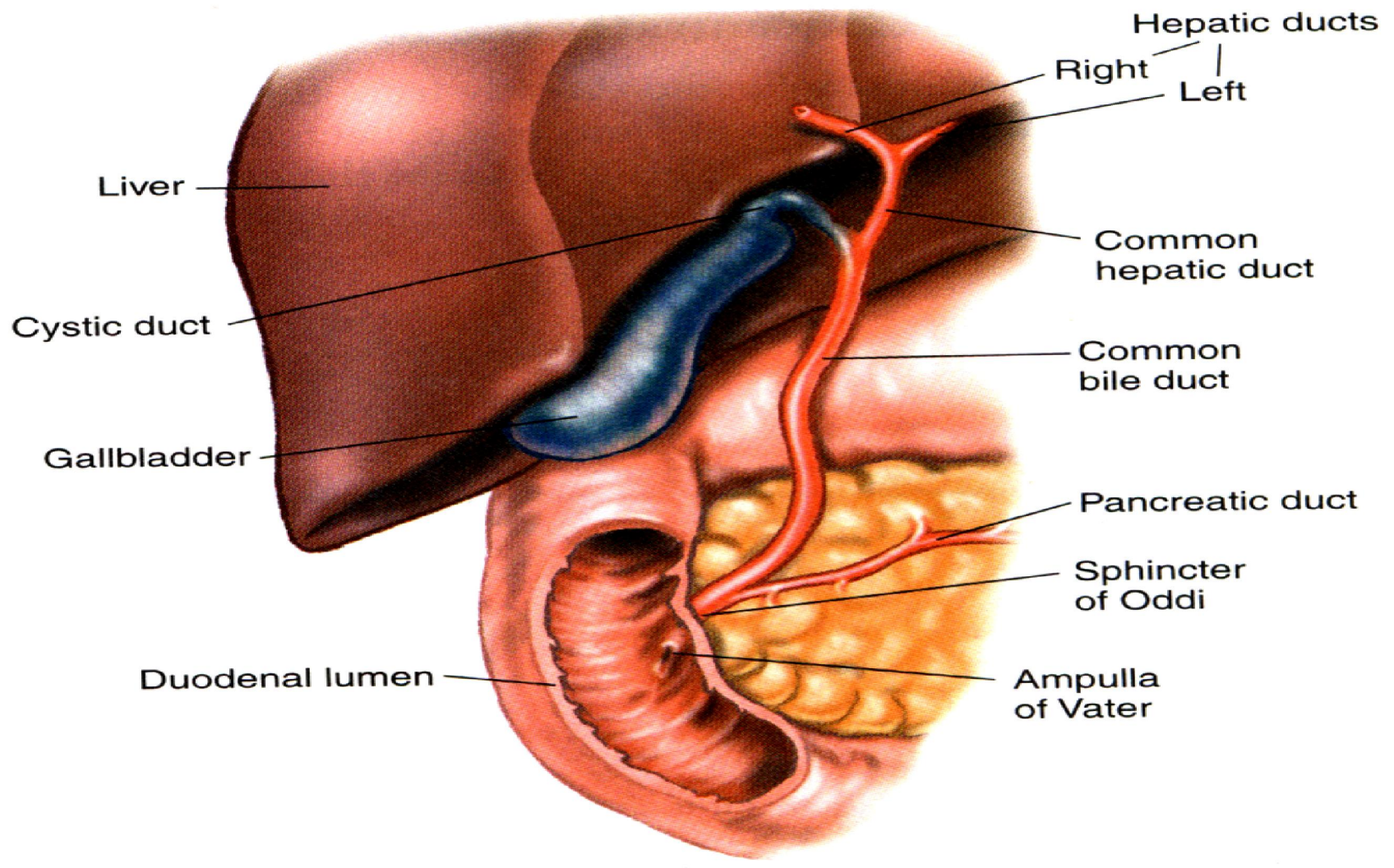


FIGURE 27.12 The stimulation of pancreatic secretion by hormones and neurotransmitters.

二、Bile Secretion





Bile secretion:


- 600~1000 ml/day

■ **Hepatic bile**

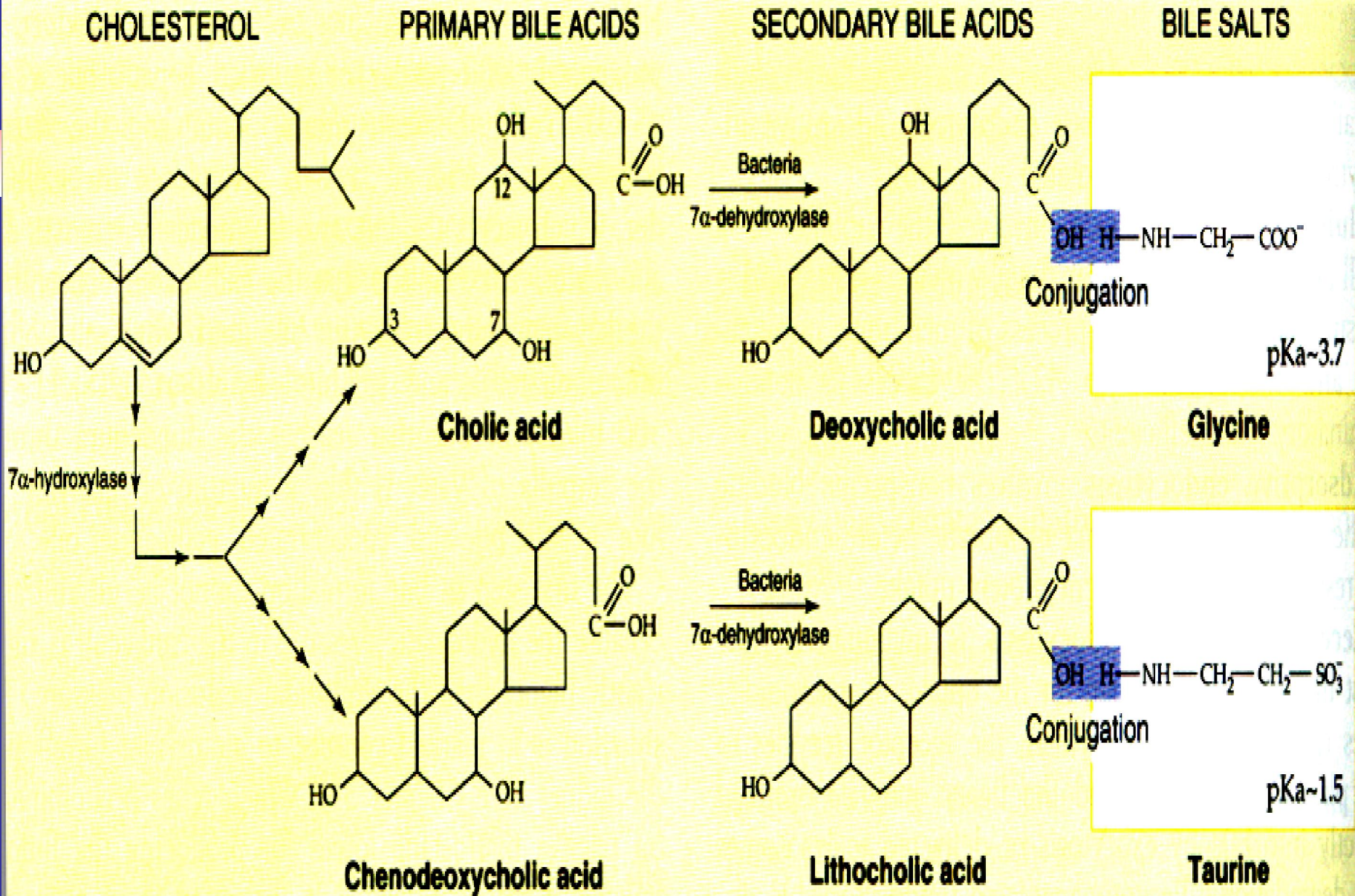
- yellow and alkaline (pH: 7.8)

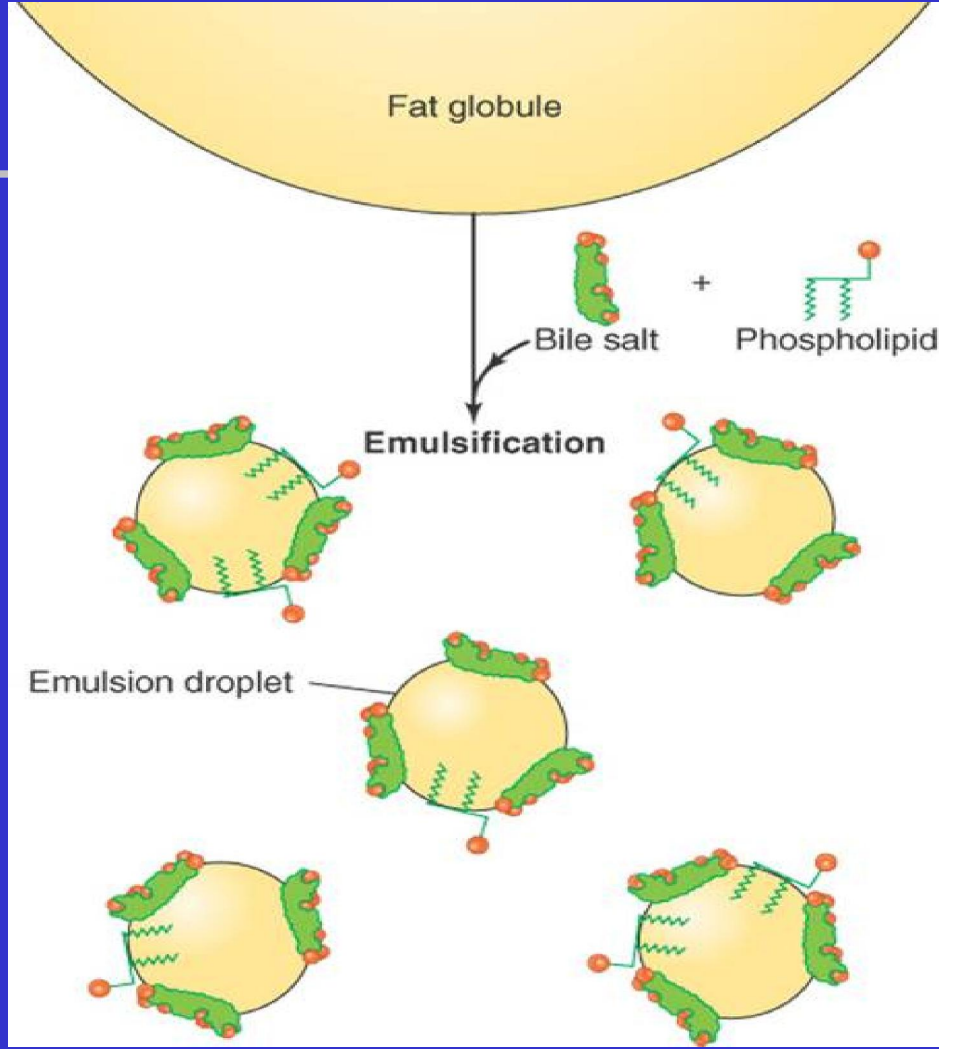
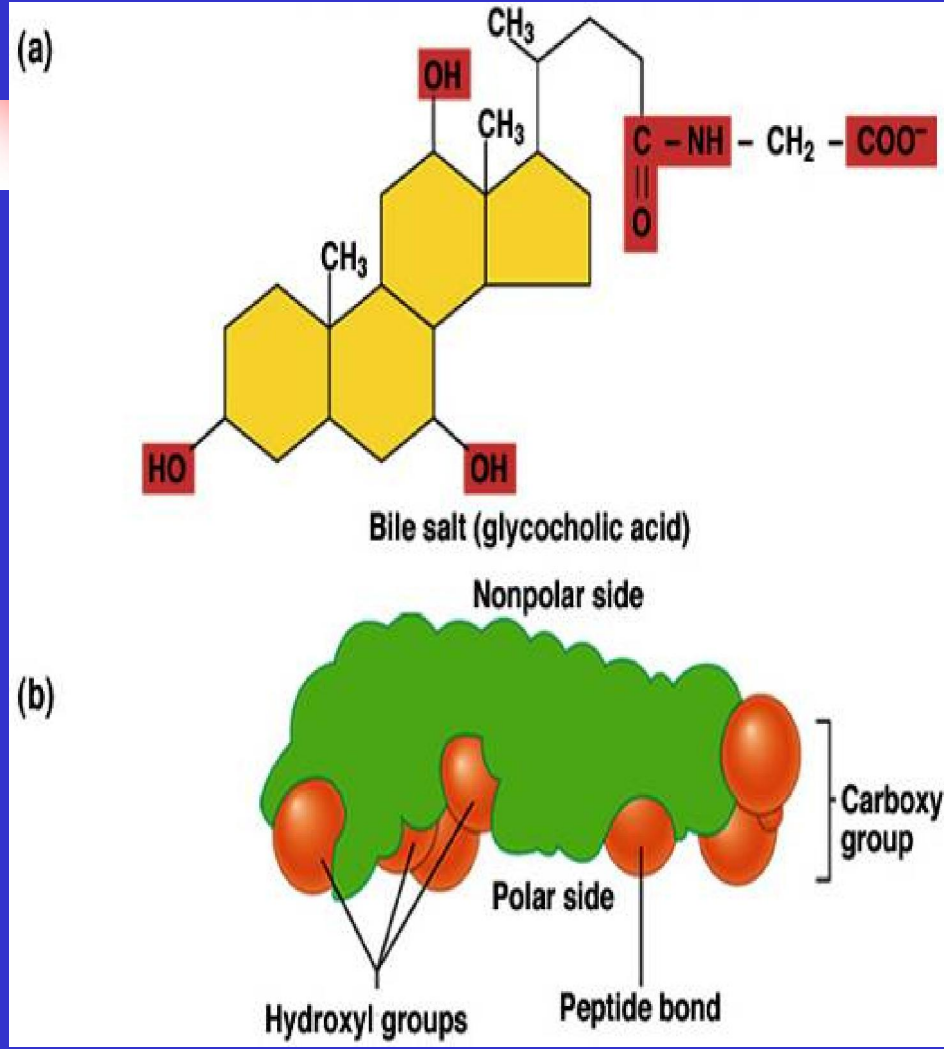
Gallbladder bile

- H₂O , NaCl, & HCO₃⁻ absorbed



Components	Liver bile (%)	Gallbladder bile (%)
Water	97.48	83.98
Bile salts	0.93	8.70
Bile pigment	0.53	4.44
Cholesterol	0.06	0.87
Fatty acid	0.12	0.85
Lecithin	0.02	0.14
Inorganic salt	0.83	1.02

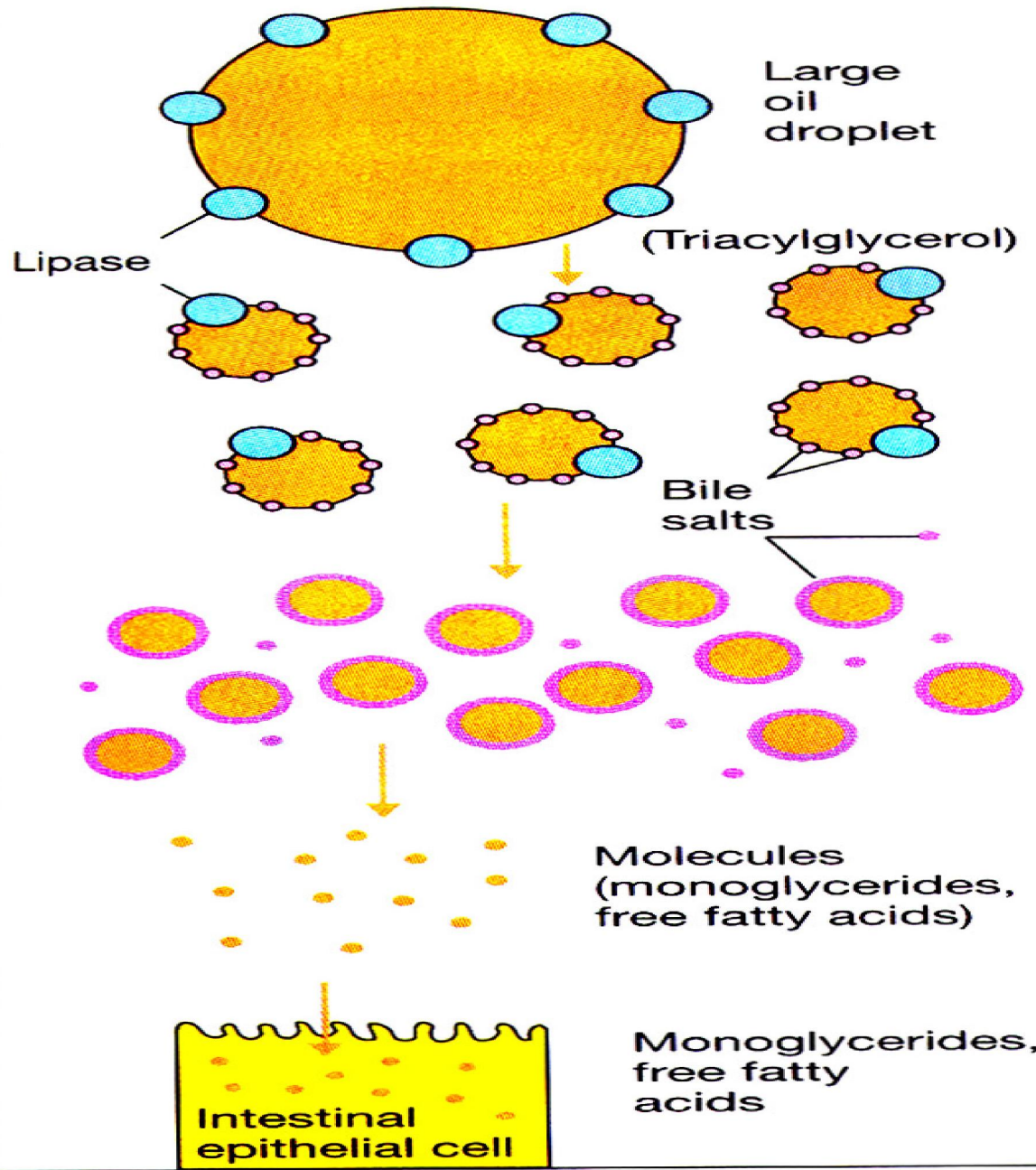






■ Actions of bile

(1) Facilitate the digestion of fats by decreasing the surface tension of fat particle, breaking fat particle into minute sizes (emulsification)



emulsifying agent bile salts, lecithin

Emulsified oil droplets (triacylglycerol, monoglycerides, free fatty acids, bile salts)

Micelles (monoglycerides, free fatty acids, bile salts)

Molecules (monoglycerides, free fatty acids)

Monoglycerides, free fatty acids

Intestinal epithelial cell



■ Actions of bile

(2) Facilitate the absorption of digested fats and fat-soluble vitamins (A,D,E,K) and other lipids by forming micelles

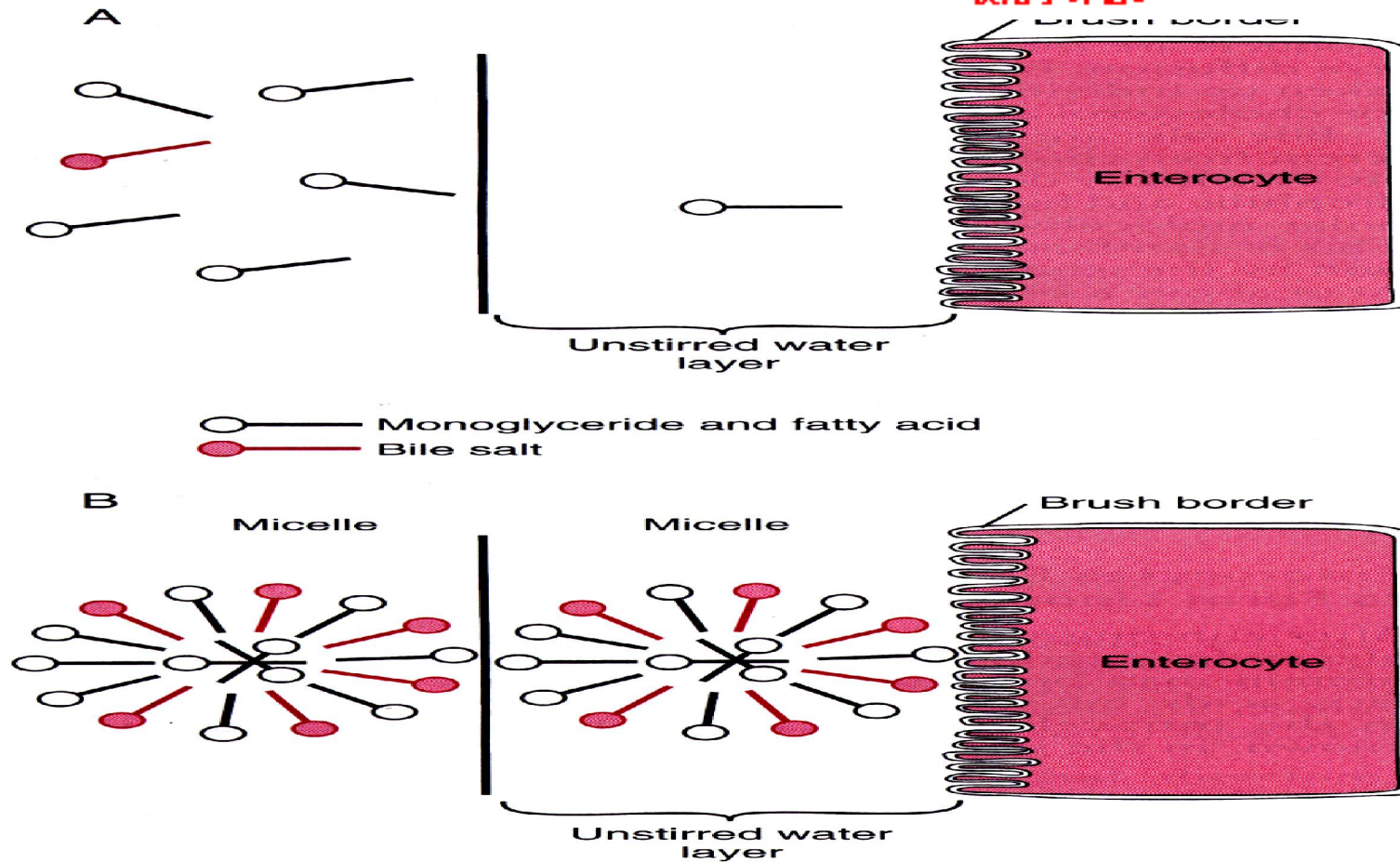


FIGURE 27.25 The micellar solubilization of lipids. Micellar solubilization enhances the delivery of lipid to the brush border membrane. **A**, In the absence of bile salts. **B**, In the presence of bile salts.

Bile salt: Amphipatic (hydrophilic & hydrophobic)
Bile salts tend to form micells

■ Control of bile secretion

(1) Neural control:

Vagus nerve plays a minor role in bile secretion and excretion

- stimulate gallbladder contraction and sphincter of Oddi relaxation to release bile**
- stimulate hepatocytes to induce bile secretion**

(2) Humoral control



CCK:

- **Contraction of gallbladder & relaxation of Oddi sphincter muscle**

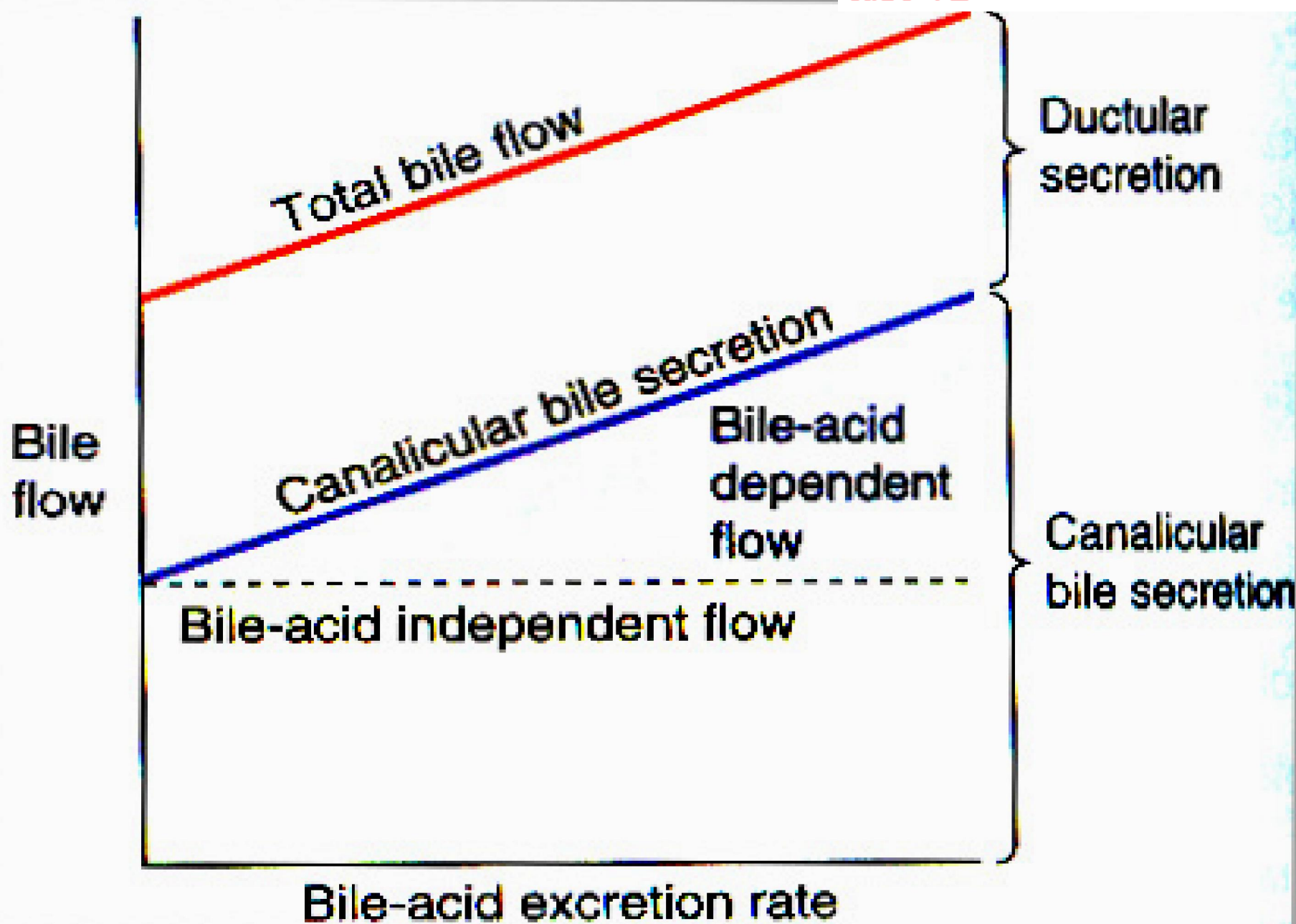
- **Secretin**

- **stimulate liver tubular system to produce H_2O & HCO_3^-**

- **Gastrin:**

- **stimulate hepatocytes to secrete bile**

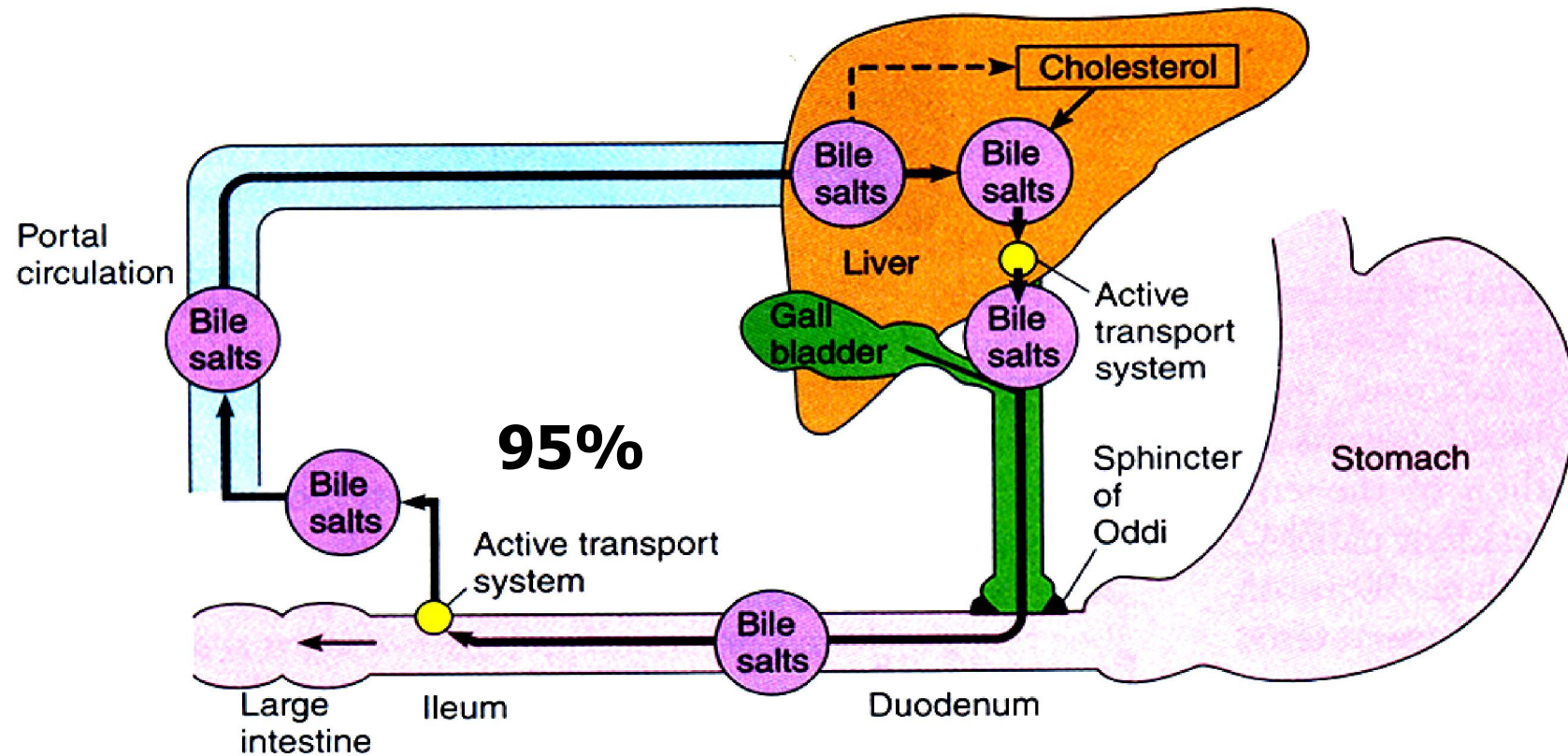
- **Bile salt :**





Enterohepatic circulation of bile salts

- **About 95% of the bile salts are reabsorbed by the intestinal mucosa in the distal ileum and back to liver via the portal blood circulation.**
- **The absorbed bile salts then stimulate the bile synthesis and re-secrete into the bile**



Enterohepatic circulation of bile salts:

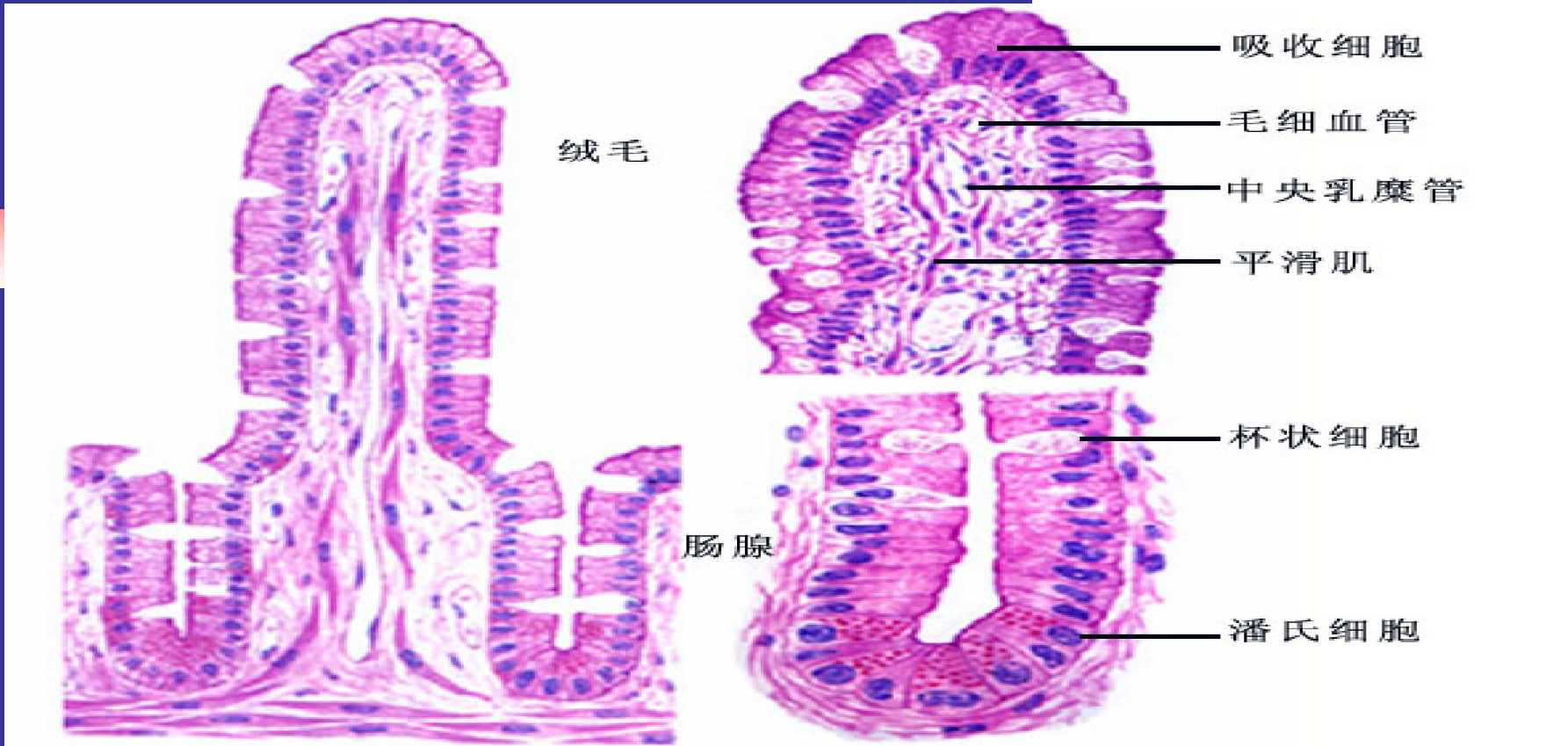
- This recycling pathway from the intestine to the liver and back to the intestine

3. Intestinal Secretion



Duodenal glands (Brunner glands):

- acinotubular glands in submucosa of duodenum
- secrete mucus / bicarbonate



Intestinal glands (Crypts of Lieberkuhn)

- Simple tubular glands in lamina propria throughout the small intestine
- Secrete isotonic fluid



Components of the small intestine juice

- **slight alkaline (pH: 7.6)**
 - **isotonic solution**
 - **1~3L/day**
 - **Enterokinase**
-
- **Actions of the small intestine juice**
 - **dilute the digested products**