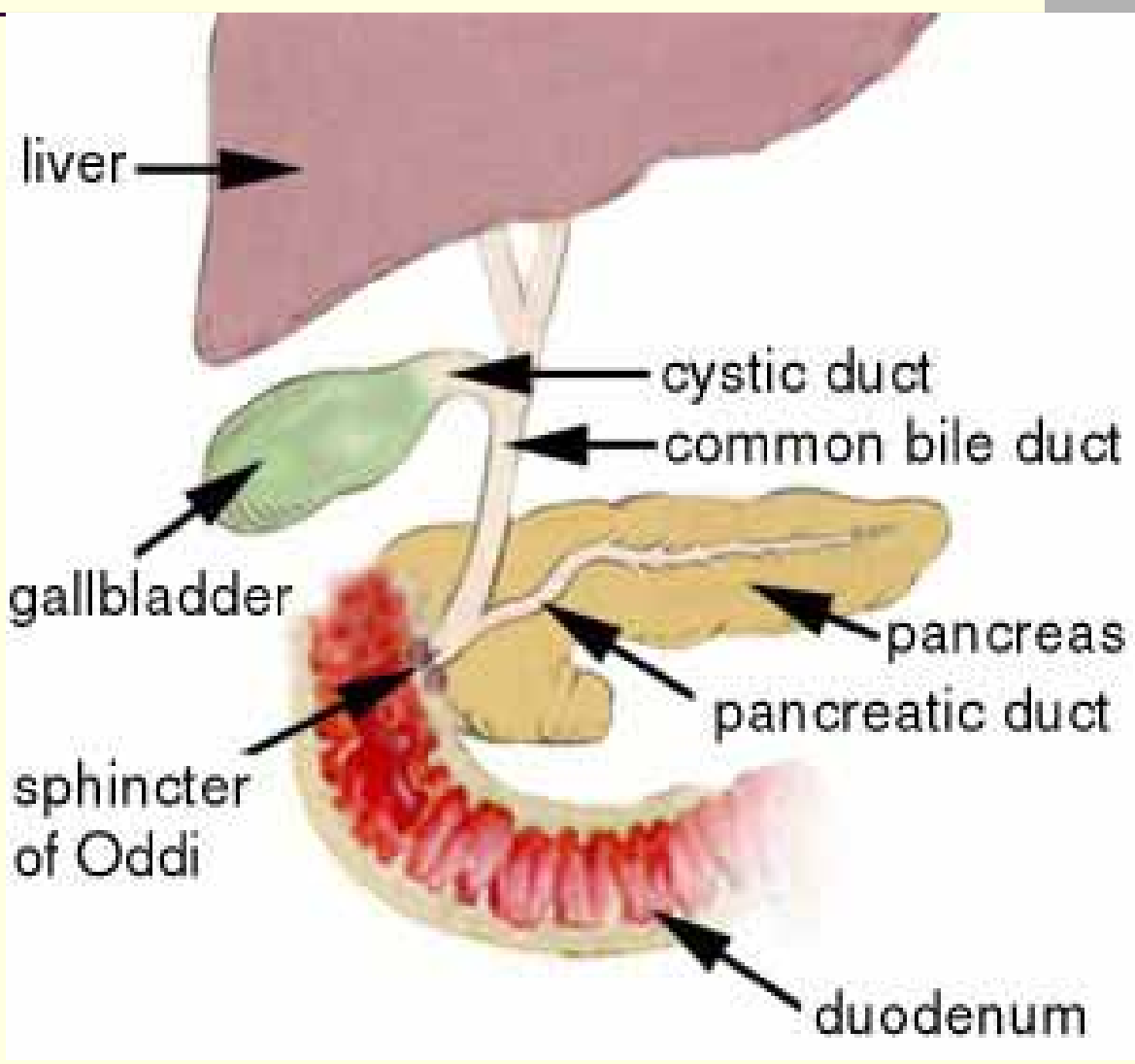
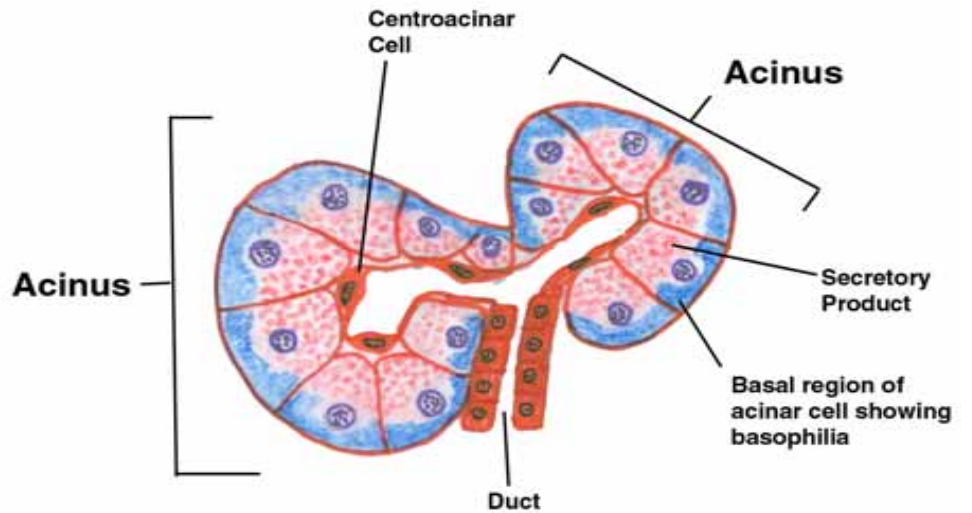
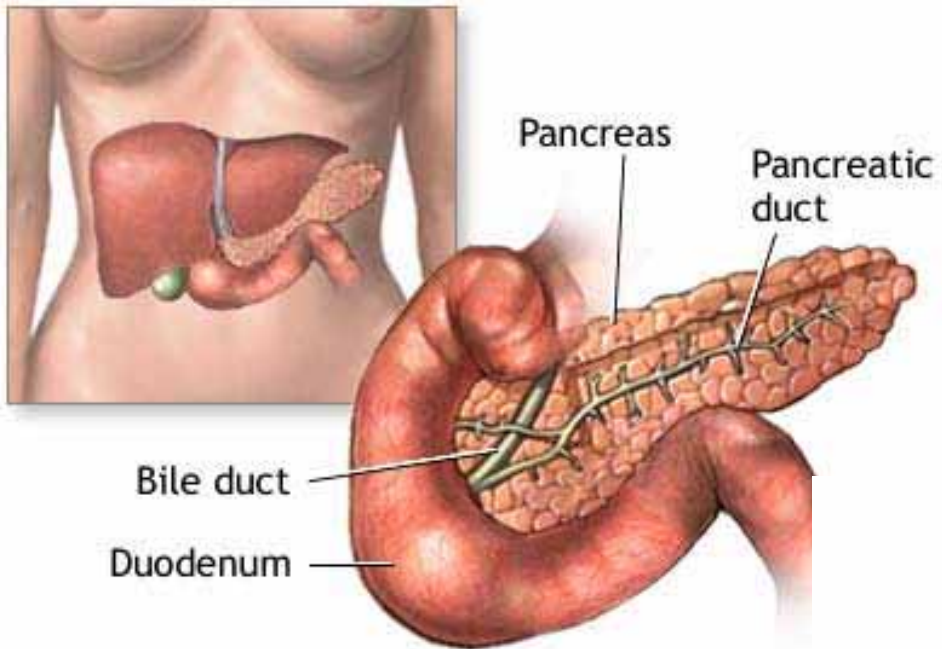


Digestion in intestine

YU Yanqin, PhD
Zhejiang University, School of Medicine



Pancreatic secretion



Pancreatic juice (胰液)

- pH 7.8~8.4
- ~1500 ml/day
- Isosmotic
- Components:
 - Pancreatic digestive enzymes (胰消化酶) : secreted by pancreatic acini
 - Sodium bicarbonate (碳酸氢钠) : secreted by small ductules and larger ducts

■ Secretion of bicarbonate ions

- Secreted by the epithelial cells of the ductules (小叶导管) and ducts that lead from acini (腺泡)
- Up to 145mmol/L in pancreatic juice (5 times that in the plasma)
- **Function:** Neutralizing acid entering the duodenum (十二指肠) from the stomach

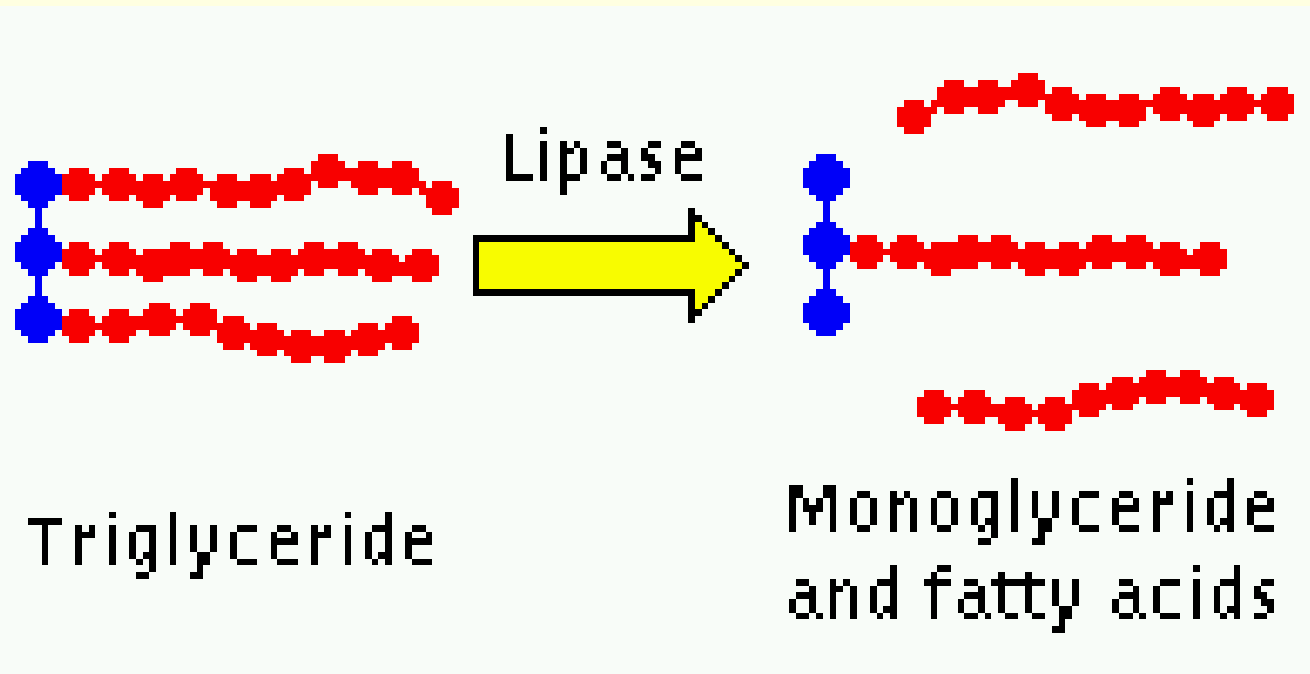
■ Secretion of pancreatic digestive enzymes

- Carbohydrates -- Pancreatic amylase (胰淀粉酶)
- Fat
 - Pancreatic lipase (胰脂肪酶)
 - Cholesterol esterase
 - Phospholipase
- Proteins
 - Trypsinogen (胰蛋白酶原)
 - Chymotrypsinogen (糜蛋白酶原)
 - Procarboxypolypeptidase (羧基肽酶)
 - Proelastase (弹性蛋白酶)

Starches 淀粉

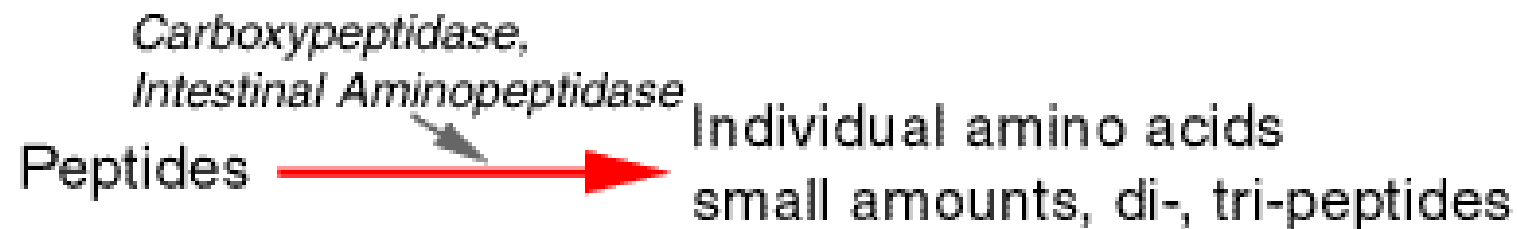
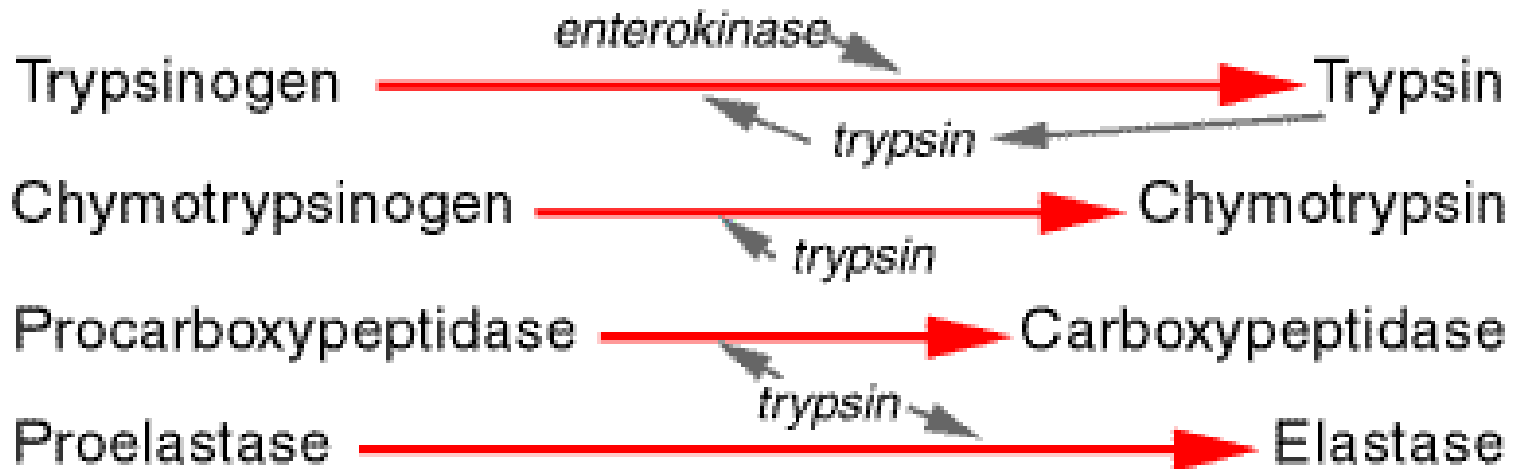
Pancreatic amylase

Maltose (麦芽糖) and
3 to 9 glucose polymers

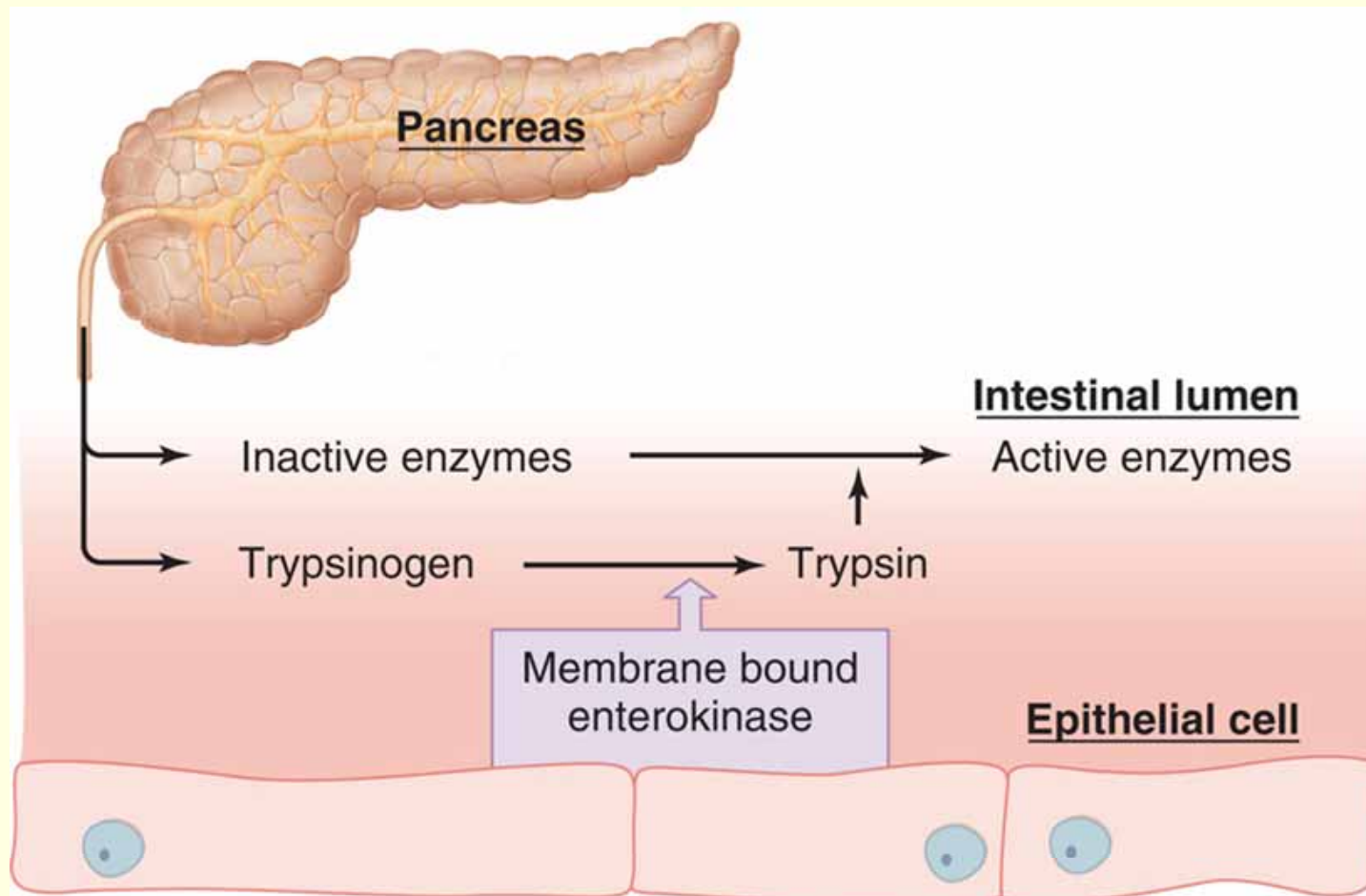


Proenzyme

Active Enzyme



Were digestive enzymes synthesized in their active form, they would digest the very cells that make them. Hence, **inactive precursors** (e.g., trypsinogen) become activated (trypsin).

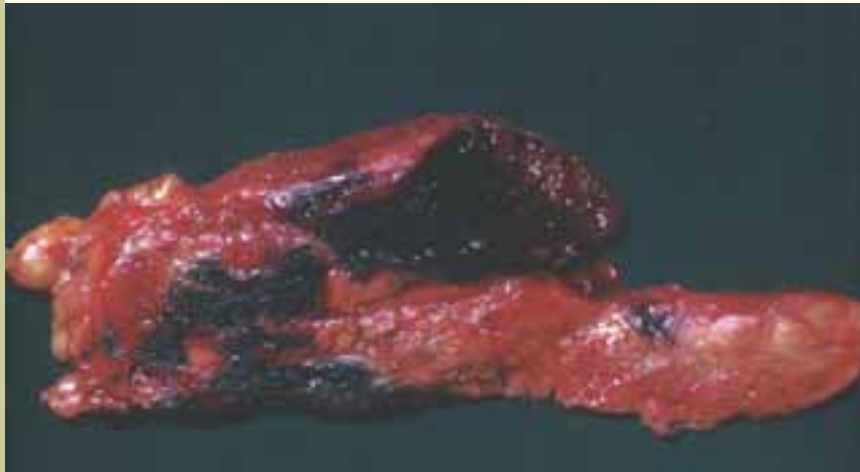


- Trypsin (胰蛋白酶) Inhibitor

- Inhibits the activity of trypsin and thus guards against the possible activation of trypsin and the subsequent autodigestion of the pancreas

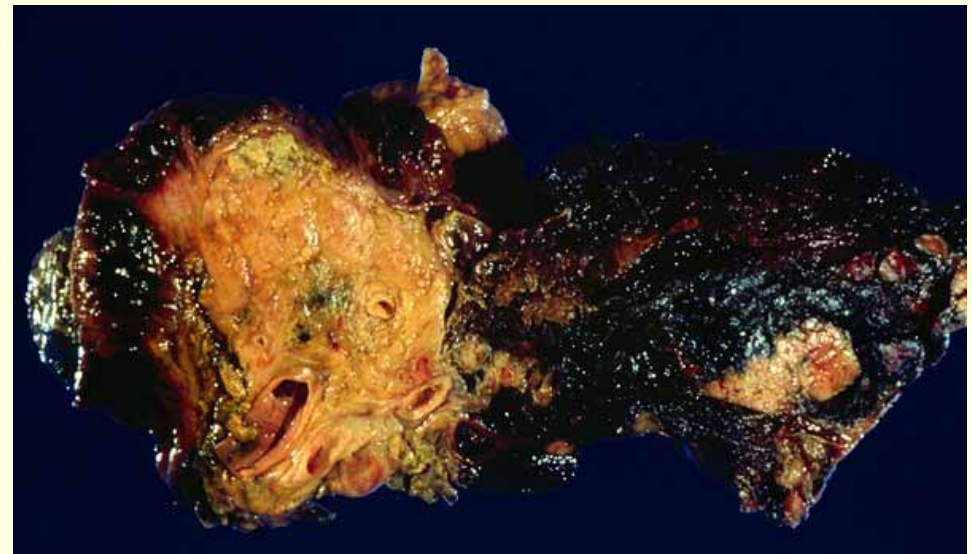


Acute pancreatitis (胰腺炎)



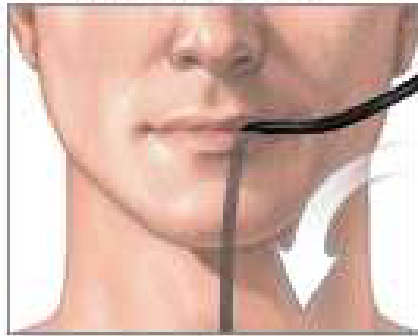
当消化酶因为病变在胰腺内被激活，就会破坏和消化胰腺本身，从而引发胰腺炎

急性胰腺炎(AP)的发生主要经历了胰酶激活、自身消化和炎症反应等过程

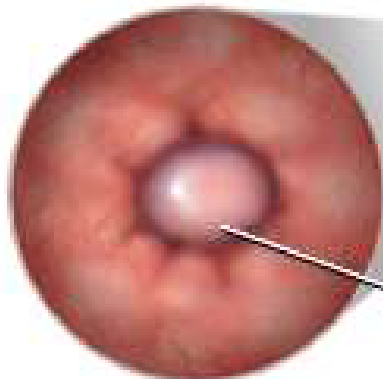
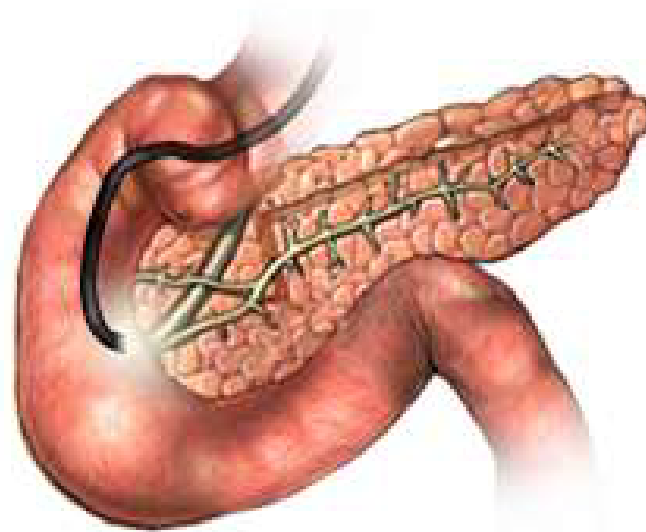


Acute pancreatitis

Endoscope inserted into mouth



Endoscope travels through gastro-intestinal tract until reaching point of blockage

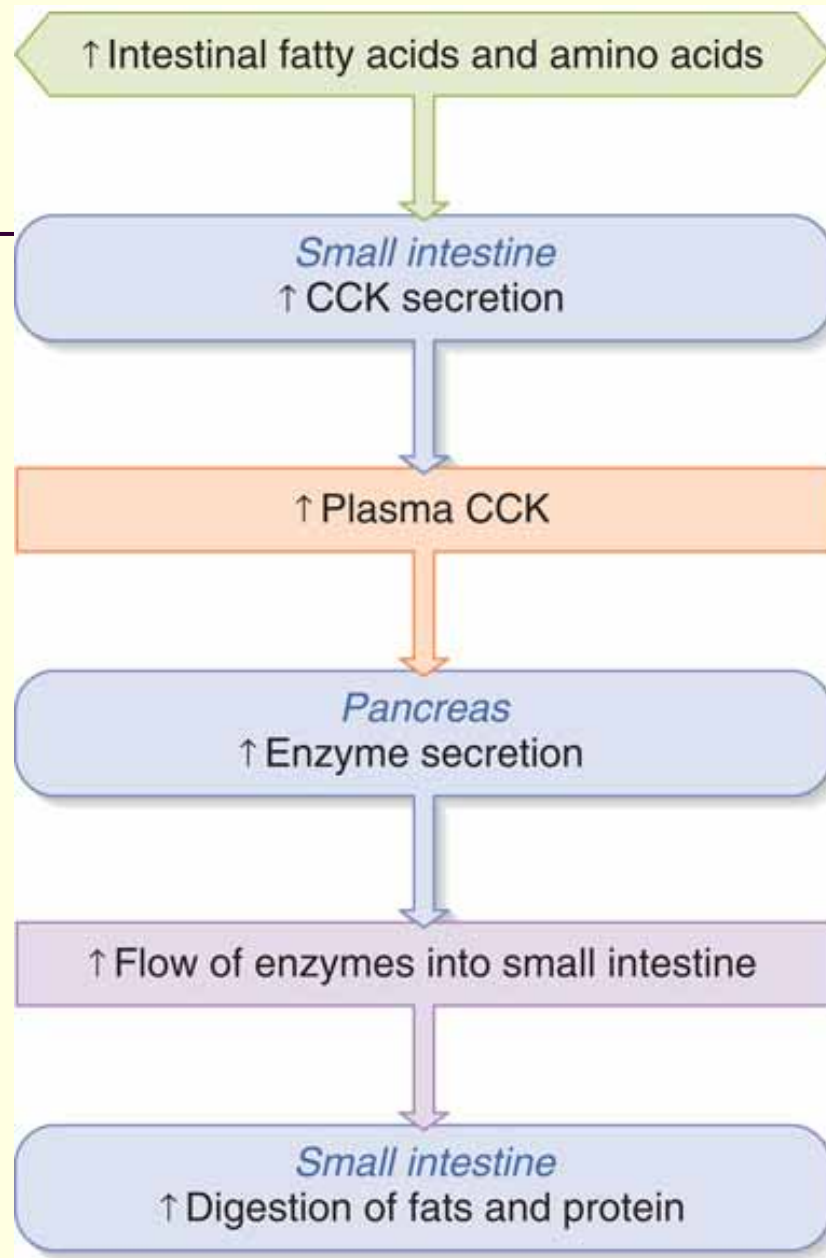


Gallstone seen through endoscope

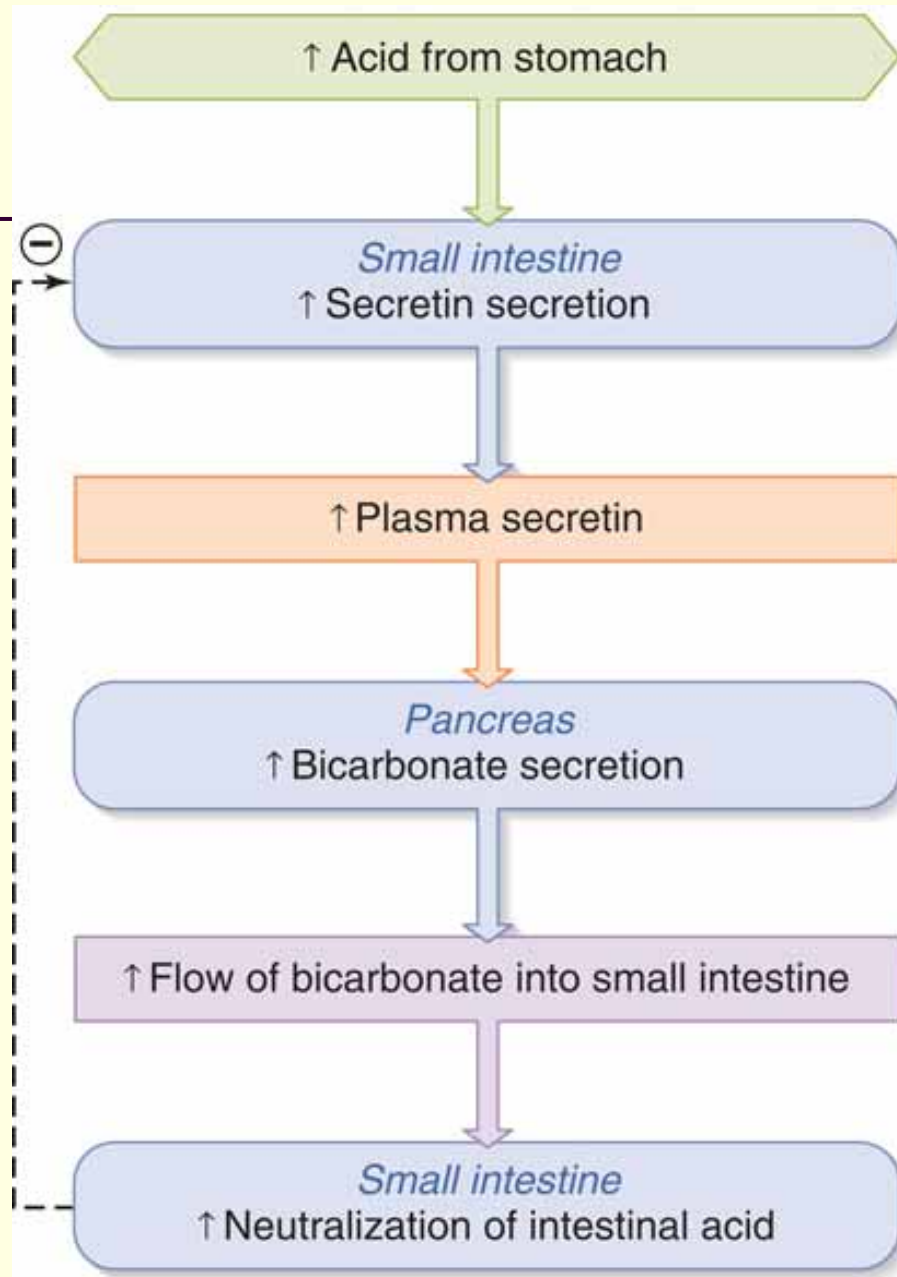
Regulation of pancreatic secretion

- Basic stimuli that cause pancreatic secretion
 - Ach
 - Cholecystokinin (胆囊收缩素/促胰酶素):
 - Secreted by I cells
 - Stimulates the acinar cells to secrete large amounts of enzymes
 - Secretin (促胰液素):
 - Released by S cells
 - Acts primarily on the duct cells to stimulate the secretion of a large volume of solution with a high HCO_3^- (Bicarbonate) concentration

Cholecystokinin's receptors are located: in the pancreas, which responds with additional enzyme delivery in the gallbladder, which contracts to deliver more Bile in the sphincter of Oddi, which relaxes to facilitate delivery of the enzymes and bile salts



Secretin's receptors are found in the pancreas, which responds with additional bicarbonate delivery: gastric motility and secretion are inhibited. (负反馈)



Regulation of pancreatic secretion

- Phases of pancreatic secretion
 - Cephalic Phase 头期
 - Gastric Phase 胃期
 - Intestinal Phase 肠期

Regulation of pancreatic secretion

■ Cephalic Phase

- An autonomic reflex response to stimulation of olfactory and taste receptors
- Stimulation of the acinar cells by 'long' parasympathetic pathways, which release ACh

Regulation of pancreatic secretion

■ Gastric Phase

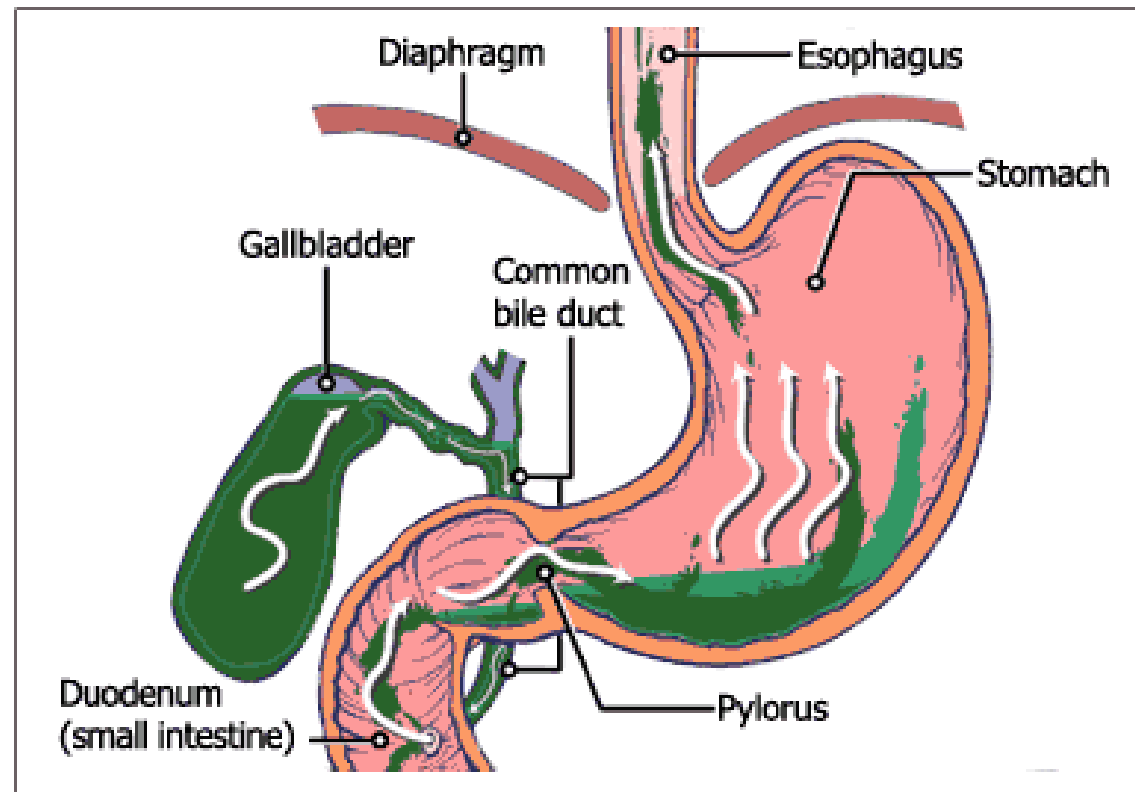
- Distension of the stomach causes increased pancreatic secretion via the release of ACh by 'long' parasympathetic reflex pathways
- In addition, the release of gastrin 促胃液素 from the stomach also stimulates the acinar cells

Regulation of pancreatic secretion

■ Intestinal Phase

- A large volume of secretion rich in both HCO_3^- and digestive enzymes
- The most important regulators are **CCK** and **secretin**
- Acid, fats, amino acids, peptides and protein are the main stimulus for pancreatic production and secretion

Secretion of **bile** 胆汁 by the liver



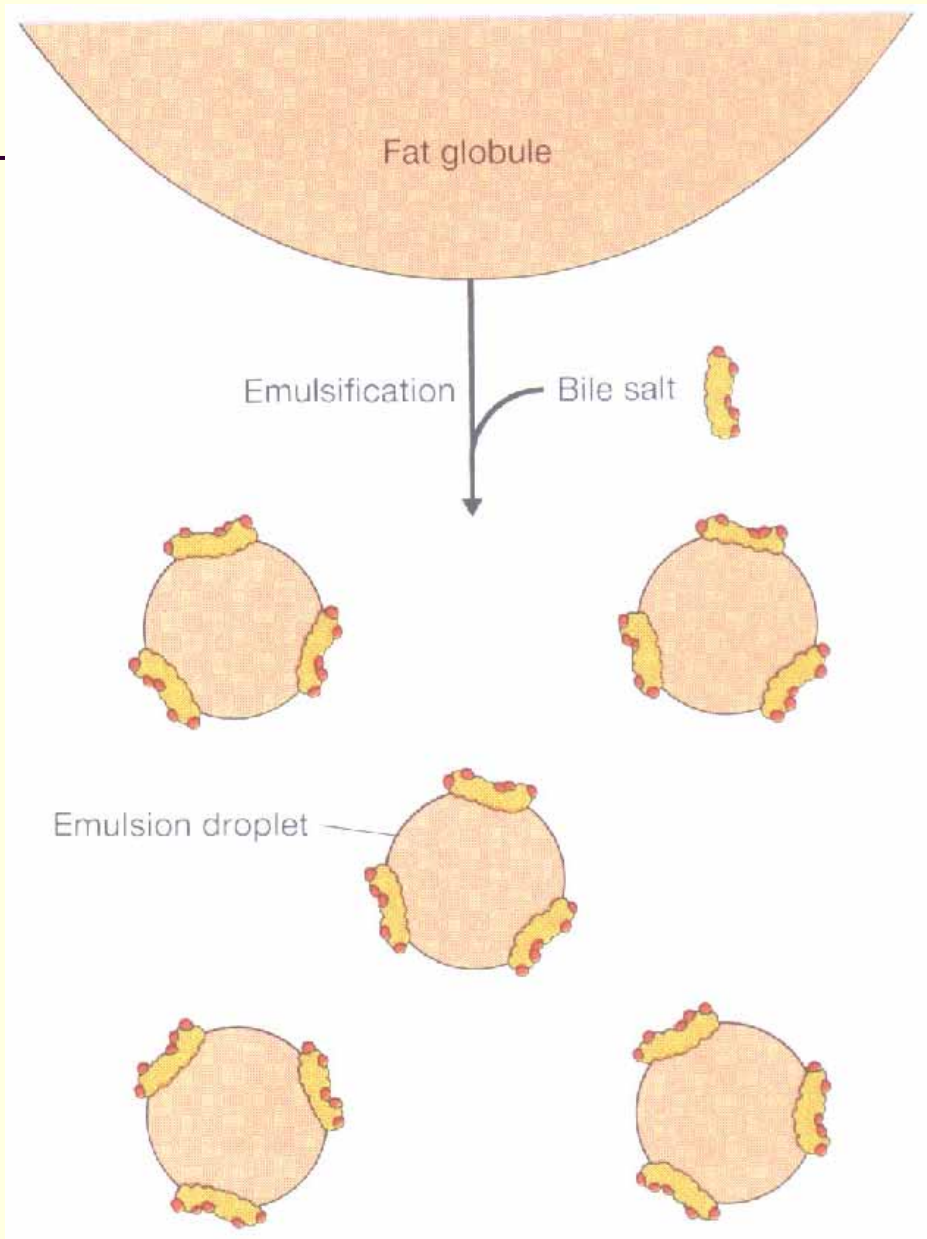
- Bile is secreted by liver cells
- Bile is stored and concentrated in the gall bladder during the interdigestive period

Composition of bile

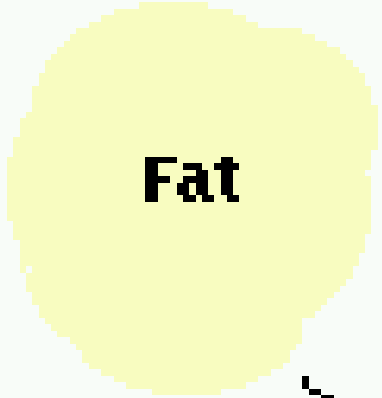
- HCO_3^-
- Bile salts
- Phospholipids
- Cholesterol
- Bile pigments
- ...

Functions of bile

- Emulsifying (乳化) or detergent function of bile salts
- Bile salts help in the absorption of:
 - Fatty acid
 - Monoglycerides 甘油一酯
 - Cholesterol
 - Other lipids

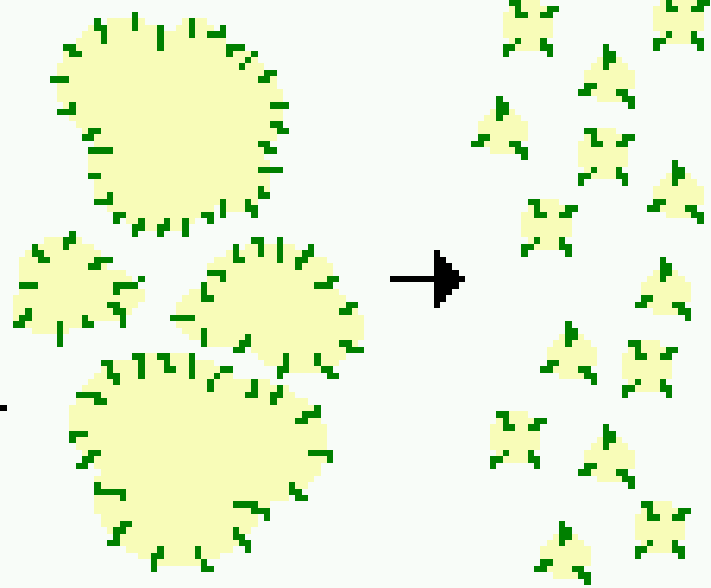


1. Emulsifying large fat particles to facilitate its digestion

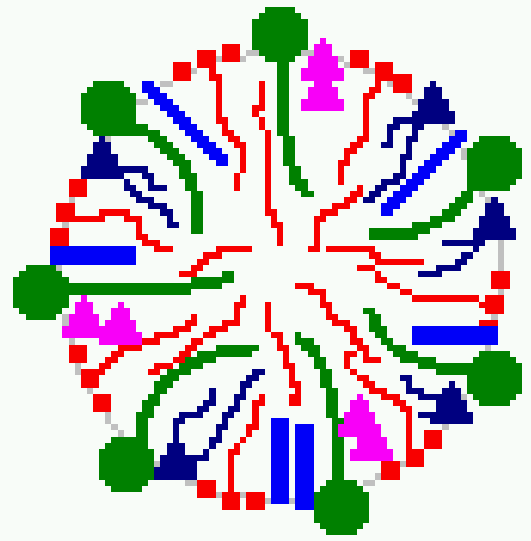


Fat

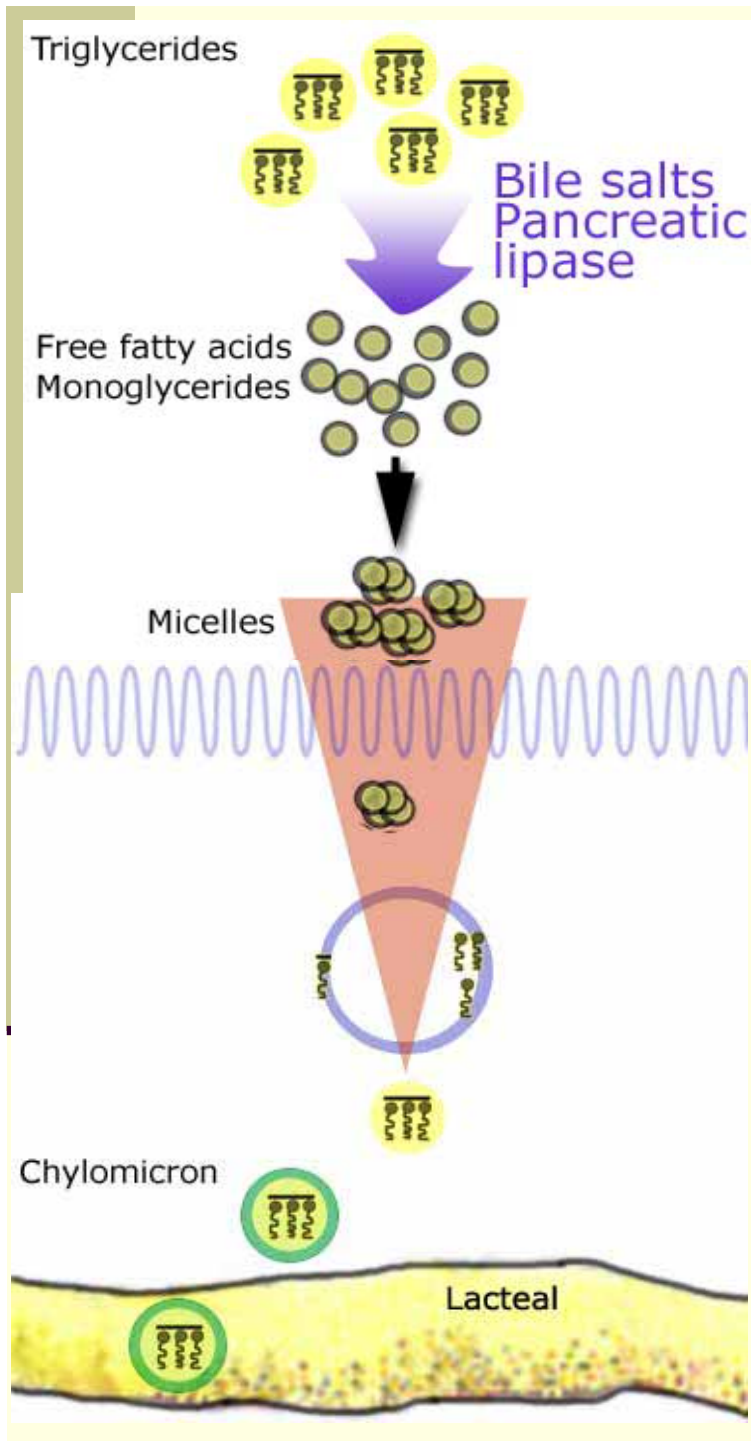
Bile salts



混合微胶粒：



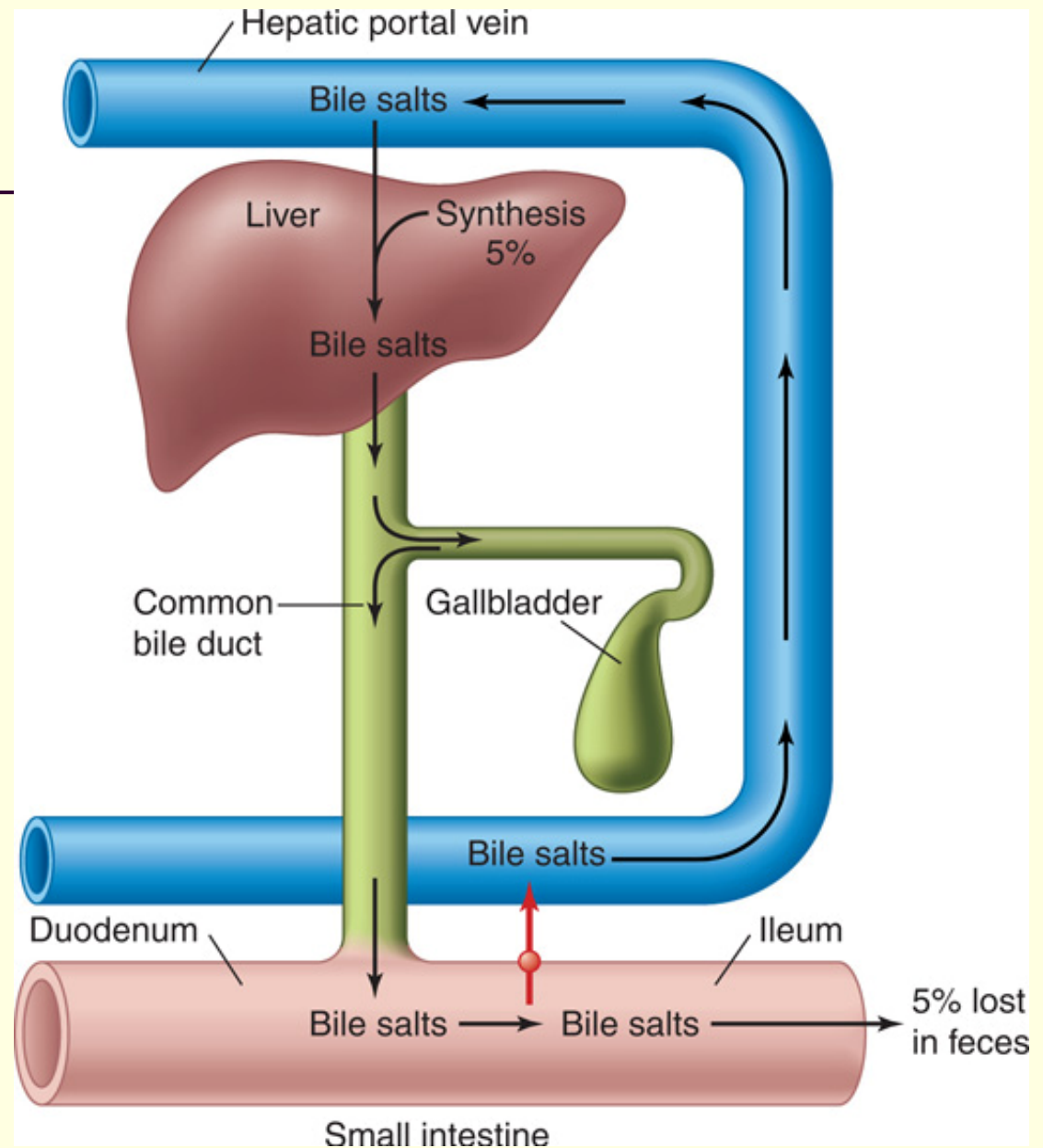
Bile salts
Monoglyceride
Fatty acids
Phospholipids
Cholesterol



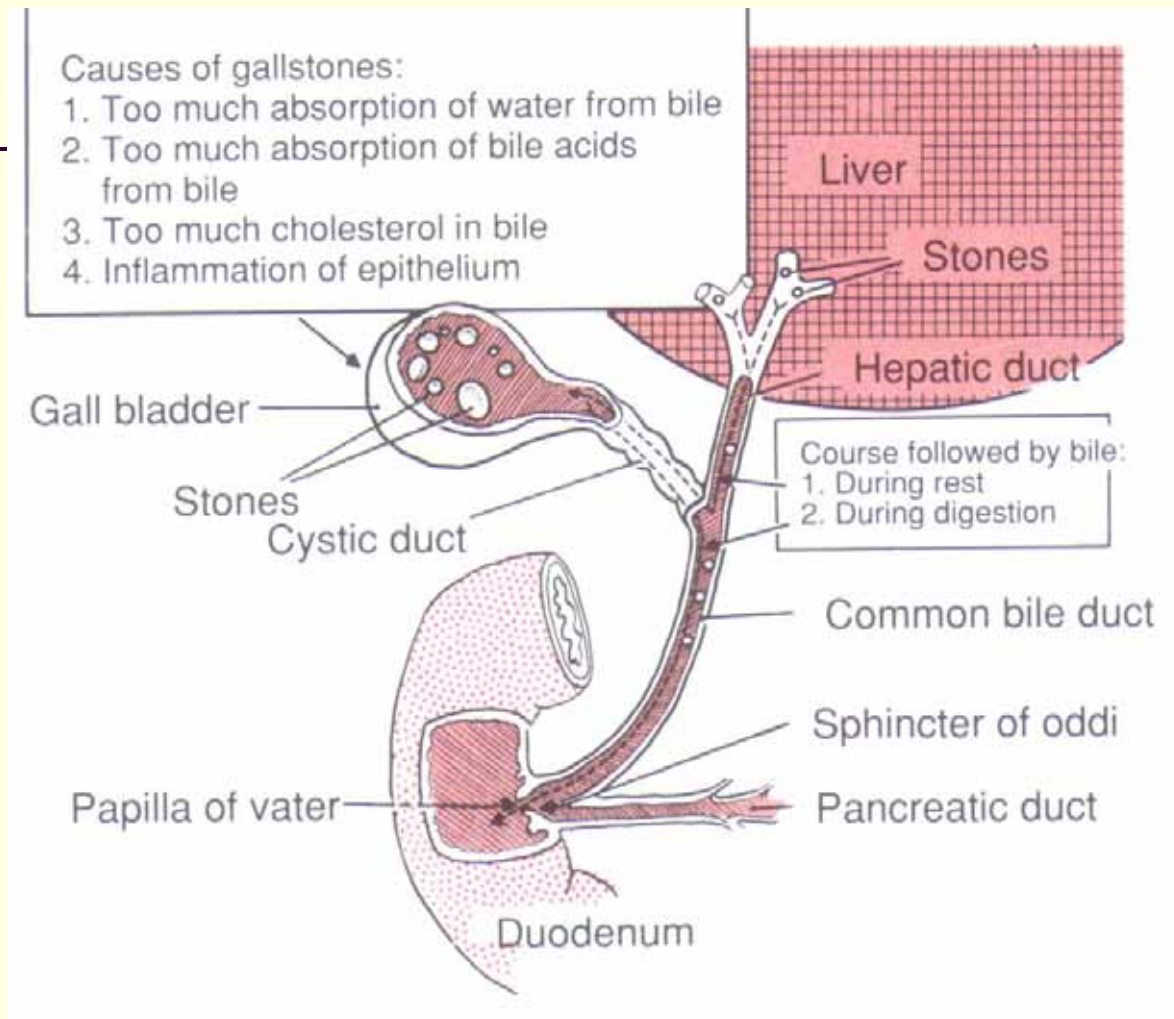
2. Bile salts interact with cholesterol (胆固醇) to form micelles (胶团) to facilitate the **absorption** of insoluble fat products

3. Increasing bile synthesis & secretion

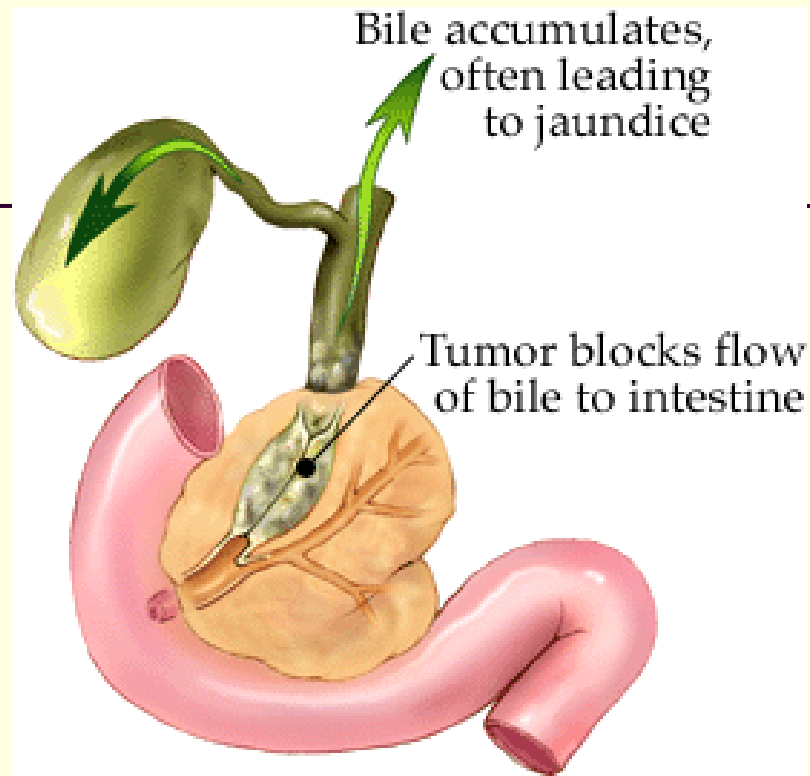
Up to 95% of the cholesterol-based bile salts are “recycled” by reabsorption along the intestine.



胆结石：



4. Preventing the cholesterol precipitation & gallstones



Patients with **bile duct cancer** most often become symptomatic when the cancer obstructs (blocks) the drainage of bile. Because bile cannot be excreted into the bowel, the bilirubin pigments (胆色素) accumulate in the blood, causing jaundice (黄疸) (yellowing of the skin and the whites of the eyes) in 90% of patients. The jaundice is usually associated with itching of the skin. The body compensates partially and excretes some of this bilirubin via the urine, so patients may have dark (cola colored) urine. Because bile cannot reach the intestine, the patient's stools become white (clay colored).

Cholecystitis (胆囊炎)



Regulation of bile secretion

■ Substances increasing bile production

- Bile salts (Enterohepatic circulation 肠肝循环 of the bile)
- Secretin: stimulating H_2O and HCO_3^- secretion from the duct cells (liver)

■ Substance inhibiting bile production

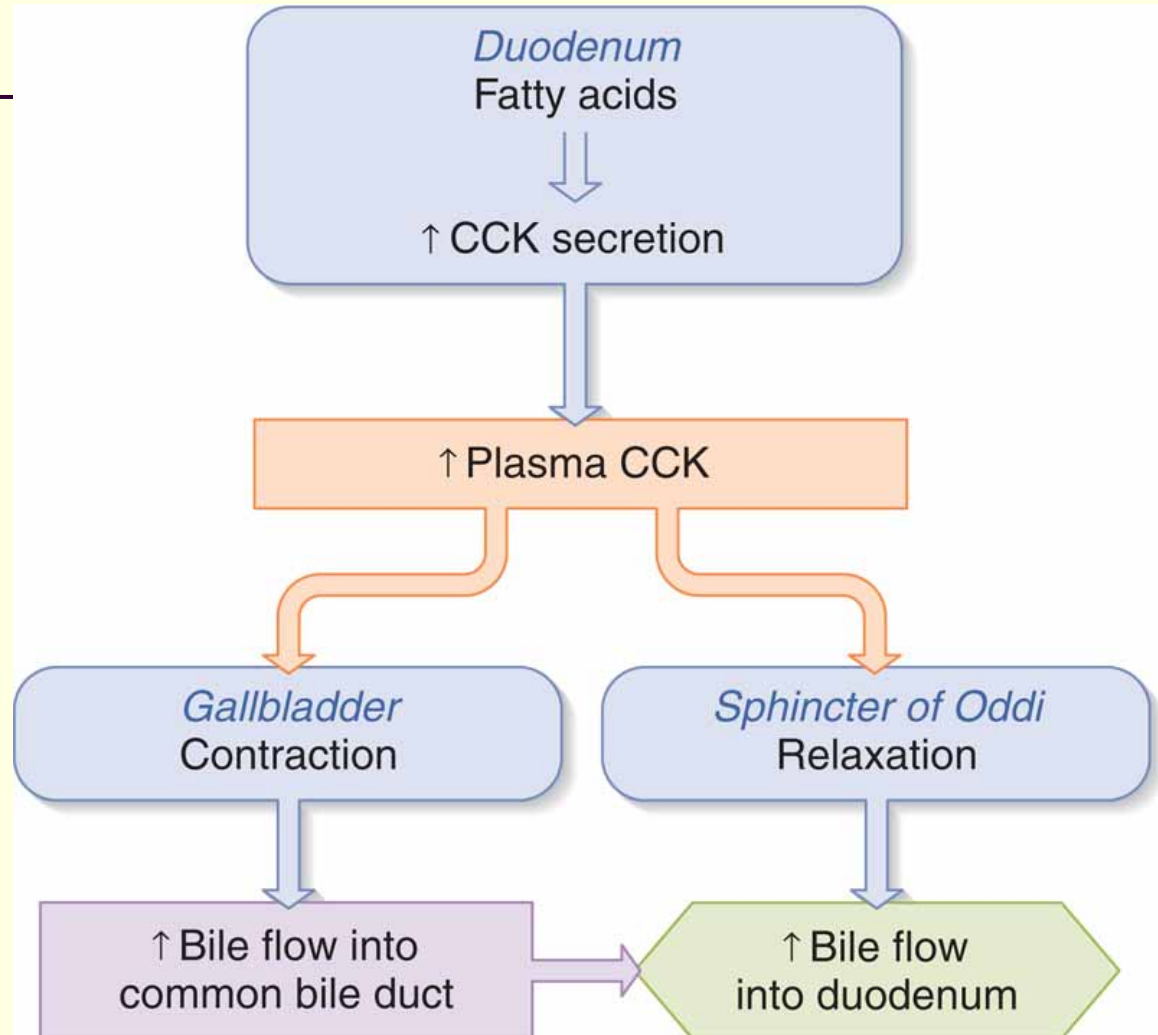
- Somatostatin 生长抑素

- Contraction of the gall bladder

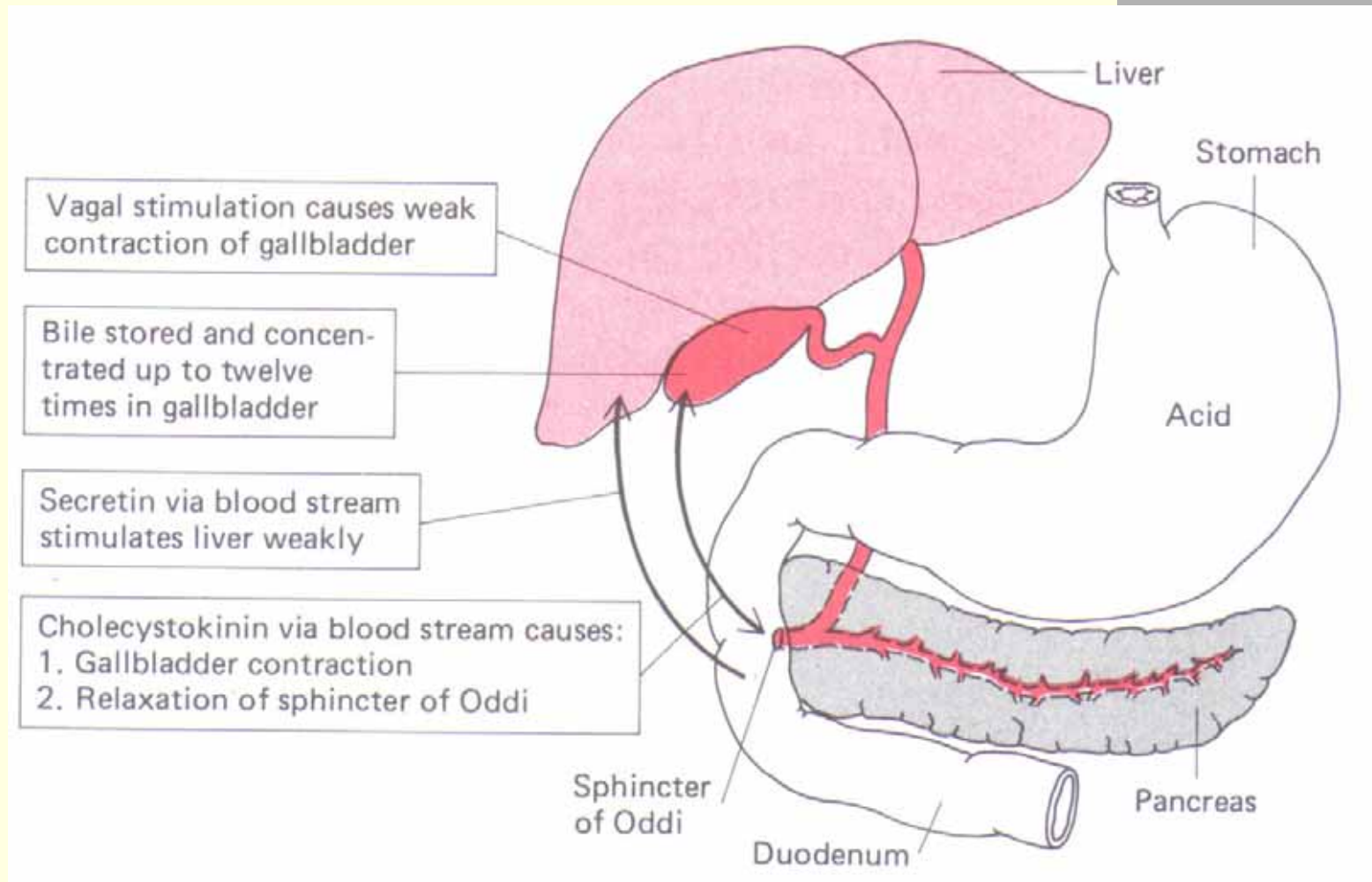
- Substances causing gall bladder contraction

- ACh
- CCK
- Gastrin 促胃液素

Cholecystikinin (CCK) stimulates the gallbladder, which responds by contracting and delivering more bile to the duodenum through the sphincter of Oddi, which relaxes (opens) in response to CCK.



Summary: regulation of bile secretion



Small intestinal juices

- Secreted by:
 - Brunners glands(十二指肠腺)
 - Crypts of Lieberkuhn (小肠腺或李氏腺)
- 1~3 L/day
- pH 7.6
- Isosmotic

Small intestinal juices

- Components

- H₂O

- Electrolytes (Na⁺, K⁺, Ca²⁺, Cl⁻)

- Mucus

- IgA

- Enterokinase 肠致活酶

Small intestinal juices

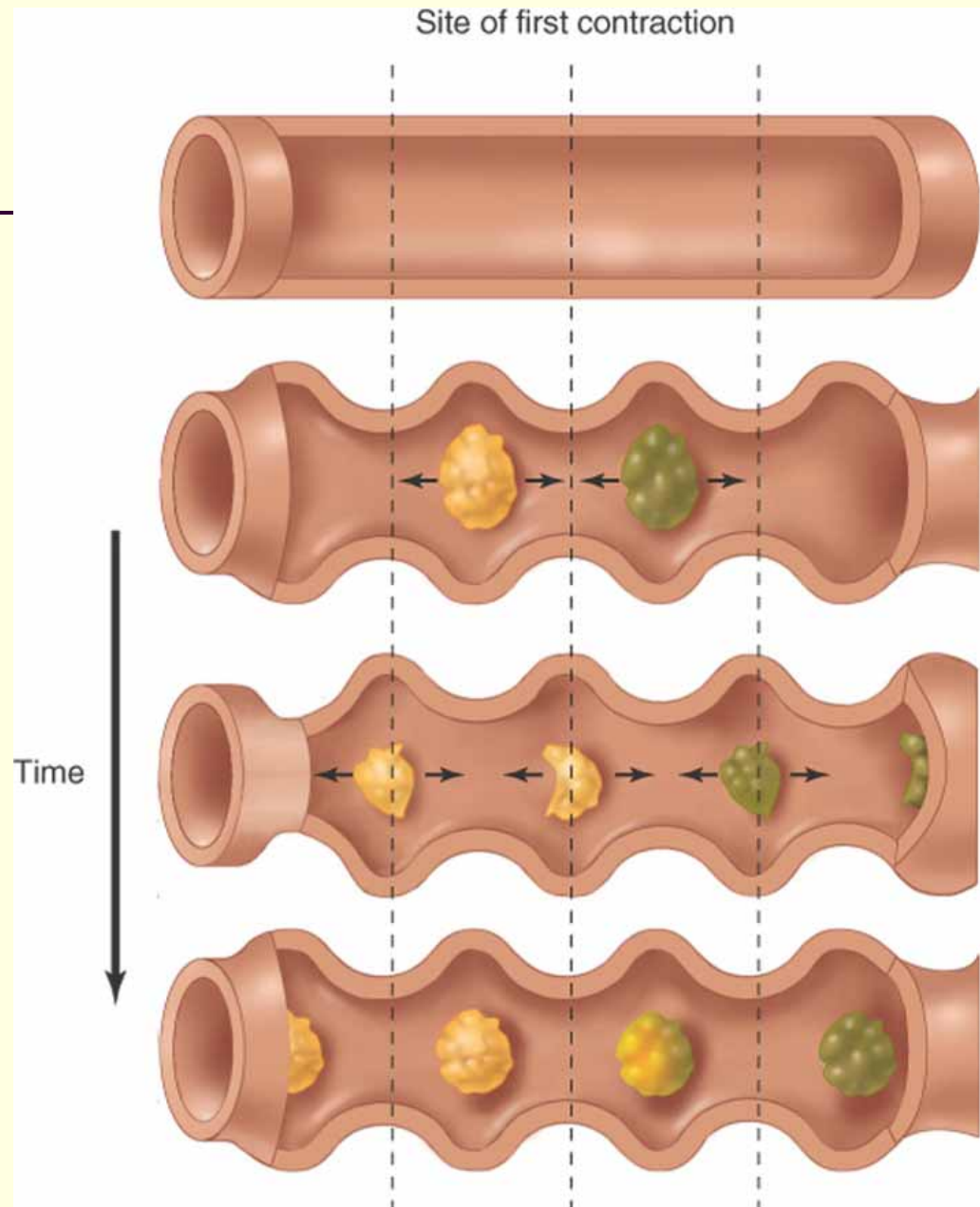
- **Function:** Completing the digestion of peptides, carbohydrates & fat
- Secretion by intestinal glands is mainly due to the local effects of chyme 食糜 in the intestine and is regulated by both neural and hormonal factors

Movement of small intestine

- Movement of small intestine during digestion
 - **Tonic contraction**: maintaining a basal state of intestinal smooth muscle contraction
 - **Segmentation** 分节运动
 - **Peristalsis** 蠕动

Segmentation

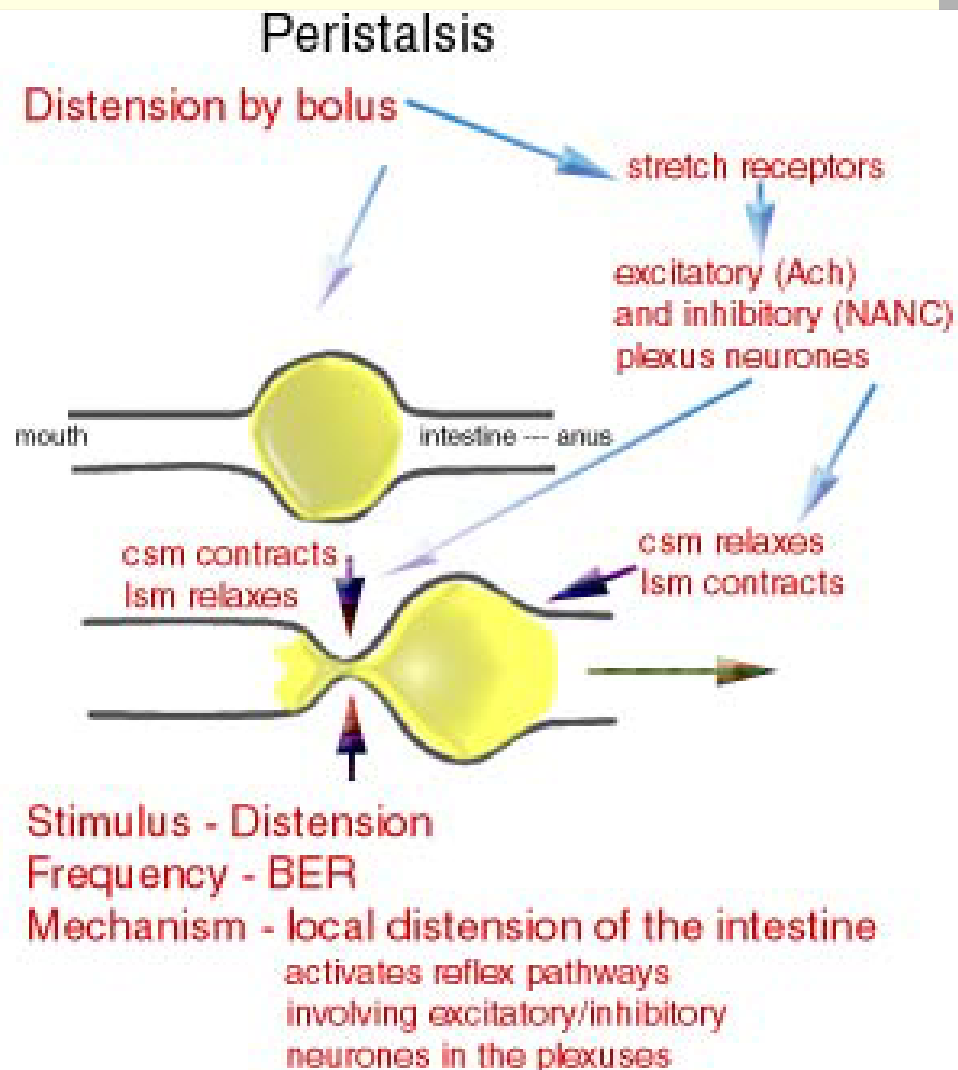
Most of the contractions of the small intestine are of the mixing and churning (搅拌) actions portrayed (描绘) here as segmentation contractions; peristalsis and the downstream movement of materials is infrequent.



Segmentation

- The most common type of activity in the intestine during digestion & absorption
- Consisting of the alternate contraction & relaxation of adjacent bands of circular smooth muscle
- **Function:** Mixing food & digestive secretions & facilitating both digestion & absorption of digestive products by the mucosal epithelium
- Regulated by excitatory & inhibitory neurons in the plexuses

Peristalsis



Regulation of intestinal motility

- **Autoregulation:** Regulated by BER
- **Neural Reflexes:**
 - mainly by 'short' reflexes in the intrinsic plexuses which are responsible for peristalsis and segmentation
 - also by extrinsic nerves (sympathetic & vagal nerves) which mediate 'long' reflexes

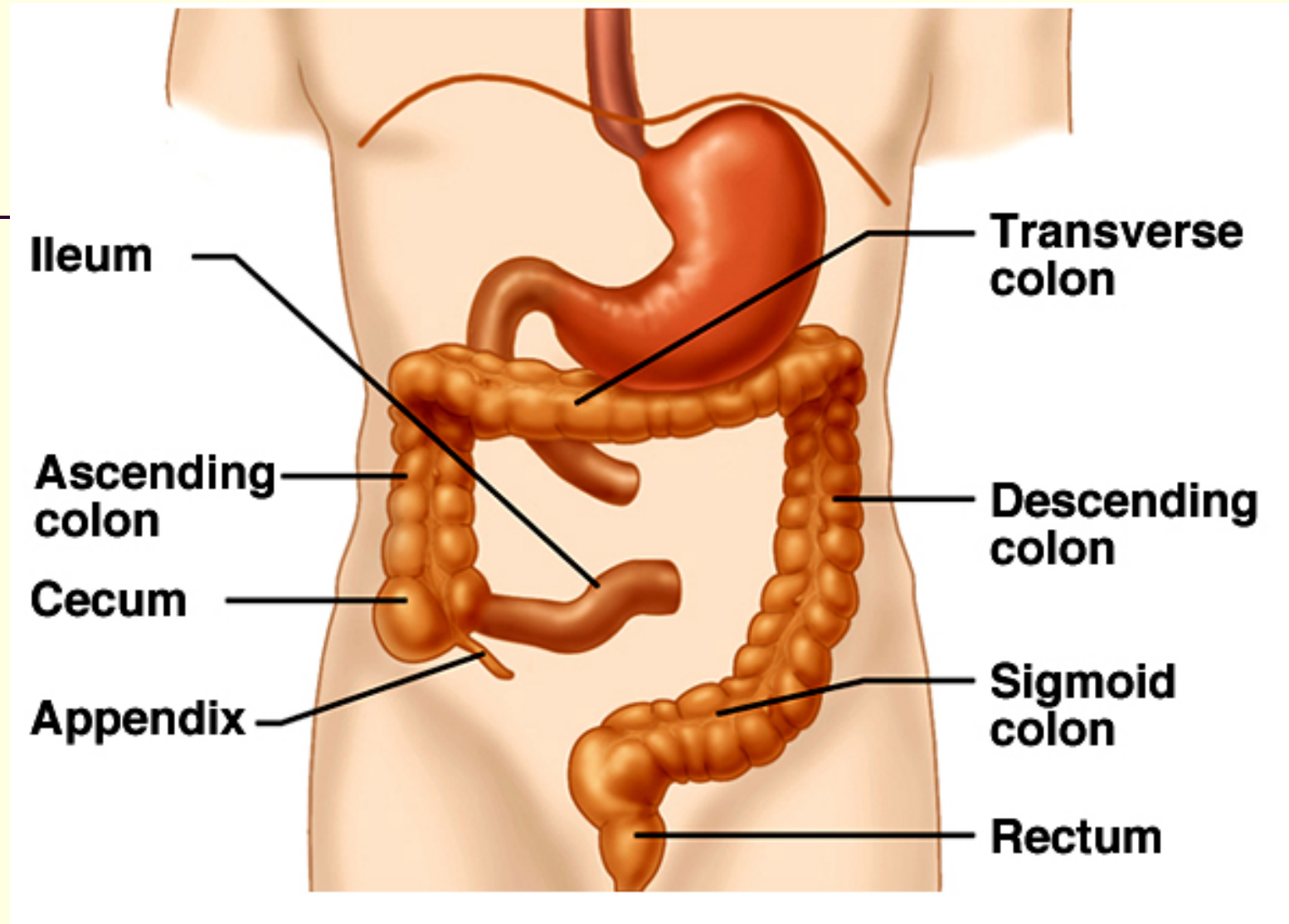
Regulation of intestinal motility

■ Hormonal controls:

- Gastrin, CCK, motilin (胃动素), 5-HT (+)
- Secretin, VIP, glucagon (胰高血糖素) (-)

Function of large intestine

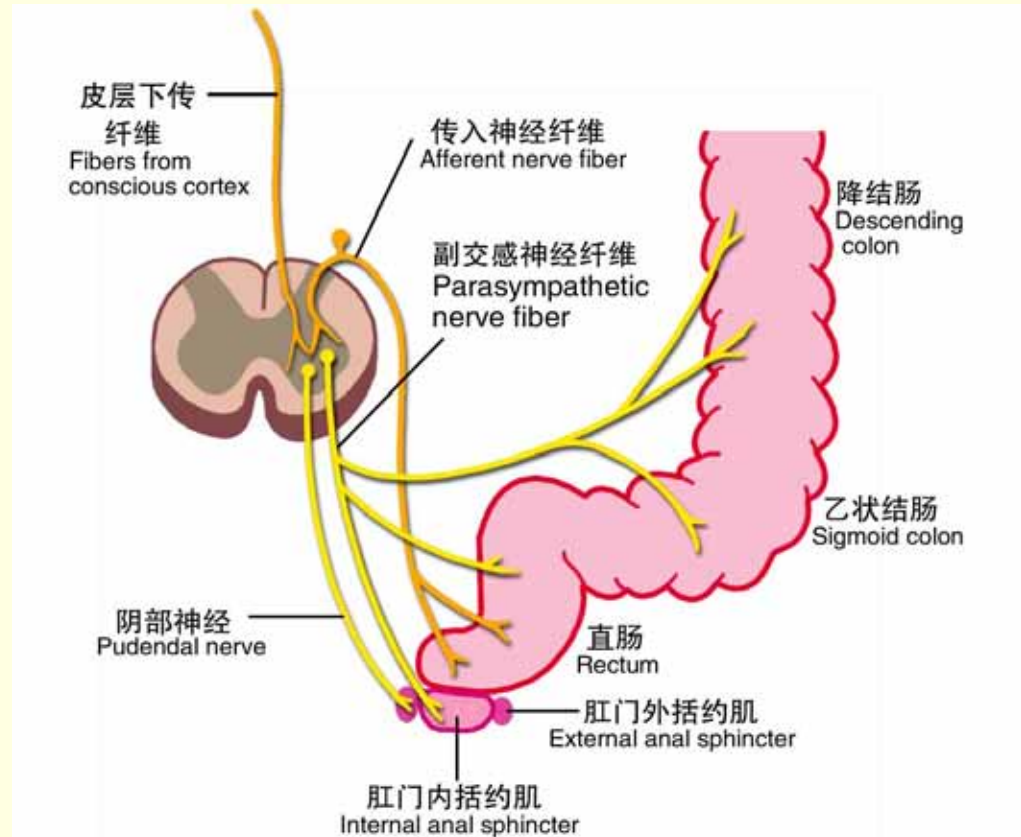
- The principle functions of the colon:
 - Absorption of water and electrolytes from the chyme (食糜) to form solid feces
 - Storage of fecal matter until it can be expelled



In the large intestine, active transport of sodium, coupled with osmotic absorption of water, are the primary activities. Microbes 微生物 here are active in the production of vitamin K.

Defecation reflex 排便反射

- 粪便刺激直肠感受器 盆神经、腹下神经传入 骶髓排便中枢 皮层 便意 兴奋盆神经， 肛门外括约肌舒张；抑制阴部神经，肛门外括约肌舒张 排便



Absorption

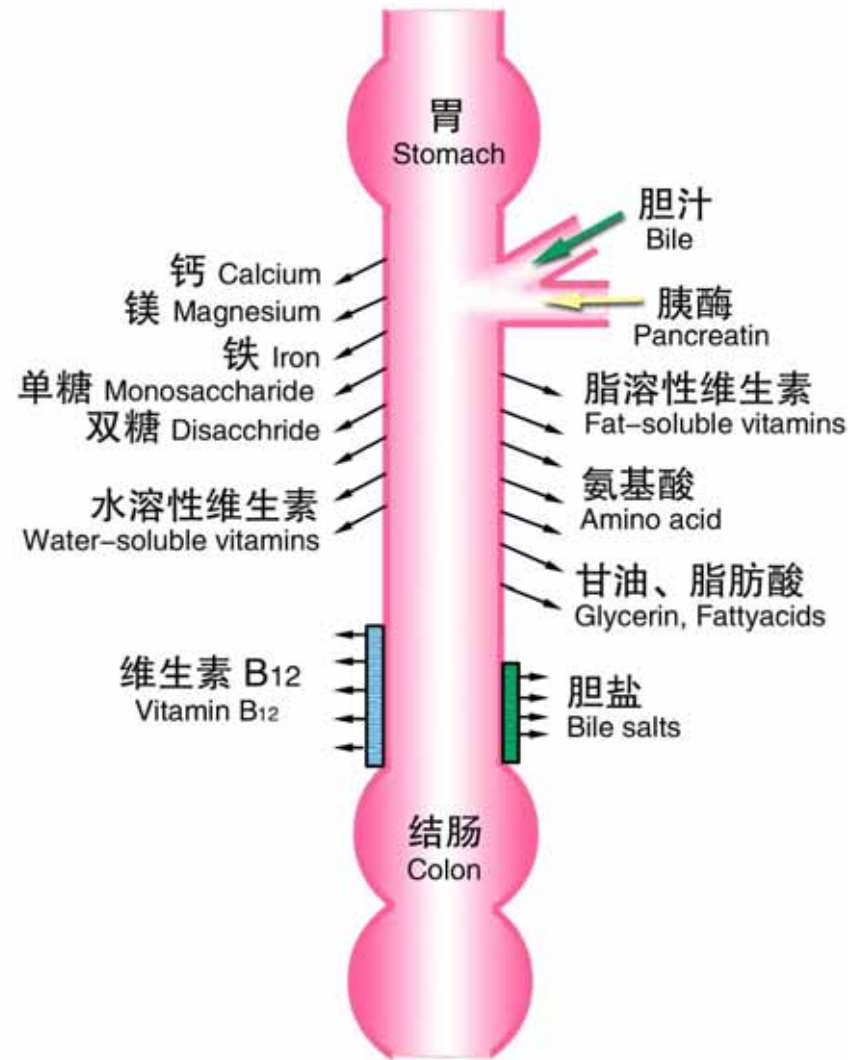
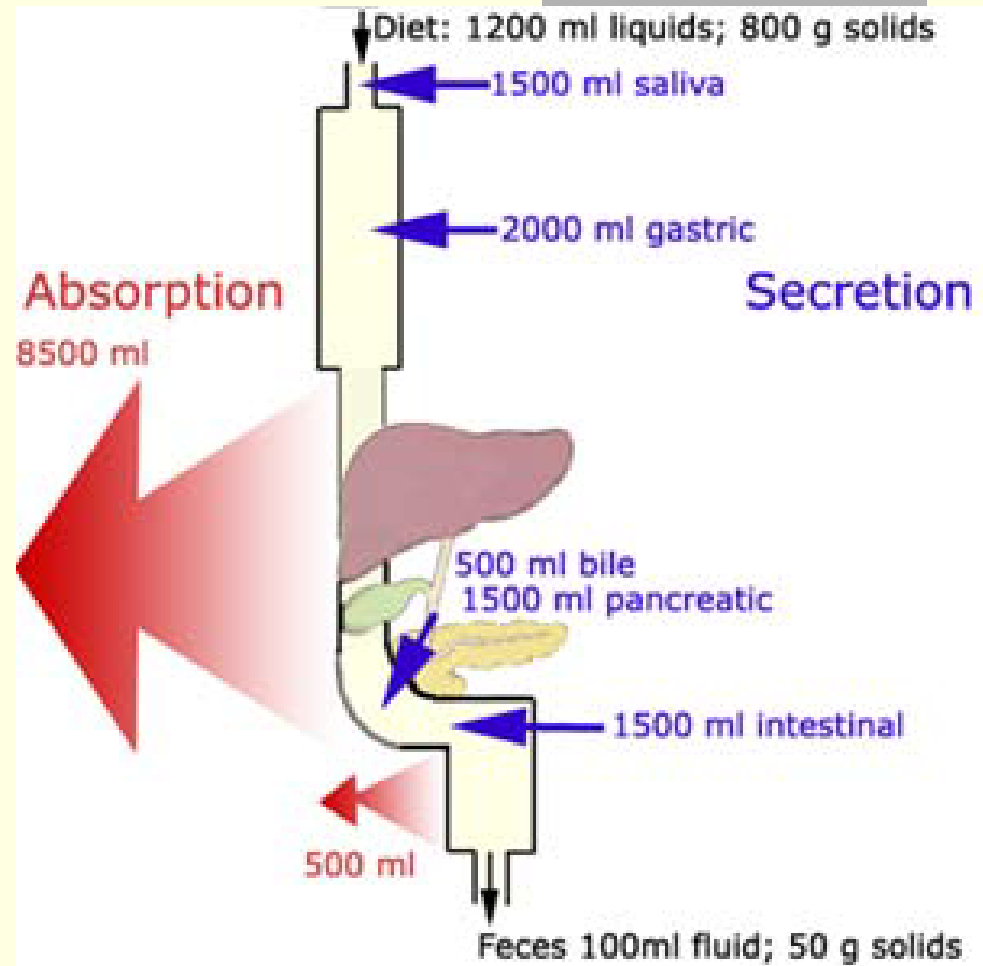


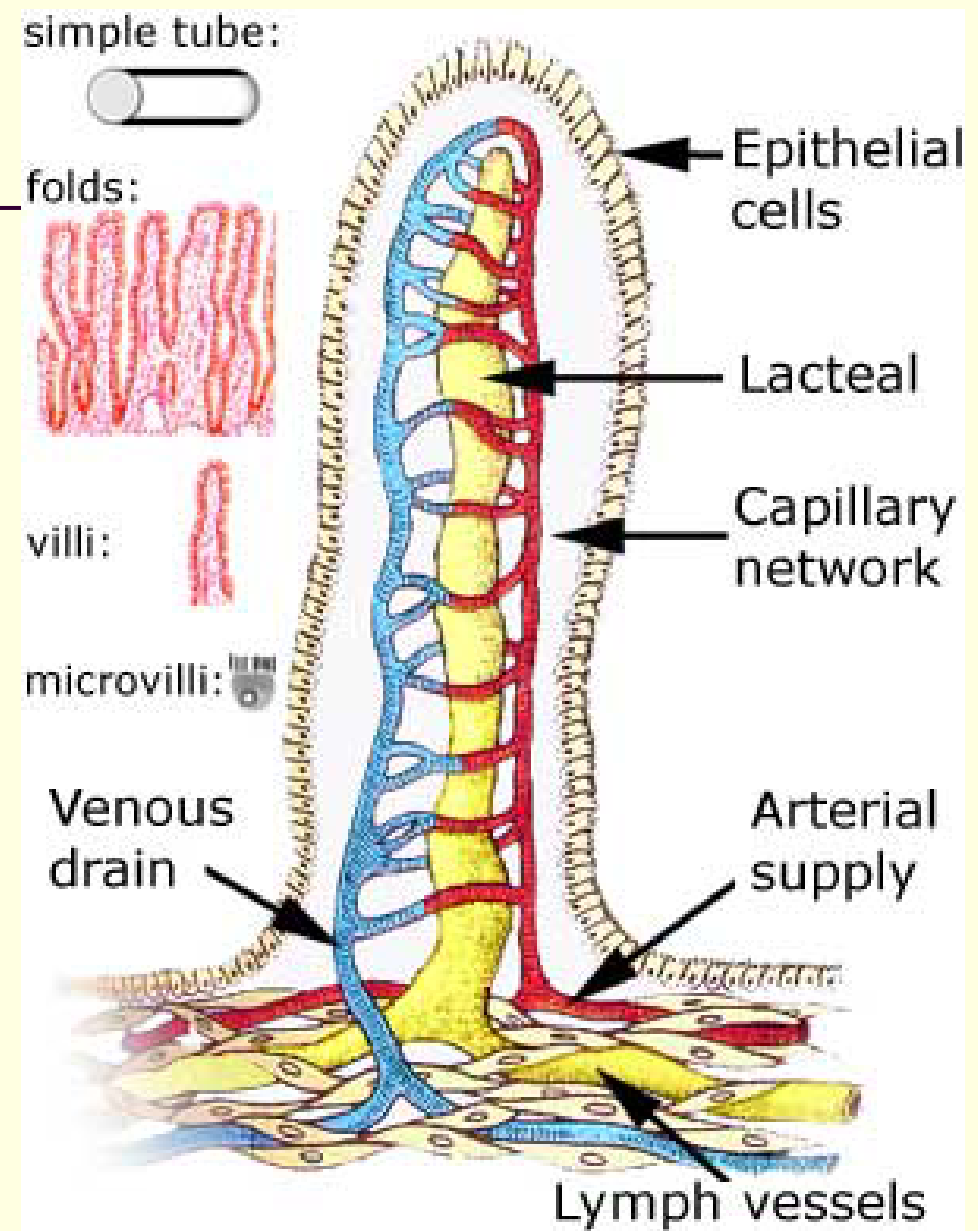
图 - 不同营养物质在小肠的吸收部位

Absorption

- Almost all absorption of nutrients occurs in the small intestine



- Structural specializations of the small intestinal mucosa



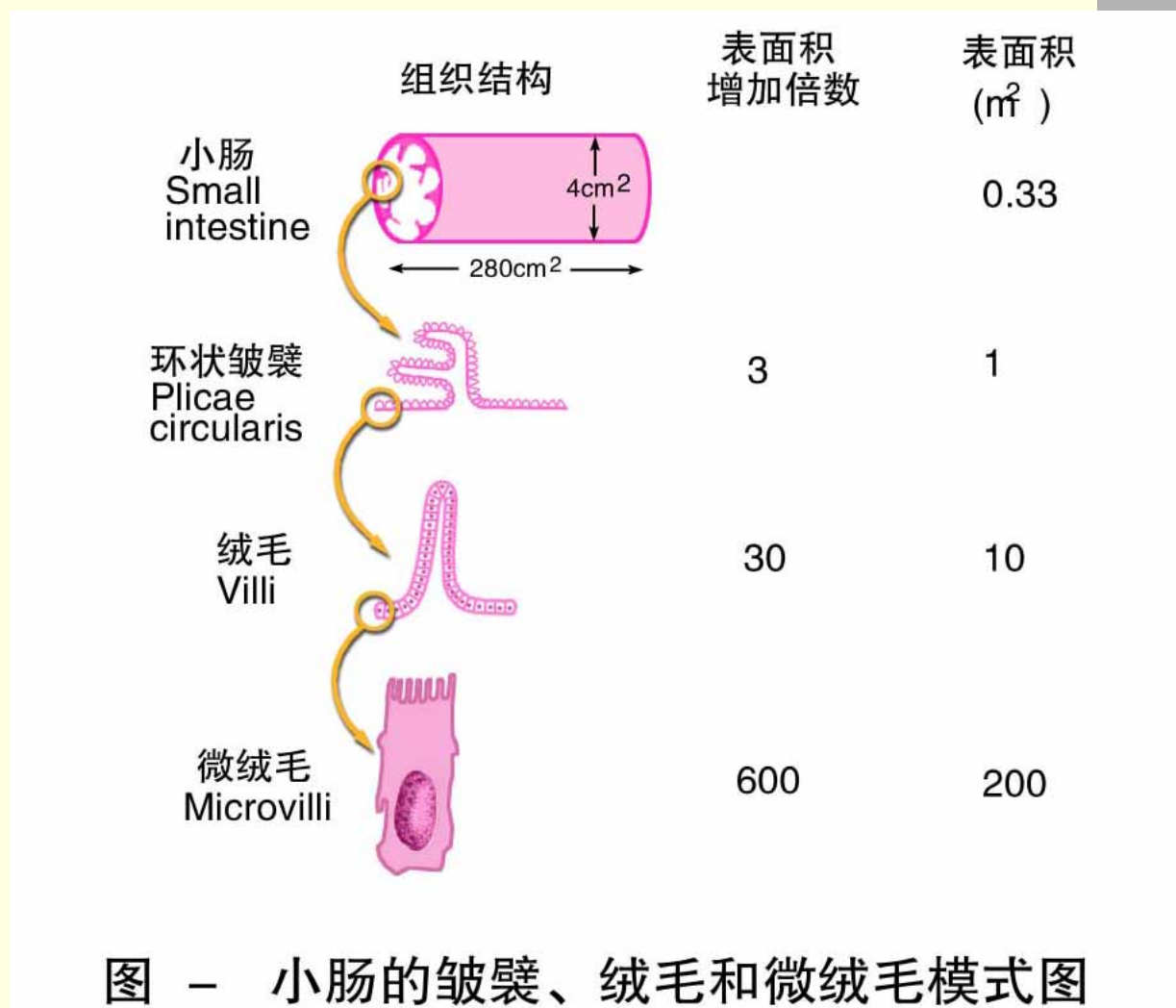
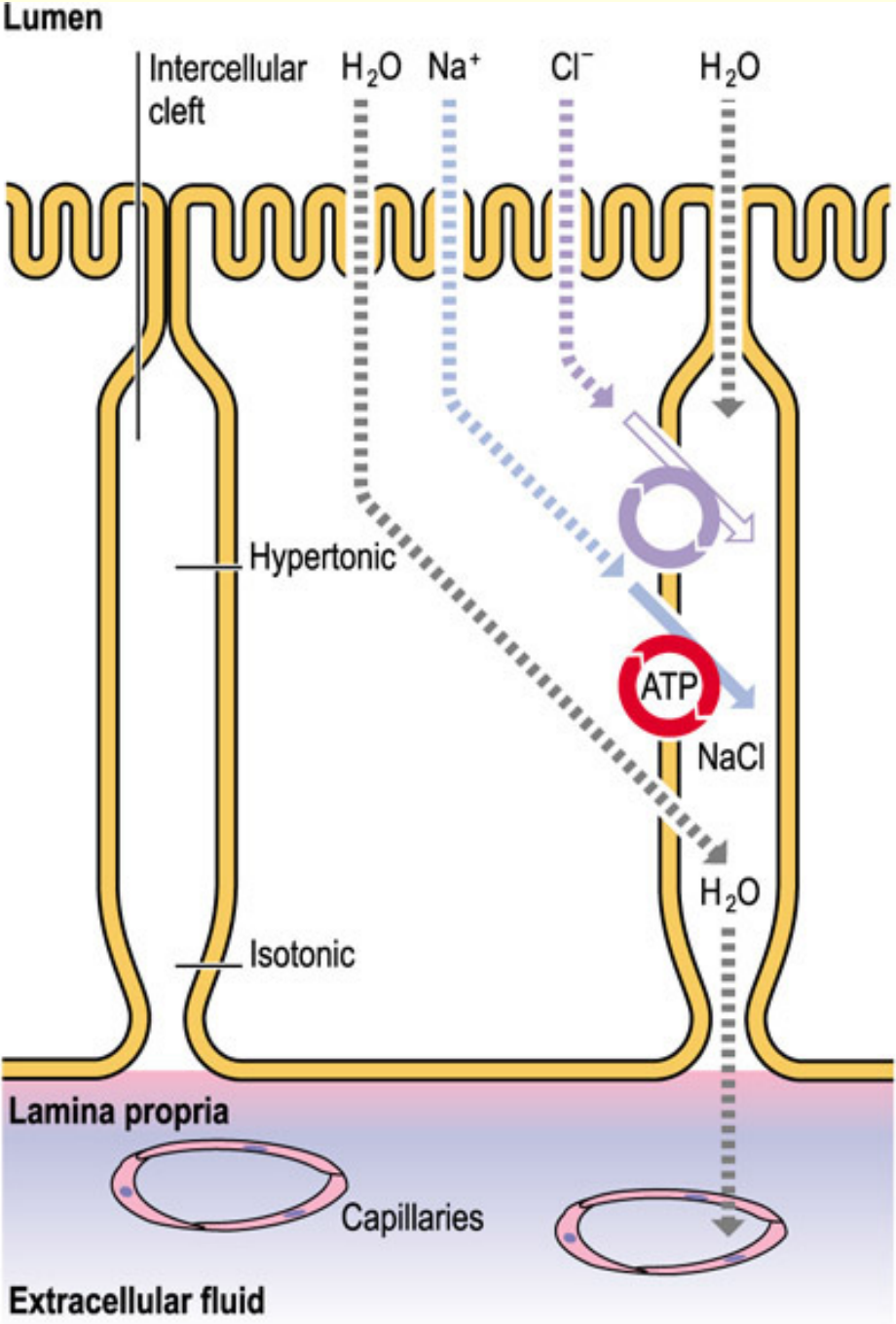


图 - 小肠的皱襞、绒毛和微绒毛模式图

Absorption pathways

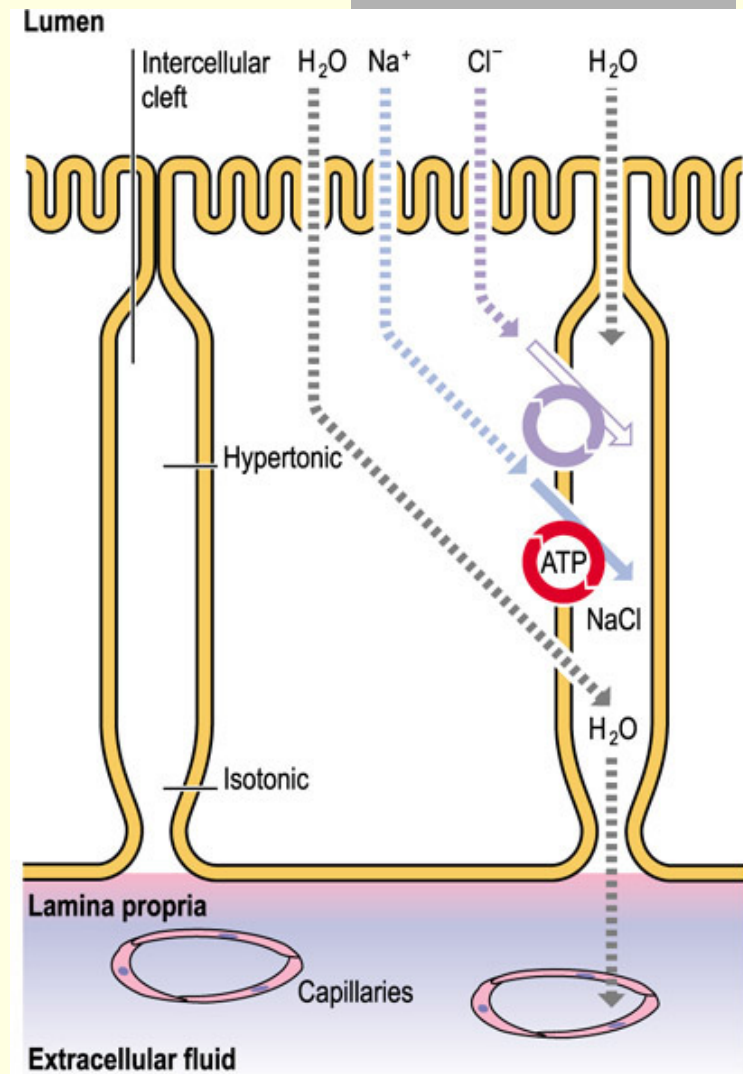


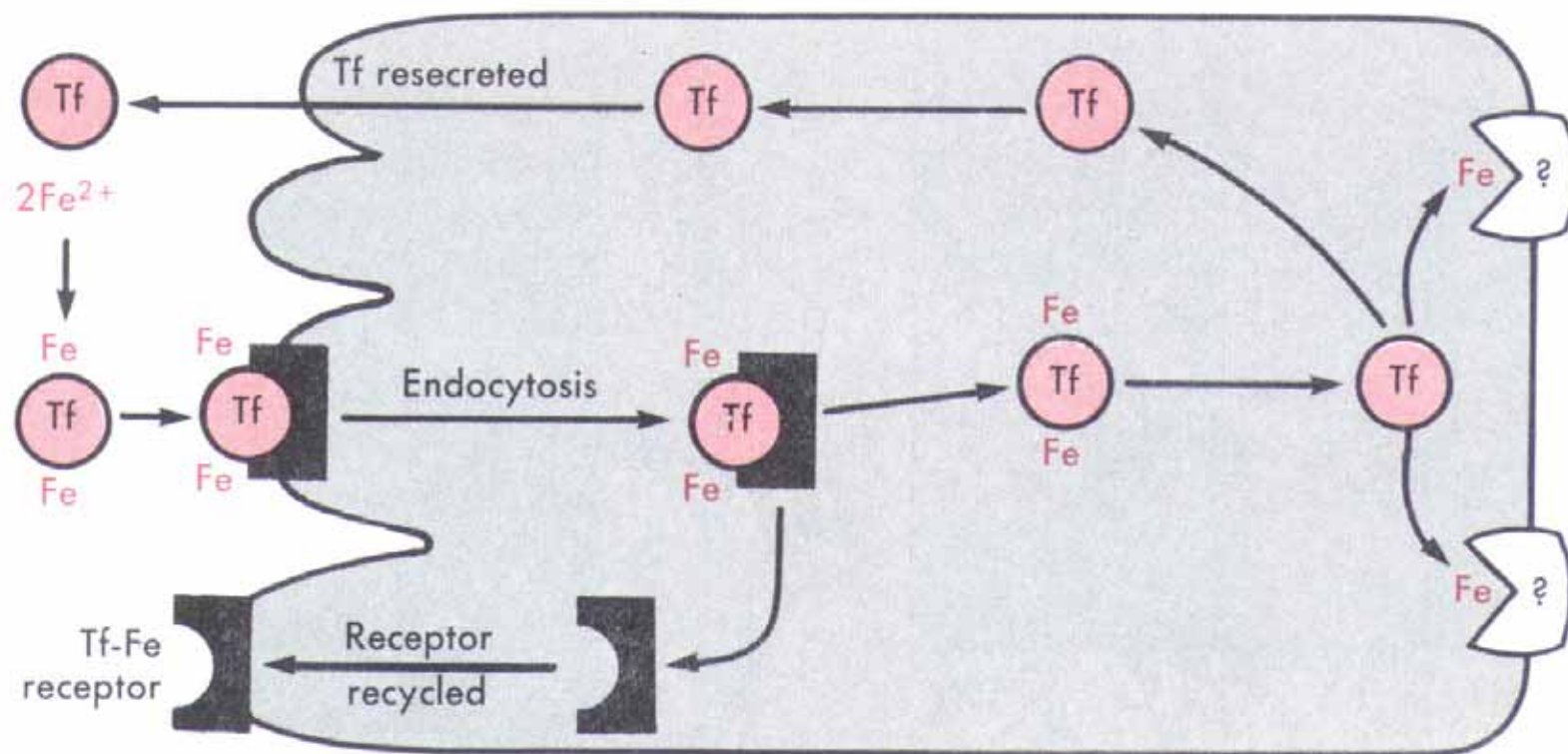
Absorption of major nutrients

- H_2O & Na^+

H_2O : Diffusion

Na^+ : Na^+ pump

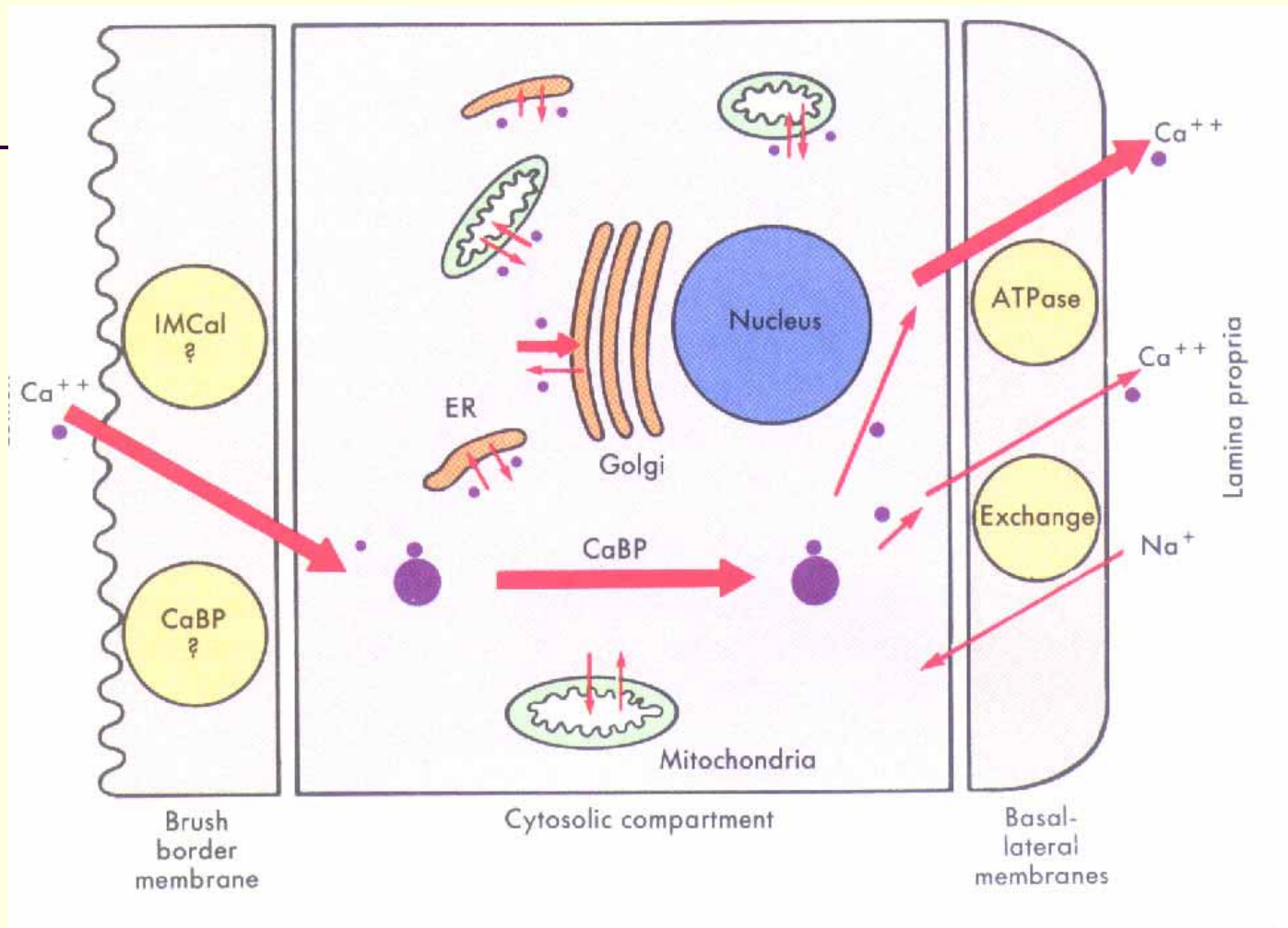




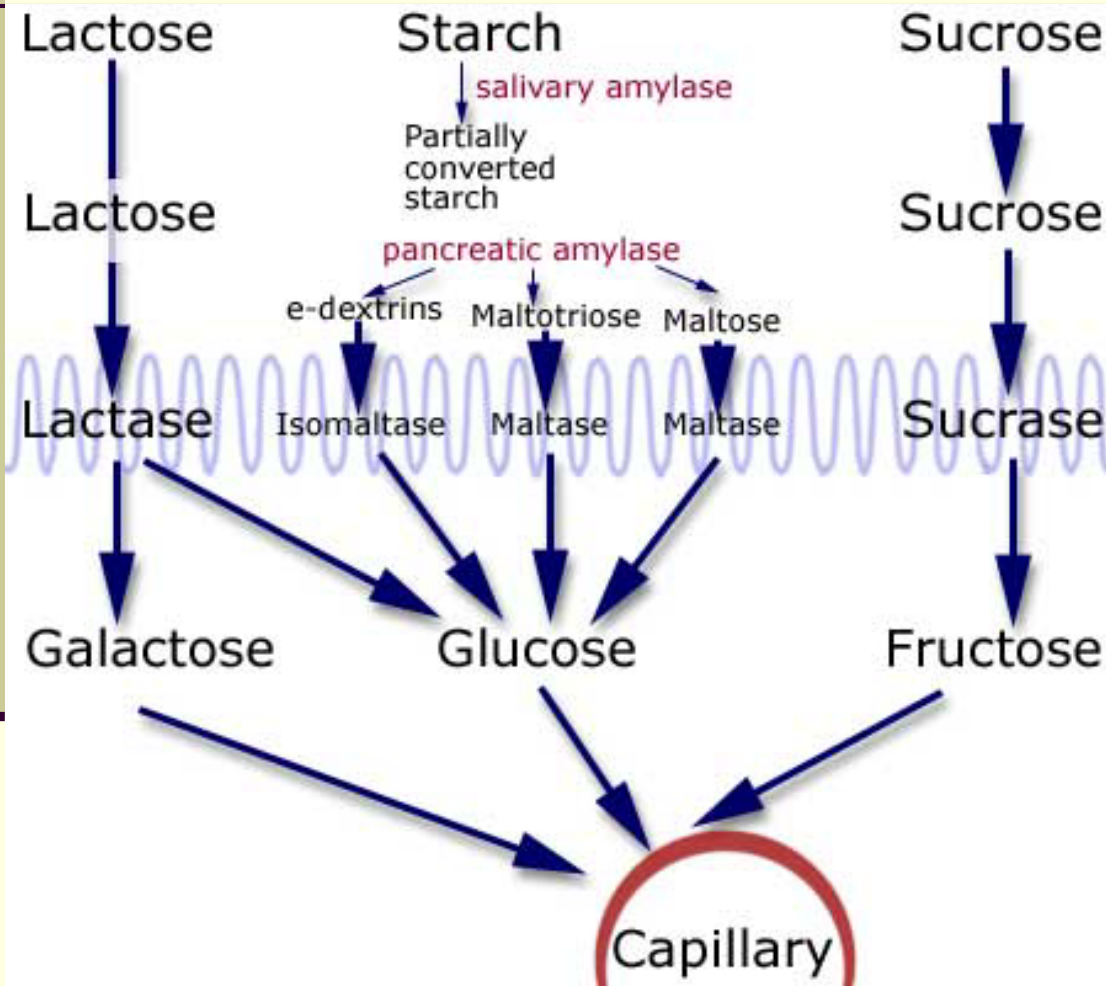
- Fe^{2+}

Receptor-mediated endocytosis

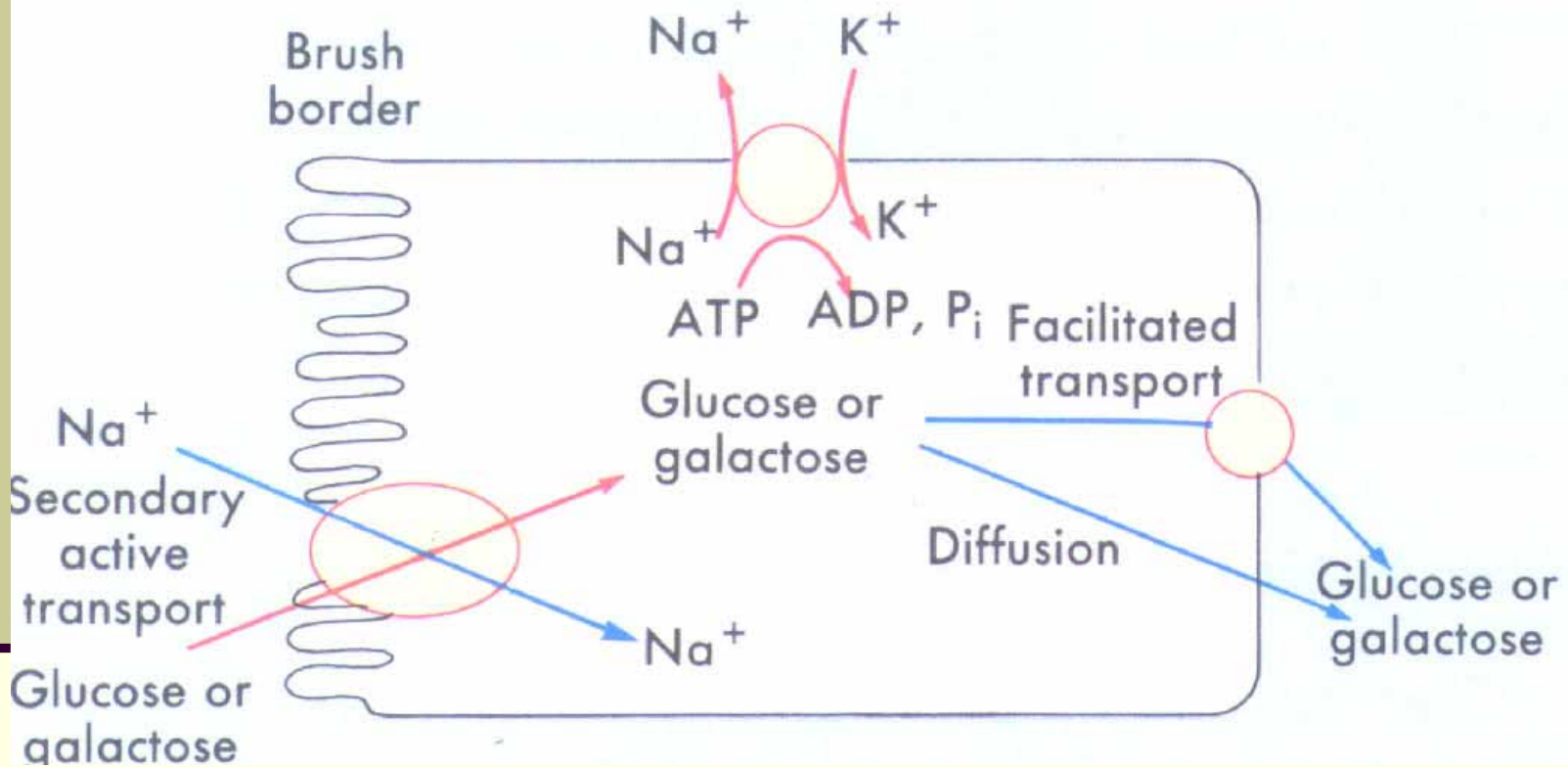
Recycle of transferrin 转铁蛋白 and its receptor



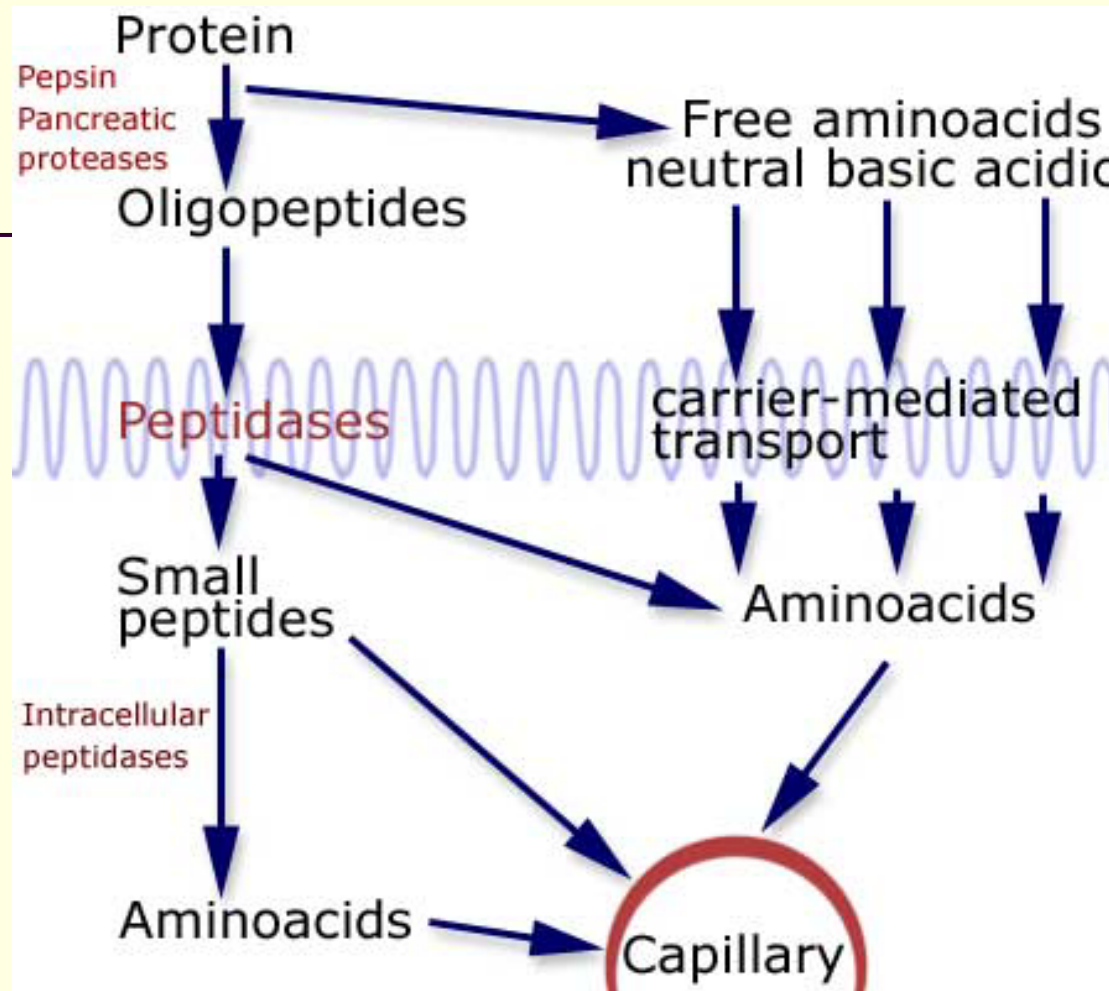
- **Ca²⁺** : Ca²⁺ pump
- 胃酸、脂肪酸、维生素D促进钙吸收



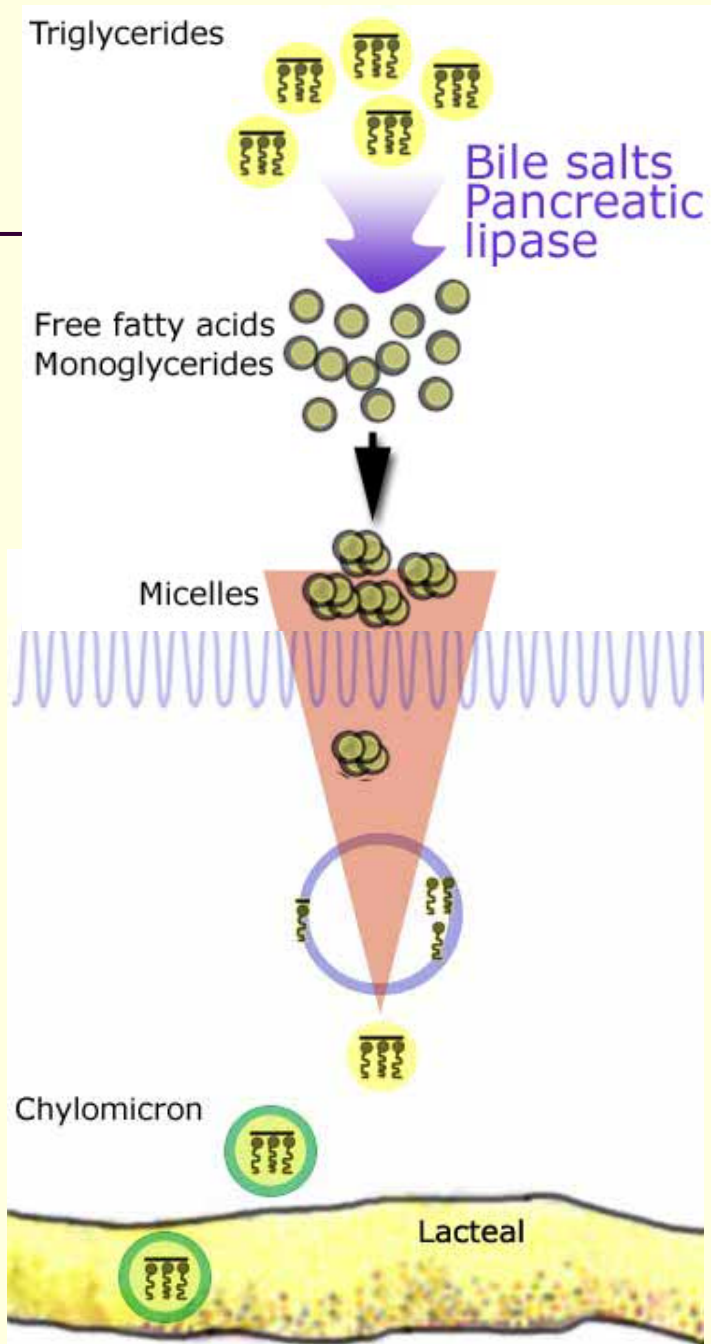
- Carbohydrates
- Na⁺-同向转运体-glucose



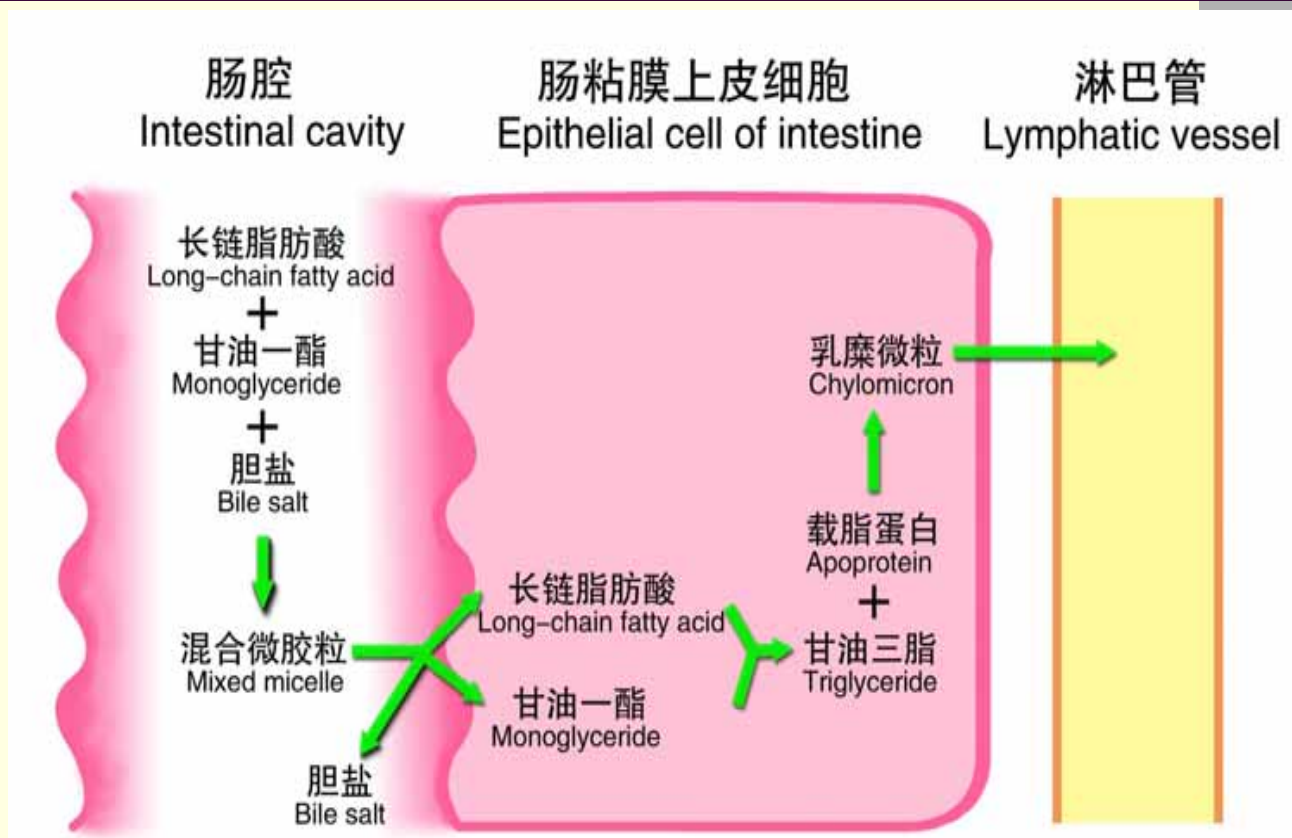
Secondary active transport



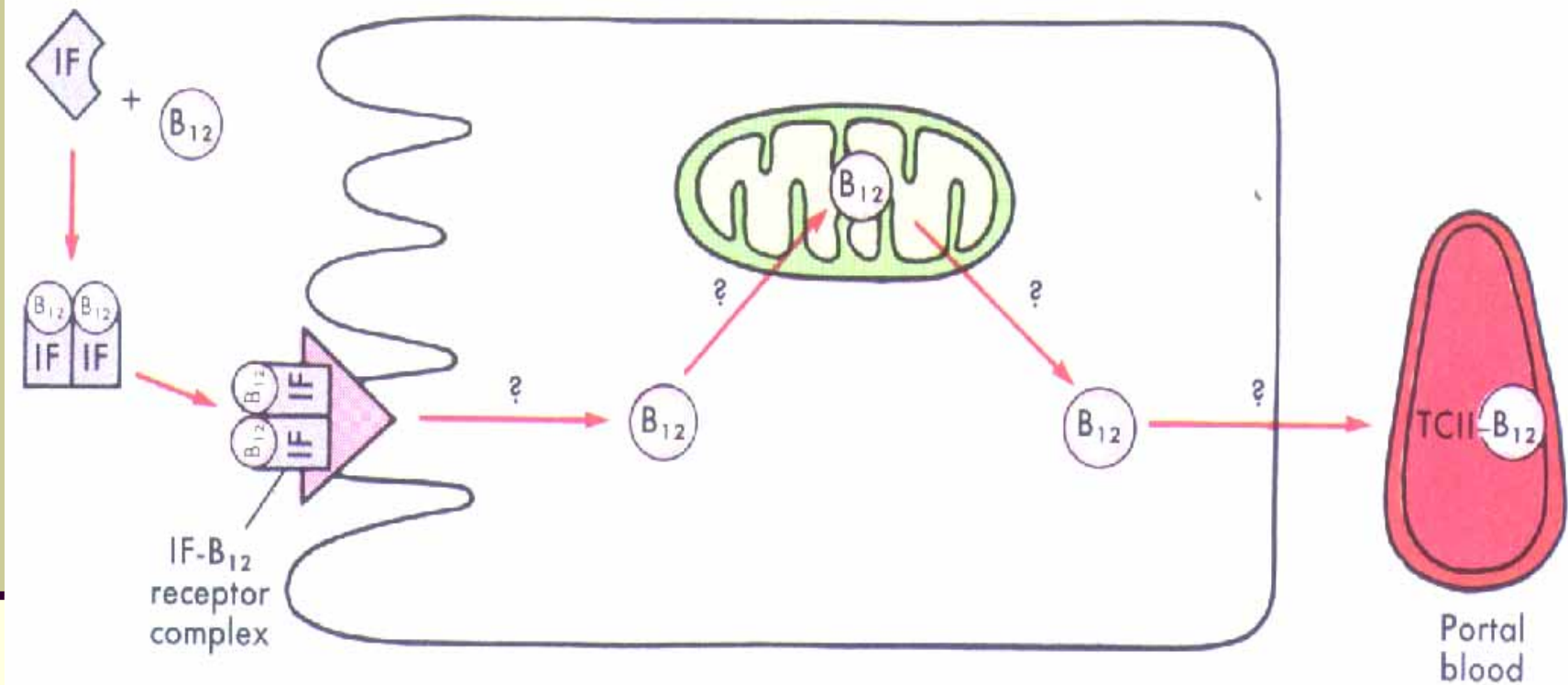
- **Protein**
- Secondary active transport



- **Fat**
- **Micelles 微胶粒**：脂类的消化产物+胆盐
- **Chylomicron 乳糜微滴**：甘油三酯+载脂蛋白

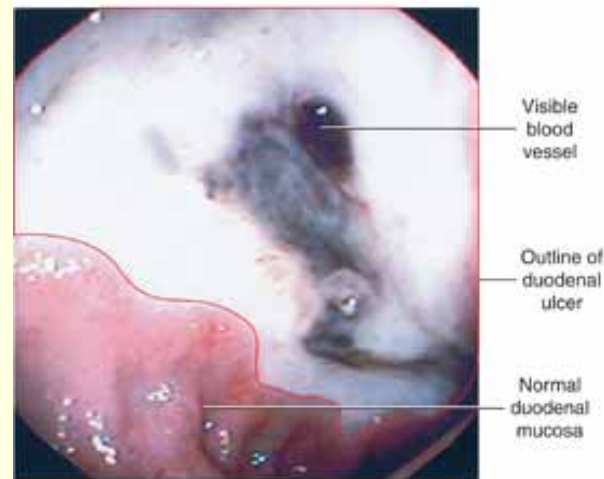
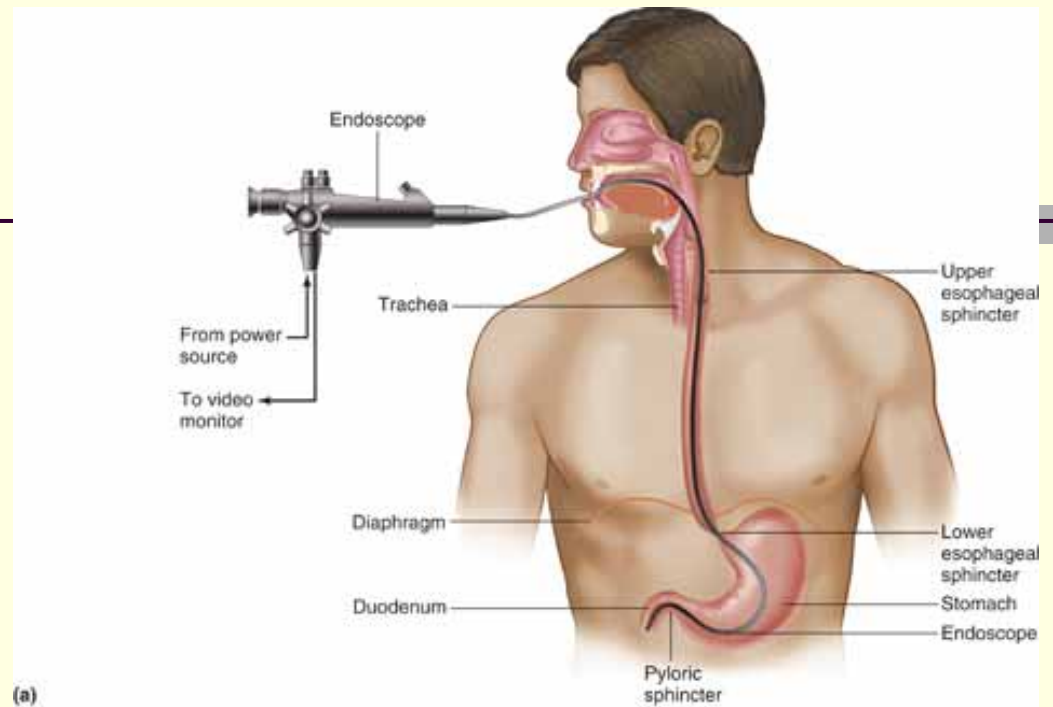


- Fat e.g. Triglyceride



- Water soluble Vitamin: diffusion
- Vitamin B12
- Vitamin A, D, E, K

Video endoscopy has greatly enhanced our understanding of normal processes in the gut, and reveals complications resulting from disease.



(b)