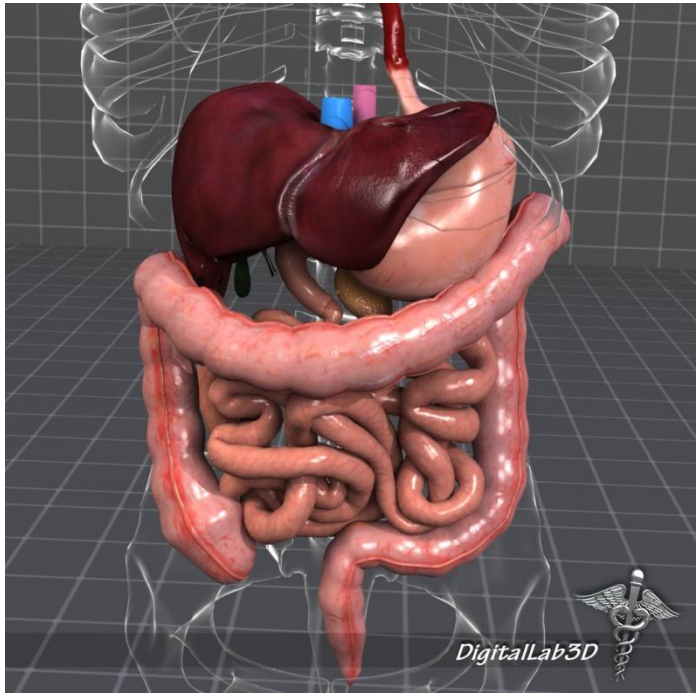
Digestive System



Dr. Naim Kittana

Department of Biomedical Sciences

Faculty of Medicine & Health Sciences

An-Najah National University

Declaration

- The content and the figures of this seminar were directly adopted from the text book “Human Anatomy and Physiology / Ninth edition/ Eliane N. Marieb 2013”

Overview

The digestive system includes

- Organs of the alimentary canal: mouth, pharynx, esophagus, stomach, small and large intestines

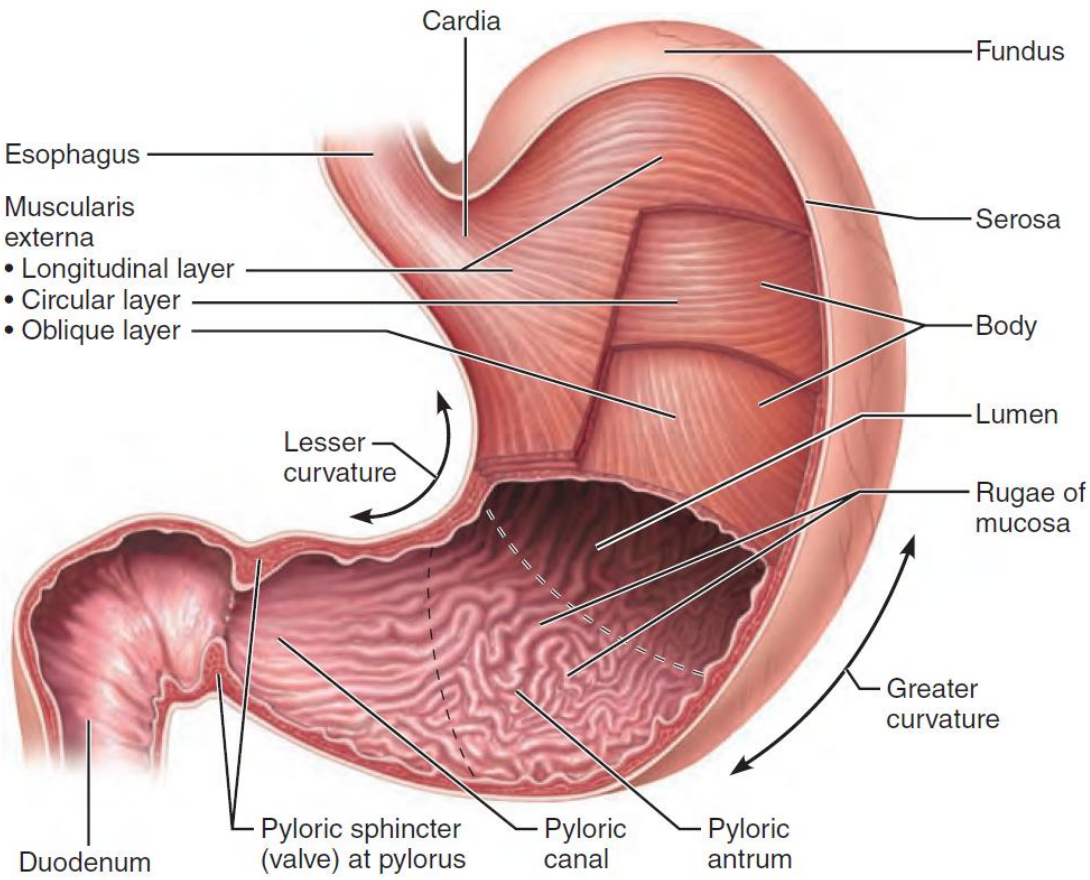
- Accessory digestive system organs: teeth, tongue, salivary glands, liver, gallbladder, and pancreas

Digestive Processes

1. Ingestion: food intake
2. Propulsion: movement of food through the tract
3. Mechanical breakdown: processes that physically mix or break foods down into smaller fragments
4. Digestion: food breakdown by enzymatic action
5. Absorption: transport of products of digestion through the intestinal mucosa into the blood
6. Defecation: elimination of the undigested residues [feces] from the body.

The Stomach

- The J-shaped stomach lies in the upper left quadrant of the abdomen.
- Its major regions are: the cardia, fundus, body, and pyloric part.
- When empty, its internal surface exhibits rugae.
- **The stomach muscularis contains a third (oblique) layer of** smooth muscle that allows it to churn and mix food.



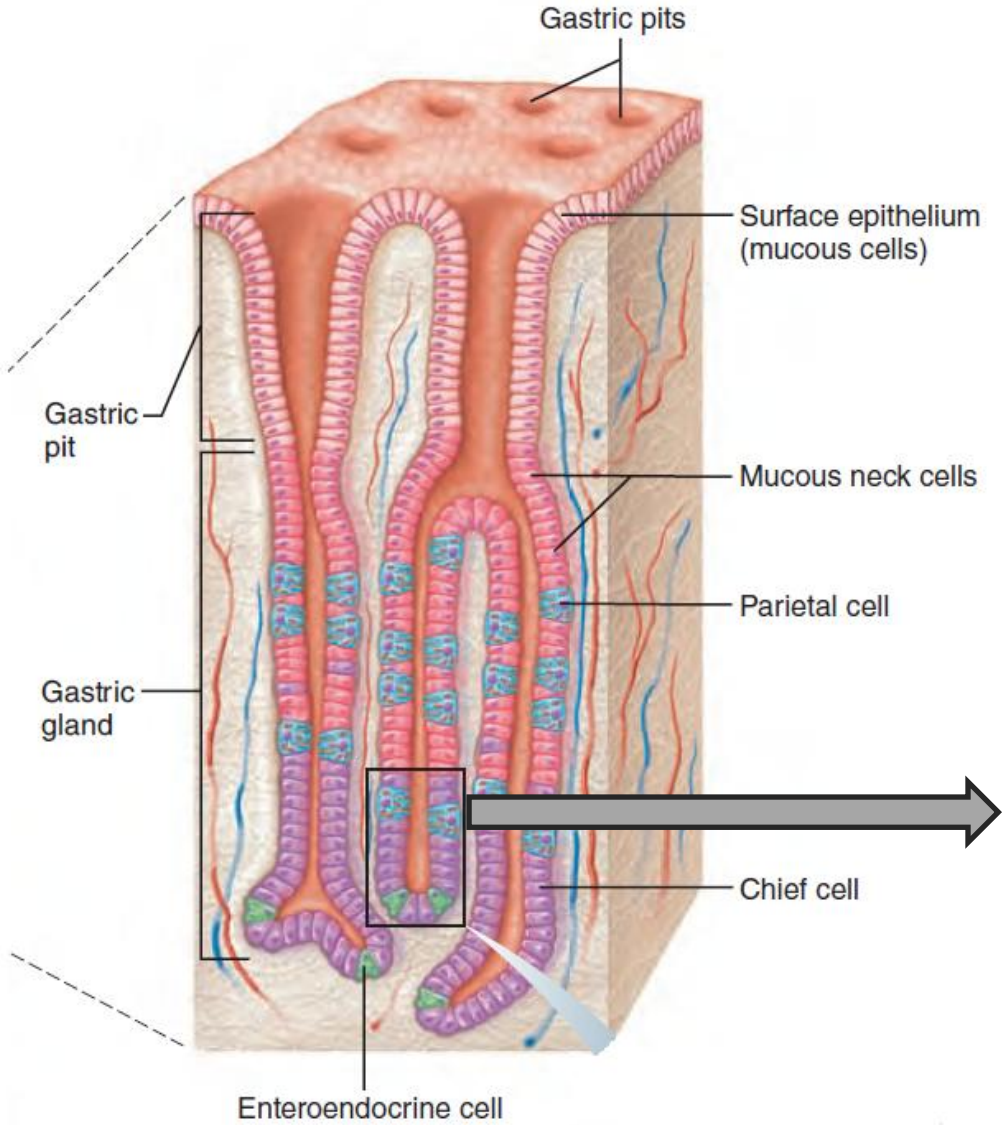
The Stomach

- **The stomach mucosa is simple columnar epithelium dotted** with gastric pits that lead into gastric glands.

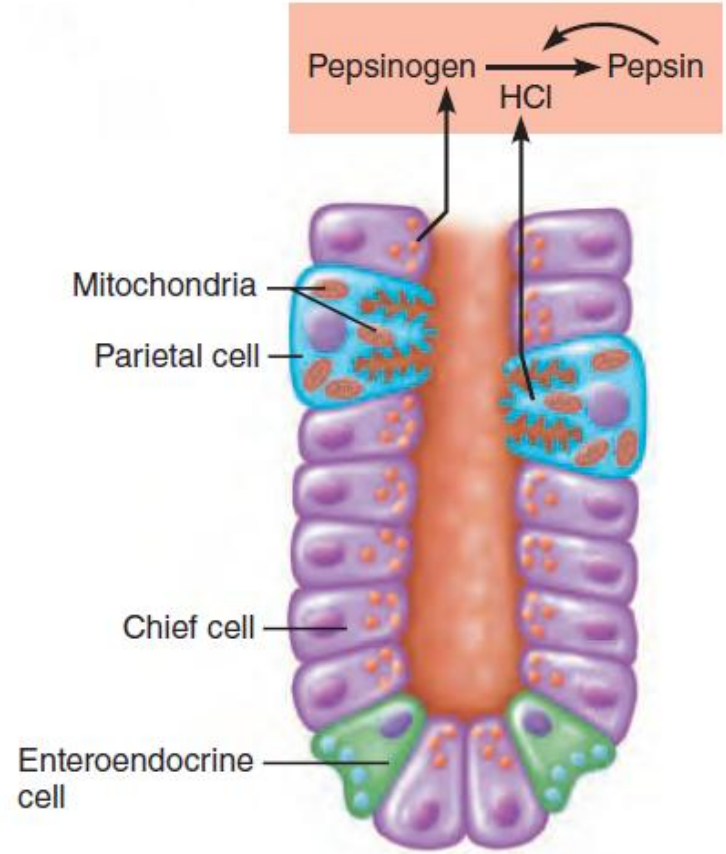
- **Secretory cells in the gastric glands include:**
  - Pepsinogen-producing chief cells
  - Parietal cells, which secrete hydrochloric acid and intrinsic factor
  - Mucous neck cells, which produce mucus
  - Enteroendocrine cells, which secrete hormones

Microscopic anatomy of the stomach

Mucosa

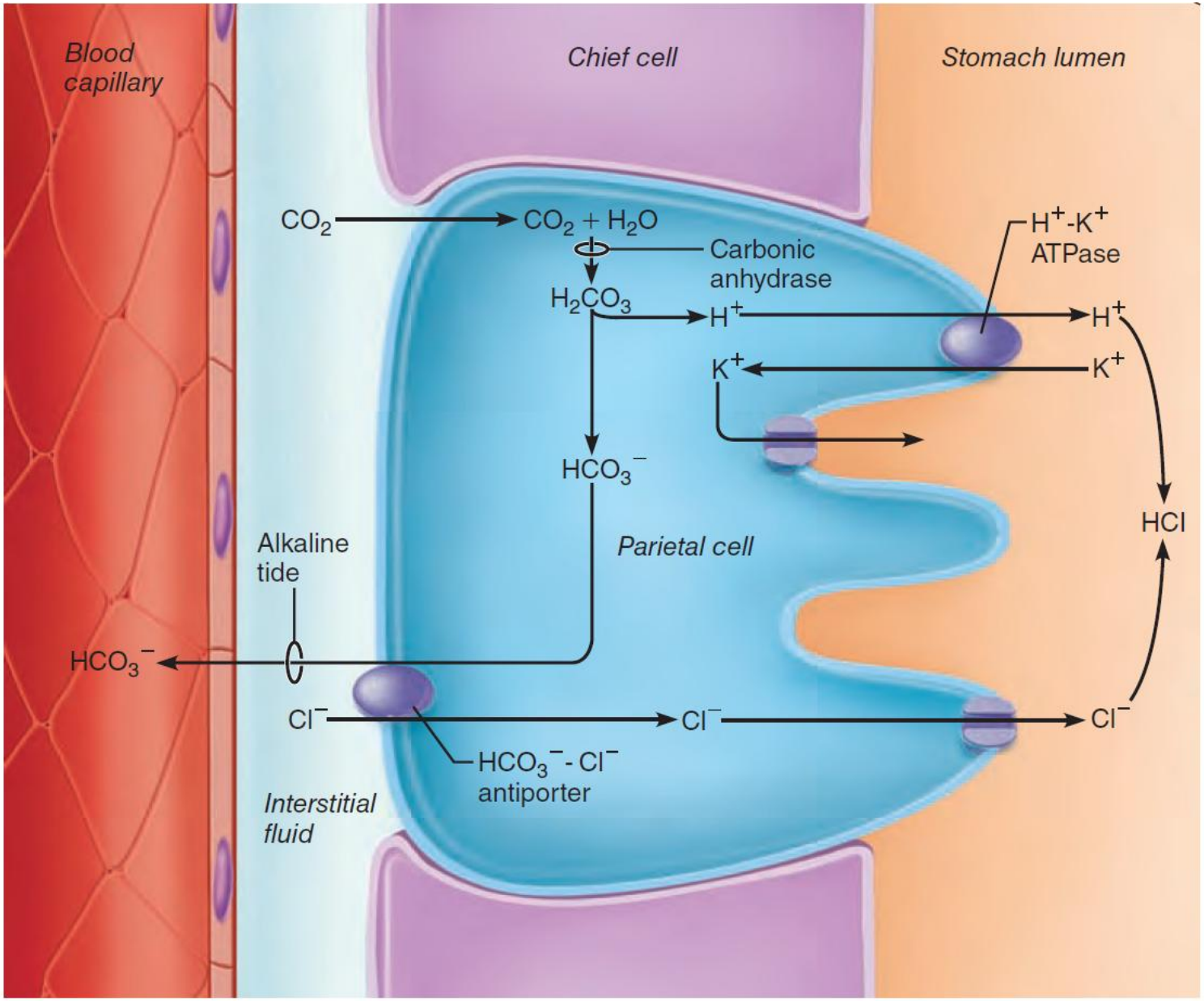


(b) Enlarged view of gastric pits and gastric glands



(c) Location of the HCl-producing parietal cells and pepsin-secreting chief cells in a gastric gland

Mechanism of HCl secretion by parietal cells



Regulation of Gastric Acid secretion

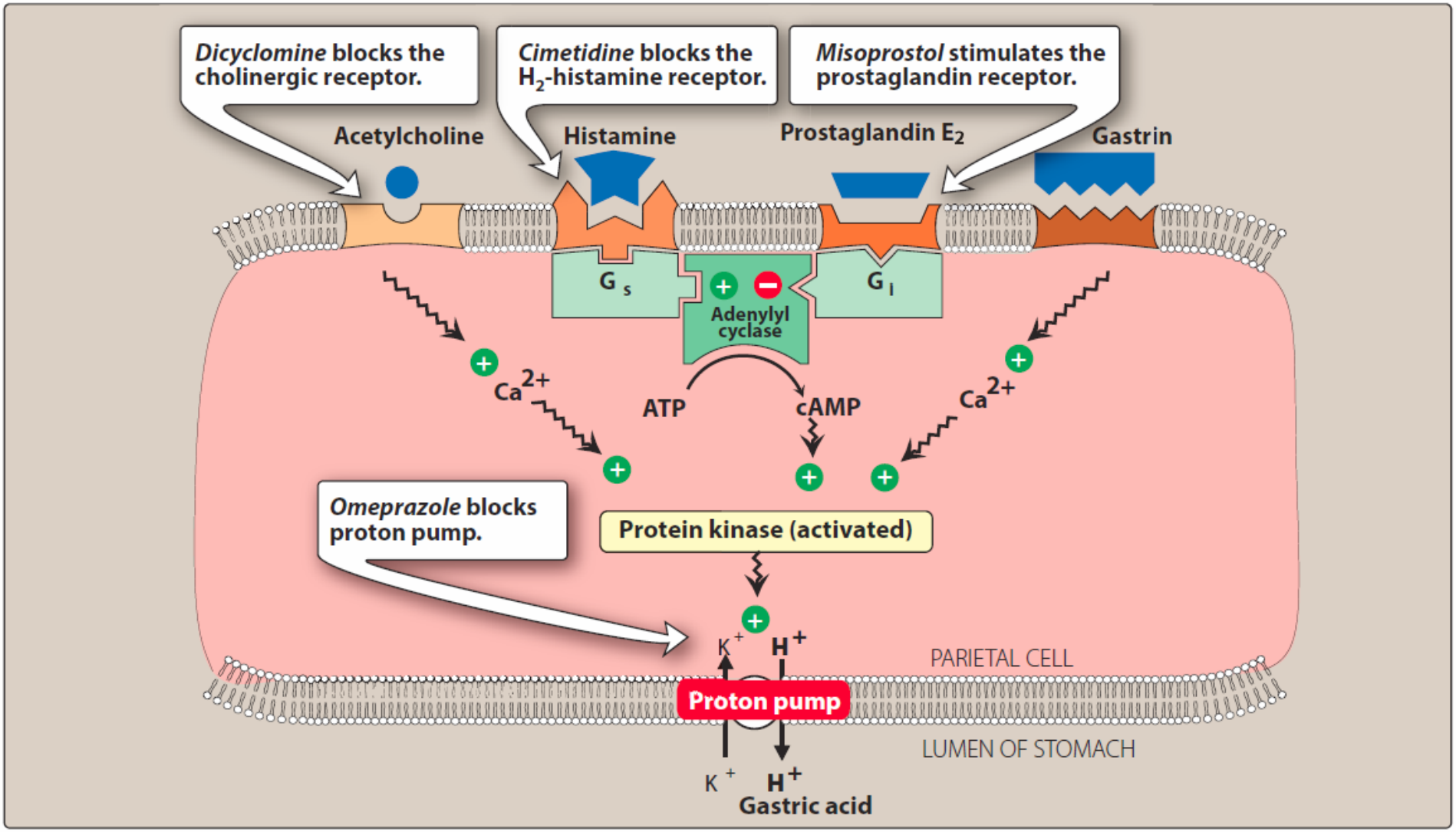


Figure 31.4

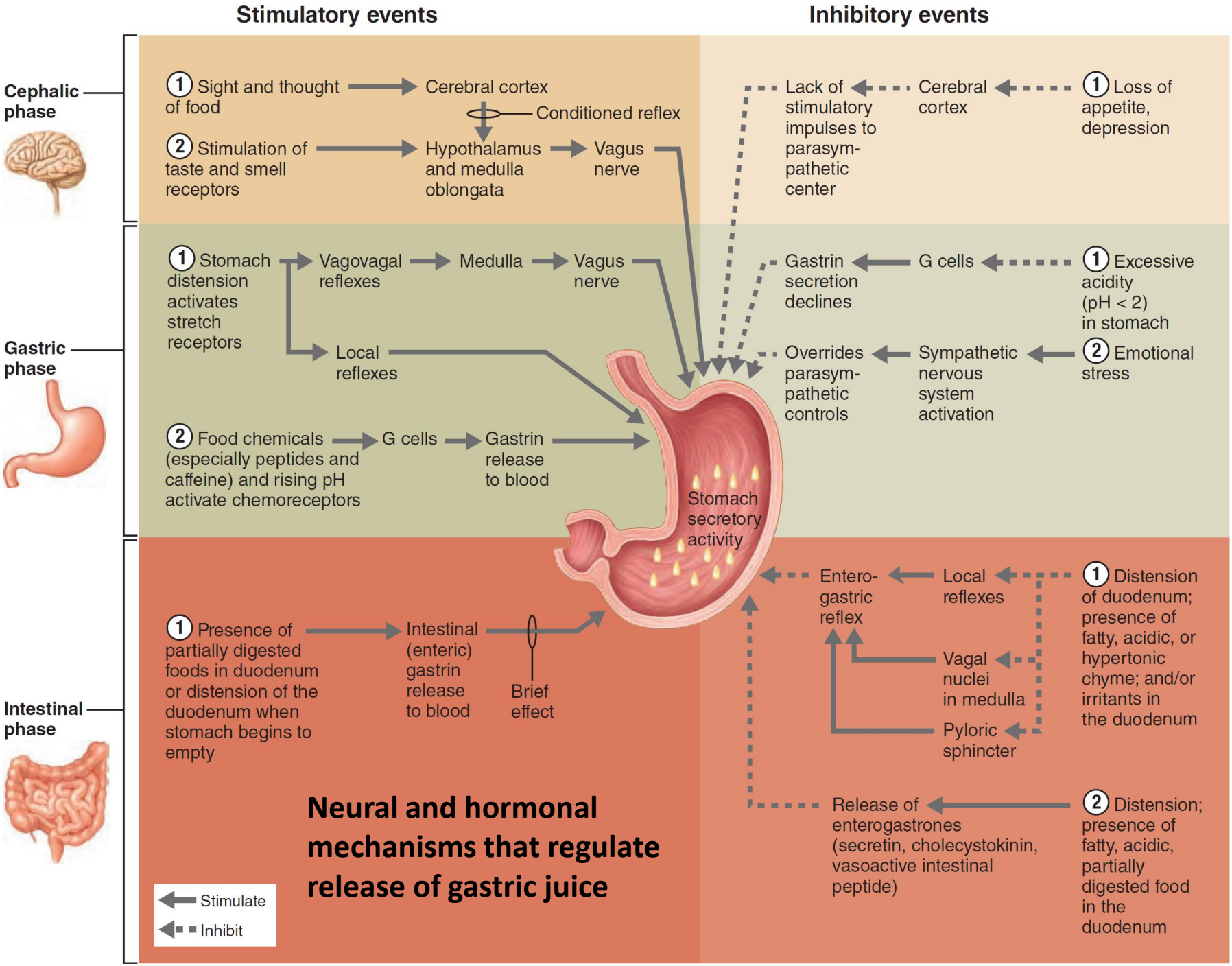
Effects of acetylcholine, histamine, prostaglandin E_2, and gastrin on gastric acid secretion by the parietal cells of stomach. G_s and G_i are membrane proteins that mediate the stimulatory or inhibitory effect of receptor coupling to adenylyl cyclase.

The Stomach

- The mucosal barrier protects the stomach from self-digestion and HCl.
- Protein digestion is initiated in the stomach by activated pepsin and requires acidic conditions (provided by HCl).
- Few substances are absorbed in the stomach

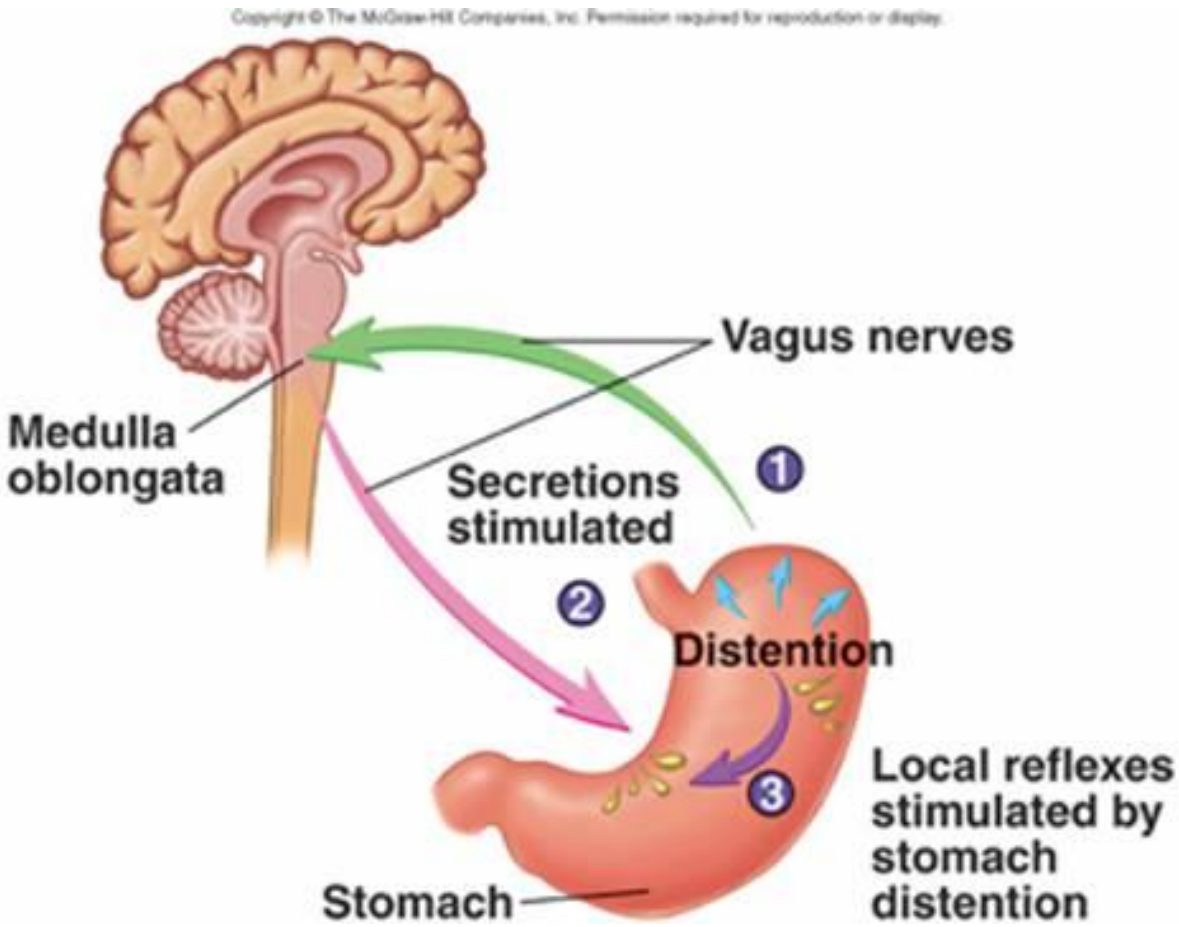
Control of gastric secretory activity in the Stomach

- Controlled by Both nervous and hormonal factors.
- The three phases of gastric secretion are cephalic, gastric, and intestinal.
- Most food-related stimuli acting on the head and stomach (cephalic and gastric, respectively) stimulate gastric secretion.



Neural and hormonal mechanisms that regulate release of gastric juice

Vagovagal reflexes



Control of gastric secretory activity in the Stomach

- Most stimuli acting on the small intestine trigger the enterogastric reflex and release of **Secretin** and **cholecystokinin (CCK):** inhibit gastric secretory activity

- Sympathetic activity also inhibits gastric secretion

Mechanical breakdown in the stomach

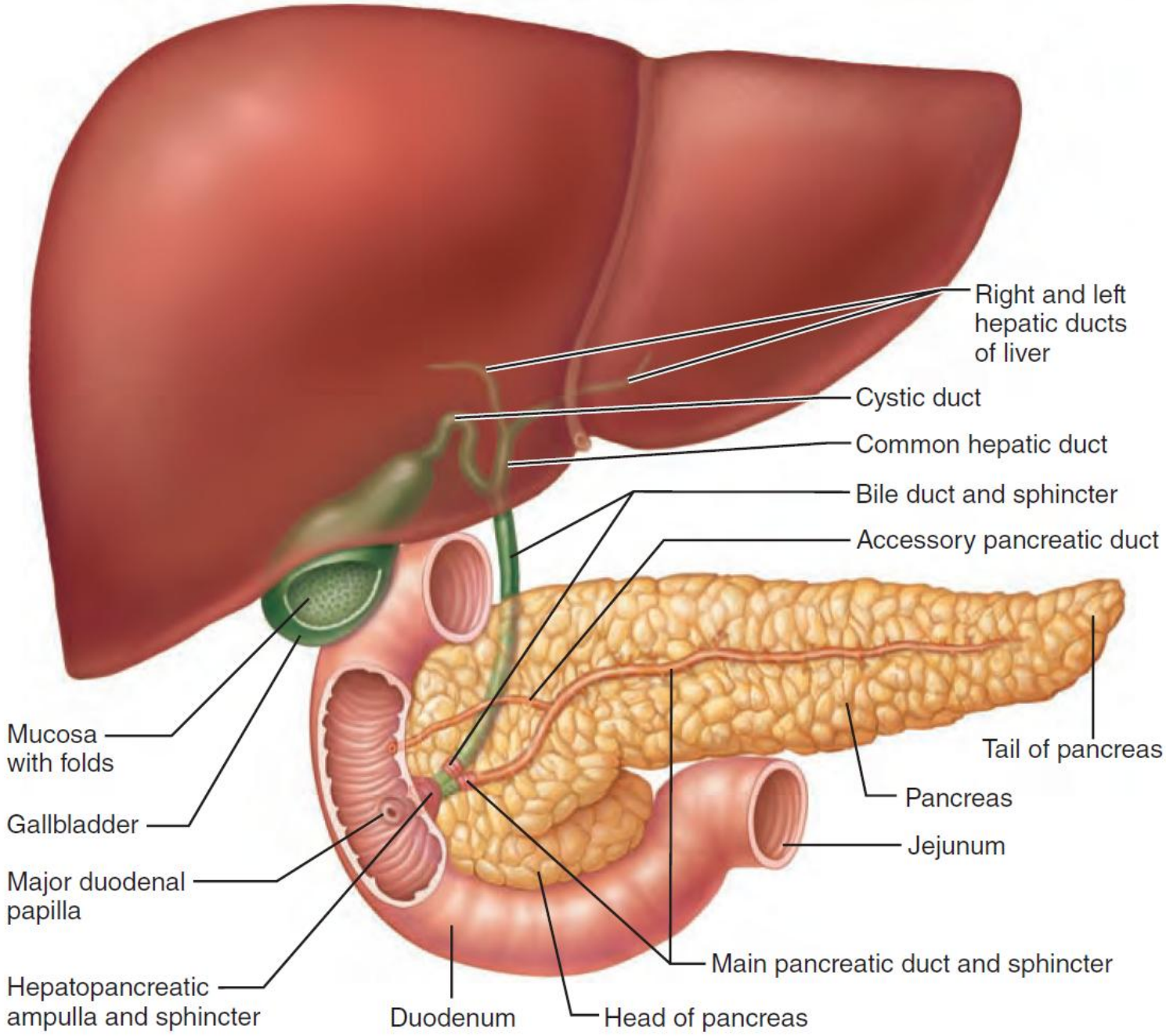
- Triggered by stomach distension and coupled to food propulsion and stomach emptying.
- Food movement into the duodenum is controlled by the pylorus and feedback signals from the small intestine.
- Pacemaker cells in the smooth muscle sheet set the maximal rate of peristalsis

The Small Intestine and Associated Structures

- The small intestine is the major digestive and absorptive organ.
- It extends from the pyloric sphincter to the ileocecal valve.
- **Its three subdivisions are**: the duodenum, jejunum, and ileum.
- The bile duct and pancreatic duct join to form the **hepatopancreatic ampulla** and empty their secretions into the duodenum through the hepatopancreatic sphincter.

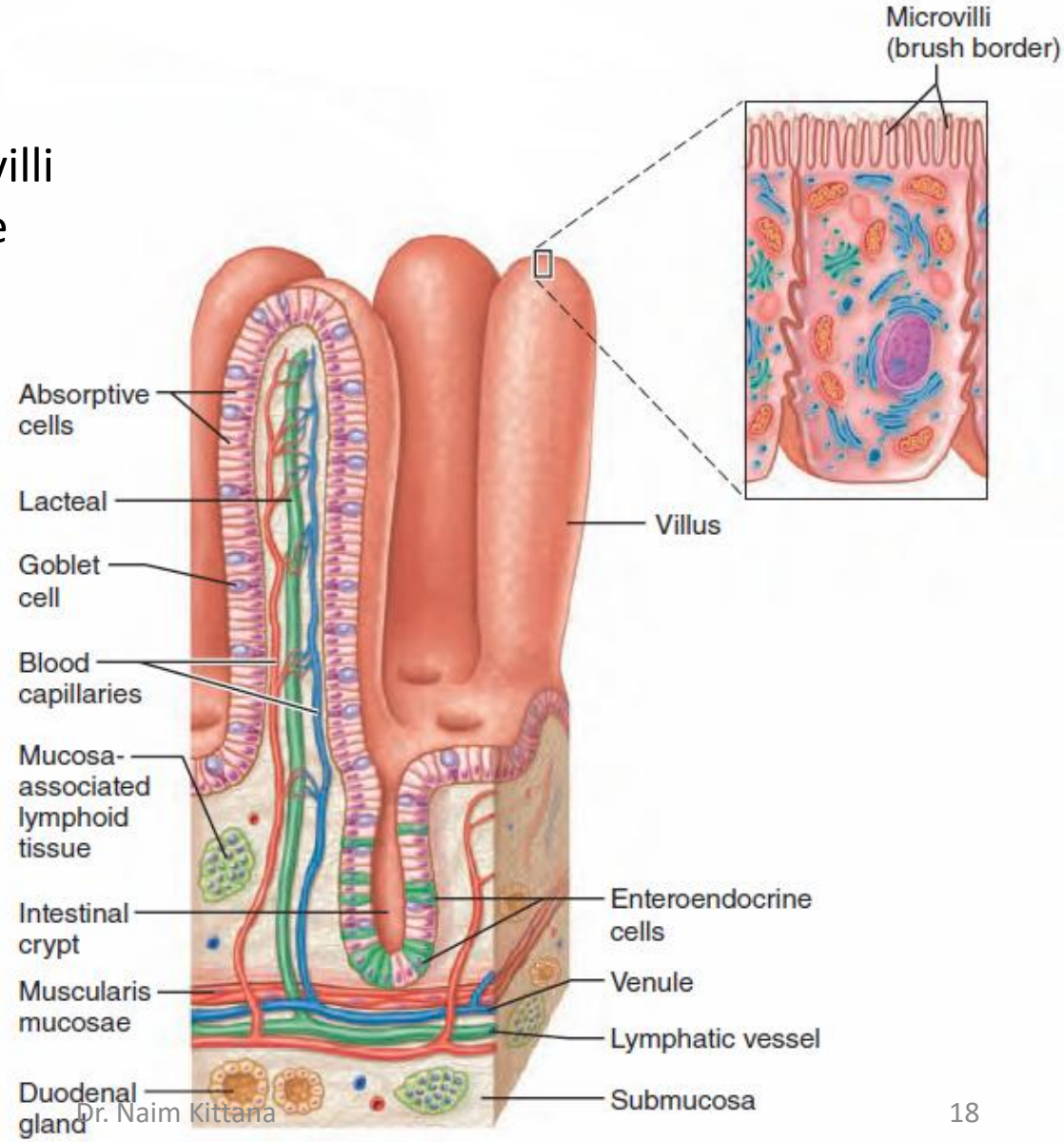
The duodenum of the small intestine, and related organs

Ducts from the pancreas, gallbladder, and liver empty into the duodenum



The Small Intestine and Associated Structures

- Circular folds, villi, and microvilli increase the intestinal surface area for digestion and absorption.
- The duodenal submucosa contains elaborate mucus-secreting duodenal glands.
- The mucosa of the ileum contains Peyer's patches (lymphoid follicles).



The Small Intestine and Associated Structures

- The duodenum is covered not with a serosa but an adventitia.

Intestinal juice

- Slightly alkaline (7.4–7.8)
- Isotonic with blood plasma.
- Largely water but also contains some mucus (secreted both by the duodenal glands and by goblet cells of the mucosa).
- Enzyme-poor because intestinal enzymes are limited to the bound enzymes of the brush border.

The liver

- The structural and functional units of the liver are the liver lobules.
- Blood flowing to and out of the liver via the **hepatic artery** and **hepatic portal vein**
- Stellate macrophages remove debris and hepatocytes remove nutrients.

The liver

- **Function of Hepatocytes:**
  - Process blood-borne nutrients in various ways (e.g., they store glucose as glycogen and use amino acids to make plasma proteins)
  - Store fat-soluble vitamins
  - Play important roles in detoxification, such as ridding the blood of ammonia by converting it to urea
  - Detoxify chemicals and drugs

The liver

- Bile is made continuously by the hepatocytes.
- Bile salts and secretin stimulate bile production.
- The gallbladder, a muscular sac that lies beneath the right liver lobe, stores and concentrates bile.

Bile

Bile is a yellow-green, alkaline solution containing:

- Bile salts
- Bile pigments (**Bilirubin)**
- Cholesterol
- Triglycerides
- Phospholipids (lecithin and others)
- A variety of electrolytes: Of these, *only bile salts* and phospholipids aid the digestive process.

Bile

- Bile salts, primarily cholic and chenodeoxycholic acids, are cholesterol derivatives.

- Their role is to emulsify fats—break them down into smaller pieces and distribute them throughout the watery intestinal contents, just as a dish detergent breaks up a pool of fat drippings in a roasting pan.

Bile

- Bile salts physically separate large fat globules entering the small intestine into millions of smaller, more accessible fatty droplets that provide large surface areas for the fat-digesting enzymes to work on.

- Bile salts also facilitate fat and cholesterol absorption.

- In addition, they help solubilize cholesterol, both that contained in bile and that entering the small intestine in food.

Enterohepatic circulation conserves bile salts

- Many substances secreted in bile leave the body in feces
- But bile salts are not among them.
- Instead, a recycling mechanism called the enterohepatic circulation conserves bile salts.

Enterohepatic circulation conserves bile salts

- In this process, bile salts are:

(1) reabsorbed into the blood by the ileum

(2) returned to the liver via the hepatic portal blood

(3) Re-secreted in newly formed bile.

- This pool of bile salts re-circulates two or three times for a single meal

Bilirubin

- A waste product of the heme of hemoglobin formed during the breakdown of worn-out erythrocytes.
- The globin and iron parts of hemoglobin are saved and recycled
- bilirubin is absorbed from the blood by liver cells, excreted into bile, and metabolized in the small intestine by resident bacteria.

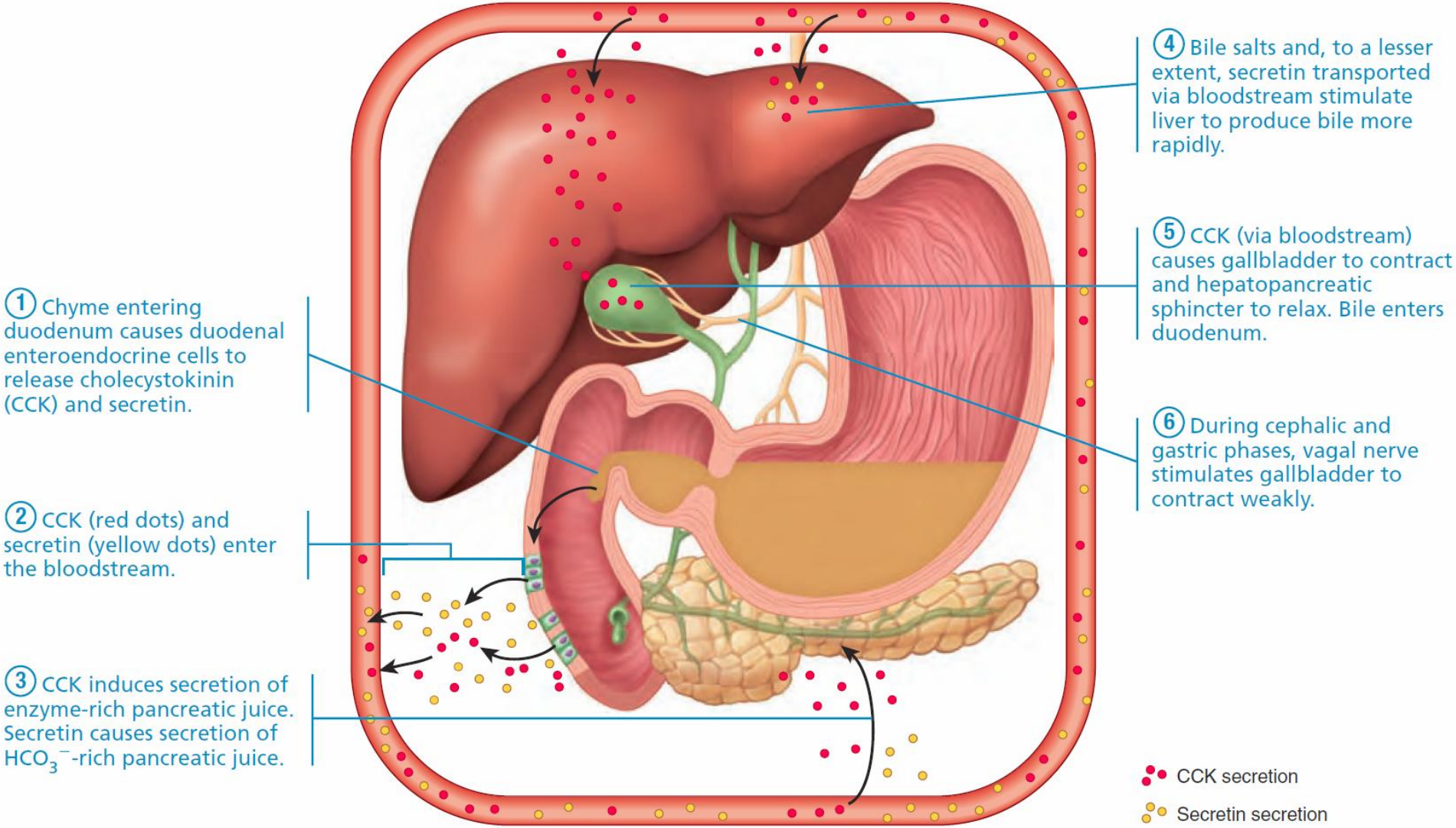
Bilirubin

- **Stercobilin** a breakdown product of biliruben's, gives feces a brown color.
- In the absence of bile, feces are gray-white and have fatty streaks because no fats are digested or absorbed.

The liver

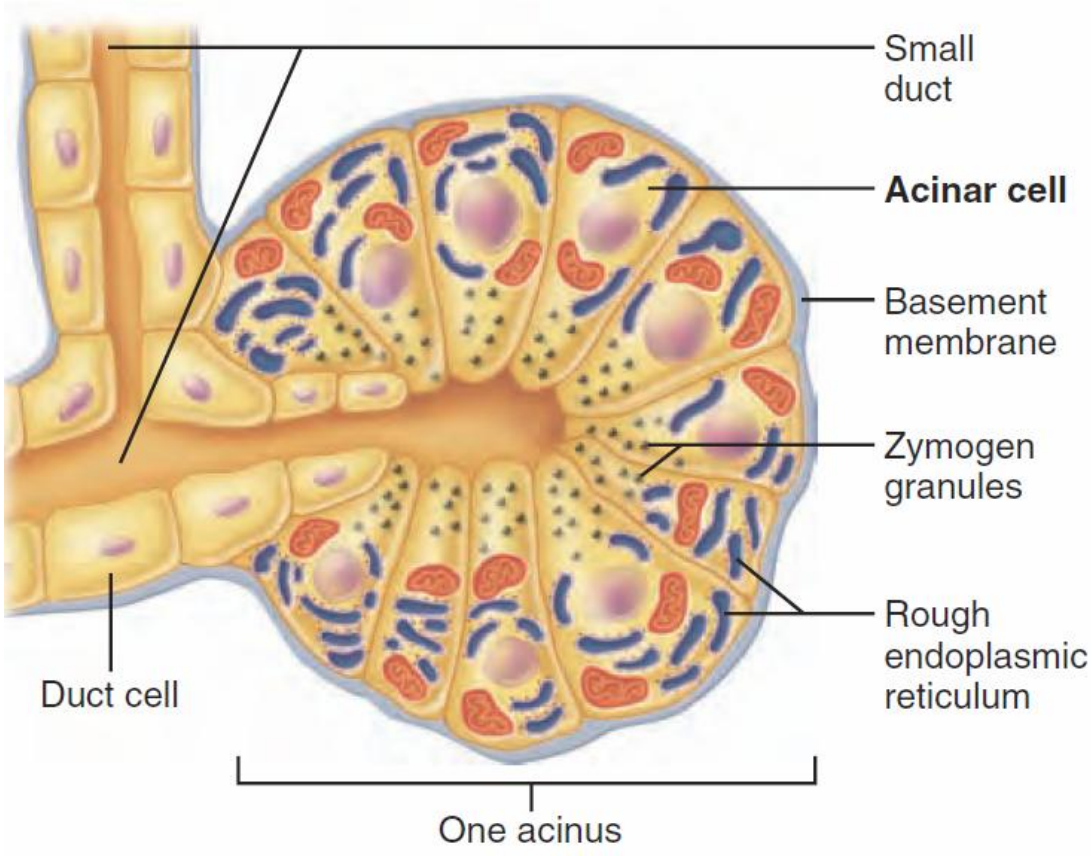
- Cholecystokinin released by the small intestine stimulates the gallbladder to contract and the hepatopancreatic sphincter to relax, allowing bile (and pancreatic juice) to enter the duodenum

Mechanisms promoting secretion and release of bile and pancreatic juice



The Pancreas

- Within the pancreas are the **acini** (singular: acinus): clusters of secretory acinar cells surrounding ducts



Composition of Pancreatic Juice

It consists mainly of

- Water
- Enzymes
- Electrolytes (primarily bicarbonate ions).

- The acinar cells produce the enzyme-rich component of pancreatic juice.

- The epithelial cells lining the smallest pancreatic ducts release the bicarbonate ions that make it alkaline (about pH 8).

Composition of Pancreatic Juice

- Normally, the amount of HCl produced in the stomach is exactly balanced by the amount of bicarbonate (HCO3-) secreted by the pancreas
- As HCO3- is secreted into the pancreatic juice, H+ enters the blood.
- Consequently, the pH of venous blood returning to the heart remains relatively unchanged because acidic blood draining from the pancreas neutralizes the alkaline blood draining from the stomach.
- The high pH of pancreatic fluid helps neutralize acid chyme entering the duodenum and provides the optimal environment for intestinal and pancreatic enzymes.

Composition of Pancreatic Juice

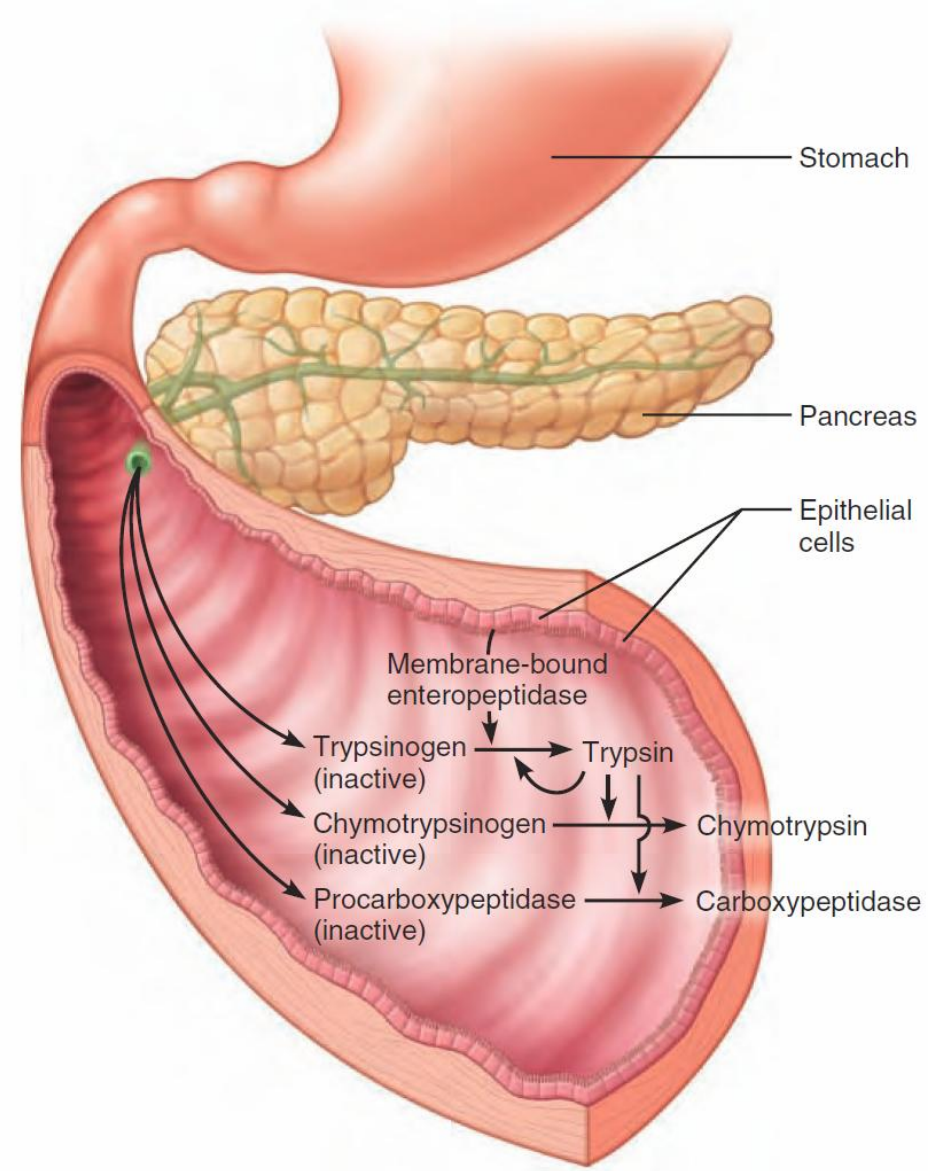
- Like pepsin of the stomach, pancreatic proteases (protein-digesting enzymes) are produced and **released in inactive forms**, which are activated in the duodenum, where they do their work.

- This protects the pancreas from digesting itself.

- For example, within the duodenum, **enteropeptidase (formerly** called enterokinase), an intestinal brush border protease, activates trypsinogen to **trypsin.**

Composition of Pancreatic Juice

- **Trypsin activates** more trypsinogen and two other pancreatic proteases:
  - Procarboxypeptidase into **Carboxypeptidase**
  - Chymotrypsinogeninto C**hymotrypsin**



Composition of Pancreatic Juice

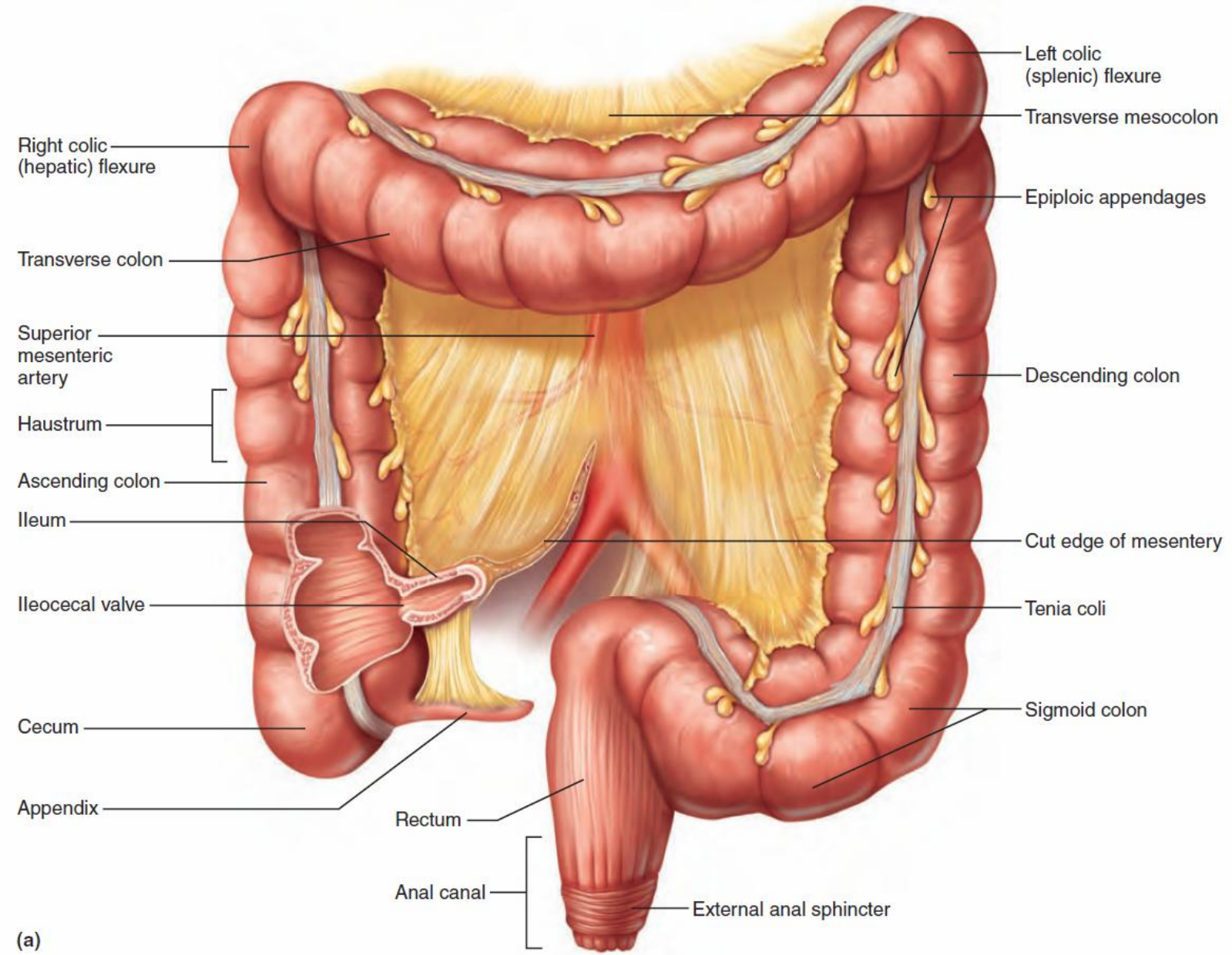
- Other pancreatic enzymes—**amylase, lipases, and nucleases—** are secreted in active form, but require that ions or bile be present in the intestinal lumen for optimal activity.

The Large Intestine

The subdivisions of the large intestine are:

- the cecum (and appendix)
- Colon (ascending, transverse, descending, and sigmoid portions),
- Rectum
- Anal canal: it opens to the body exterior at the anus

Gross anatomy of the large intestine



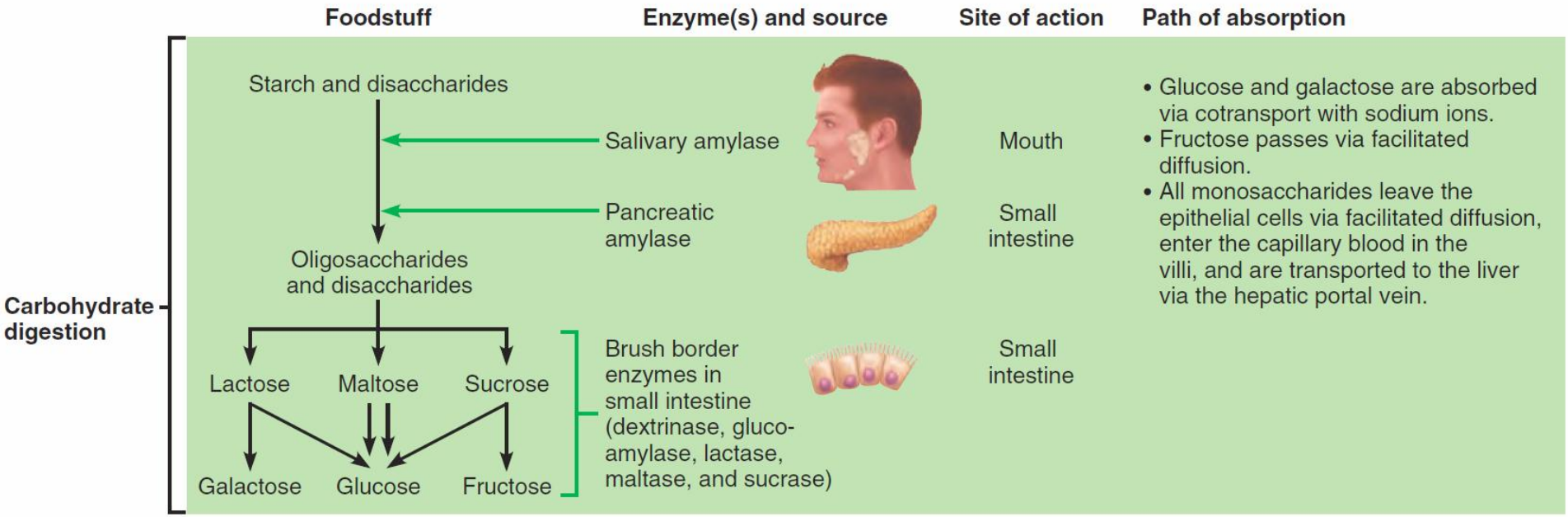
The major functions of the large intestine

- Absorption of water, some electrolytes, and vitamins made by enteric bacteria, and defecation (evacuation of food residues from the body).
- The defecation reflex is triggered when feces enter the rectum.
- It involves parasympathetic reflexes leading to contraction of the rectal walls

The major functions of the large intestinal normal flora

- Synthesize B complex vitamins and vitamin K (the liver needs to produce several clotting proteins)
- Metabolize some host-derived molecules (mucin, heparin, and hyaluronic acid)
- Ferment some of the indigestible carbohydrates (cellulose, xylan, and others),
- Releasing irritating acids and a mixture of gases (including dimethyl sulfide, H2, N2, CH4, and CO2)
- Suppress the growth of pathogenic bacteria

Flowchart of digestion and absorption of foodstuffs



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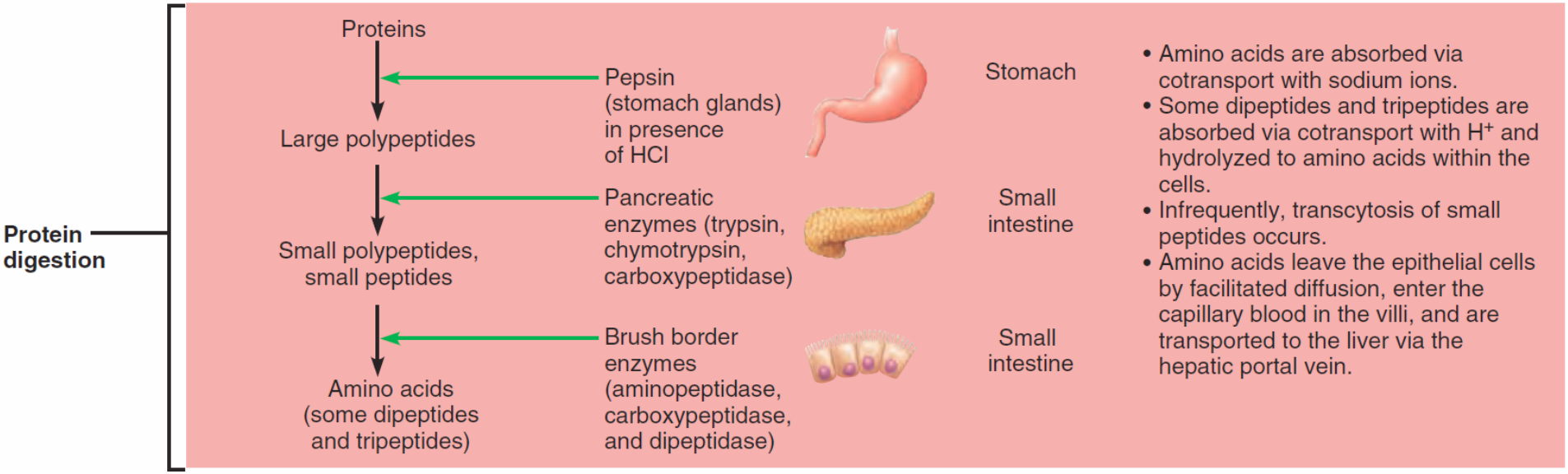

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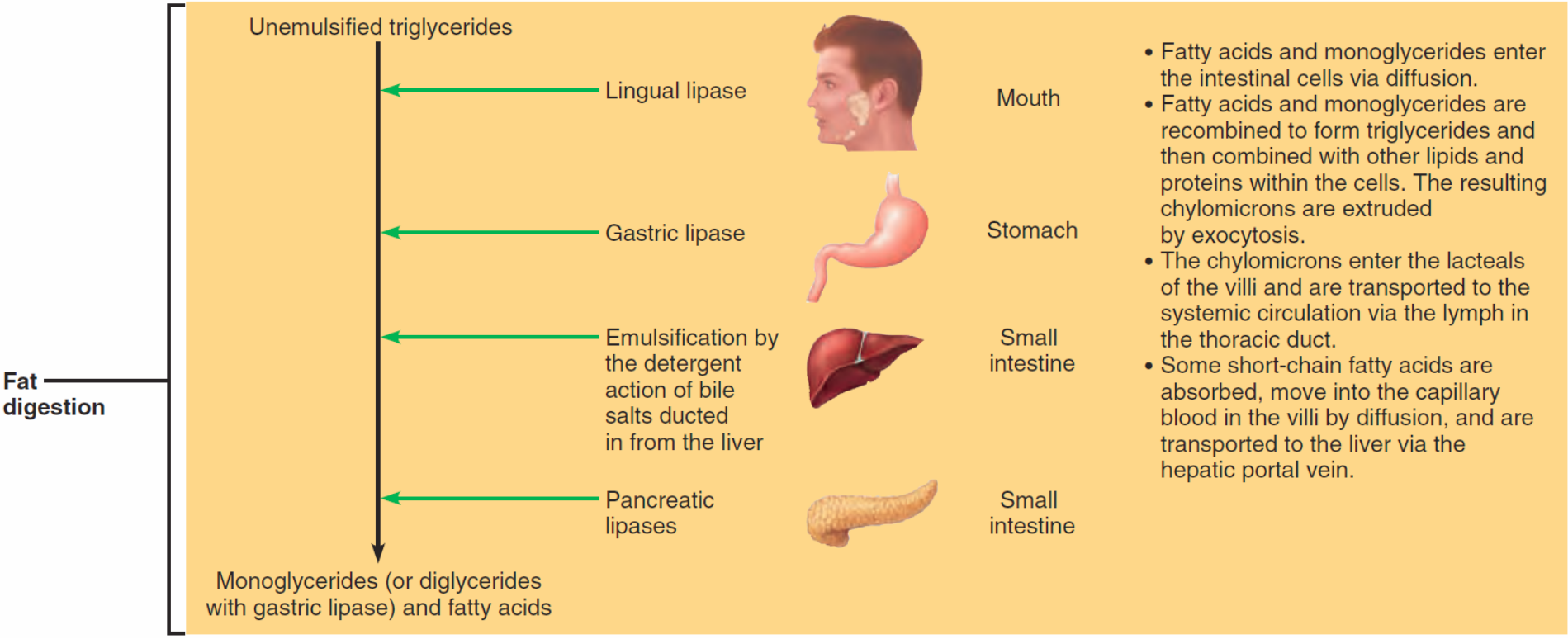

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