Digestive System

- The alimentary canal or gastrointestinal (GI) tract **digests and absorbs food**

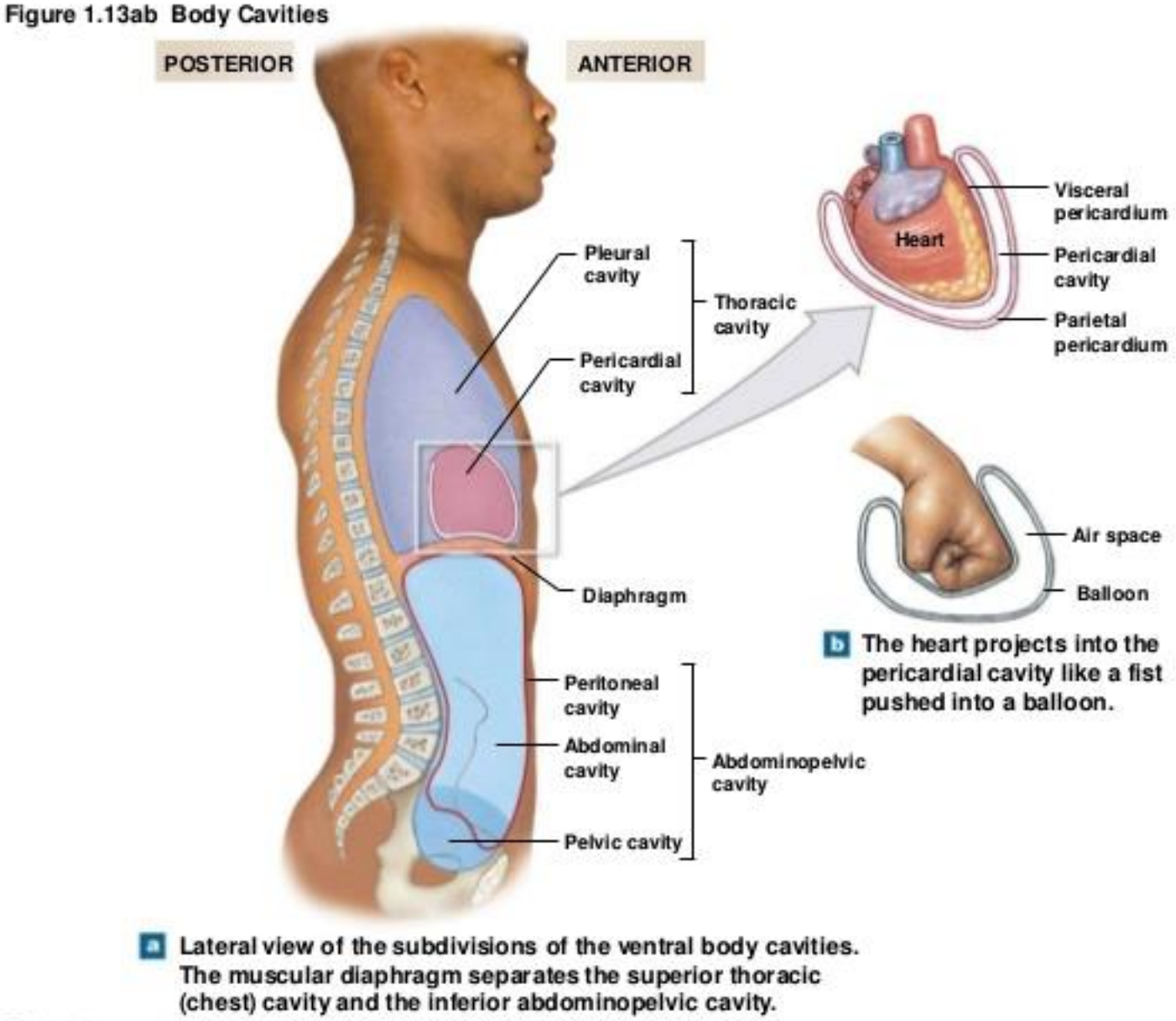
- **Alimentary canal** – mouth, esophagus, stomach, small intestine, and large intestine

- **Accessory digestive organs** – teeth, tongue, gallbladder, salivary glands, liver, and pancreas

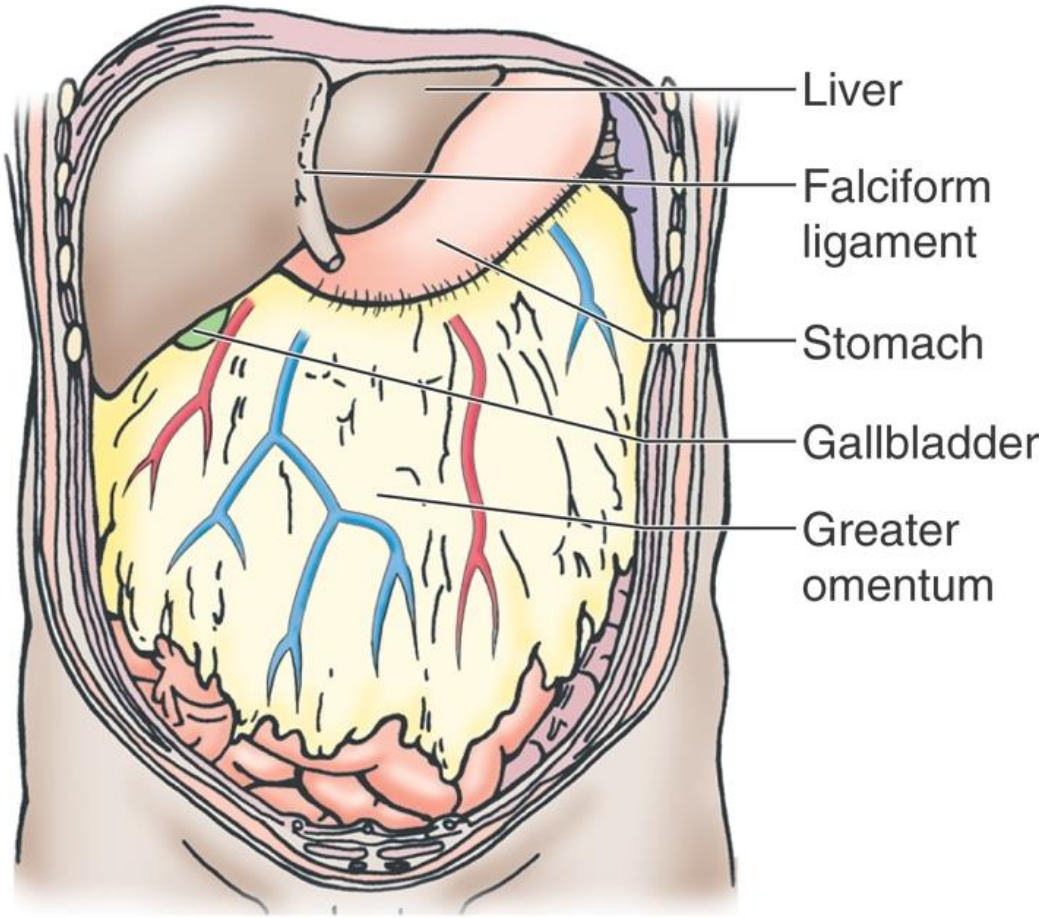
Gastrointestinal Tract Activities

- **Ingestion** – taking food into the digestive tract
- **Propulsion** – **swallowing and peristalsis**
  - Peristalsis – waves of contraction and relaxation of muscles in the organ walls
- **Mechanical digestion** – chewing, mixing, and churning food
- **Chemical digestion** – catabolic breakdown of food
- **Absorption** – movement of nutrients from the GI tract to the blood or lymph
- **Defecation** – elimination of indigestible solid wastes

Peritoneal Cavity – lateral view

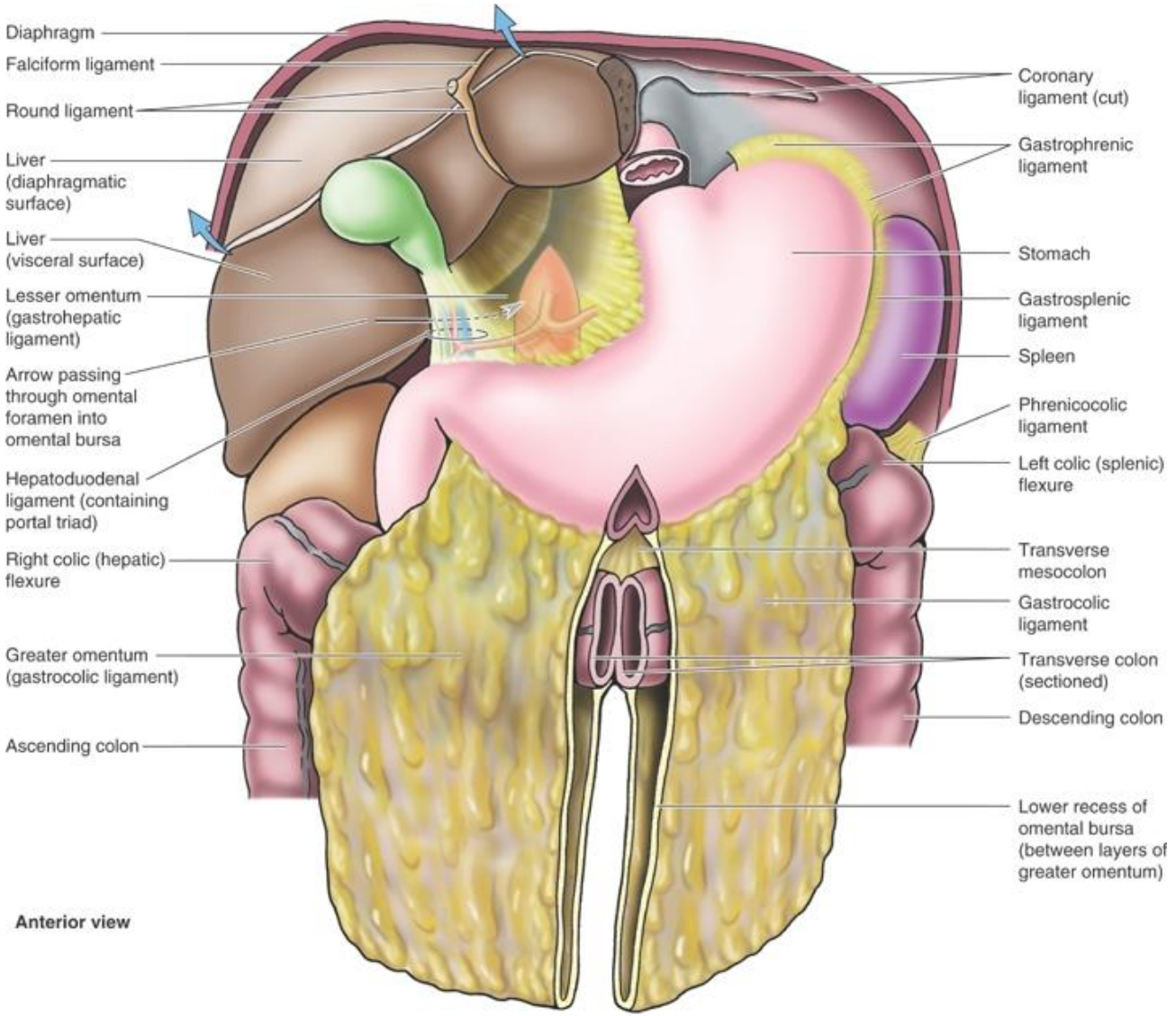


Peritoneal Cavity – Anterior View

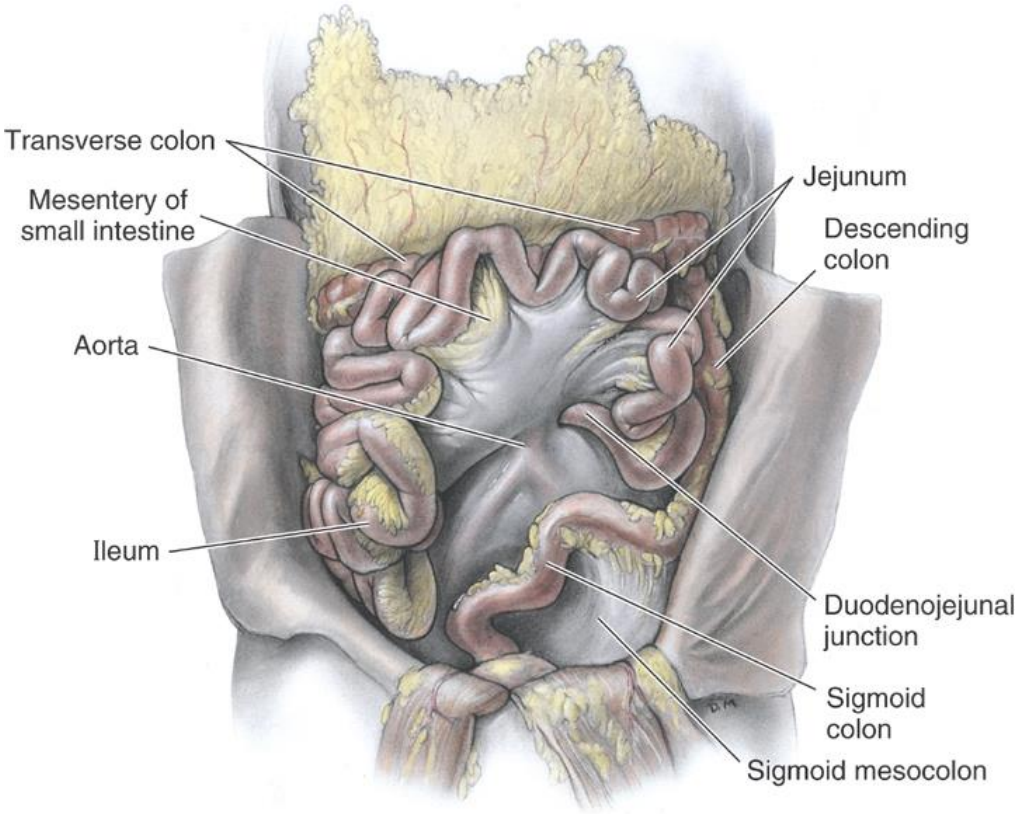


Anterior view

Greater and Lesser Omentum



Mesentery

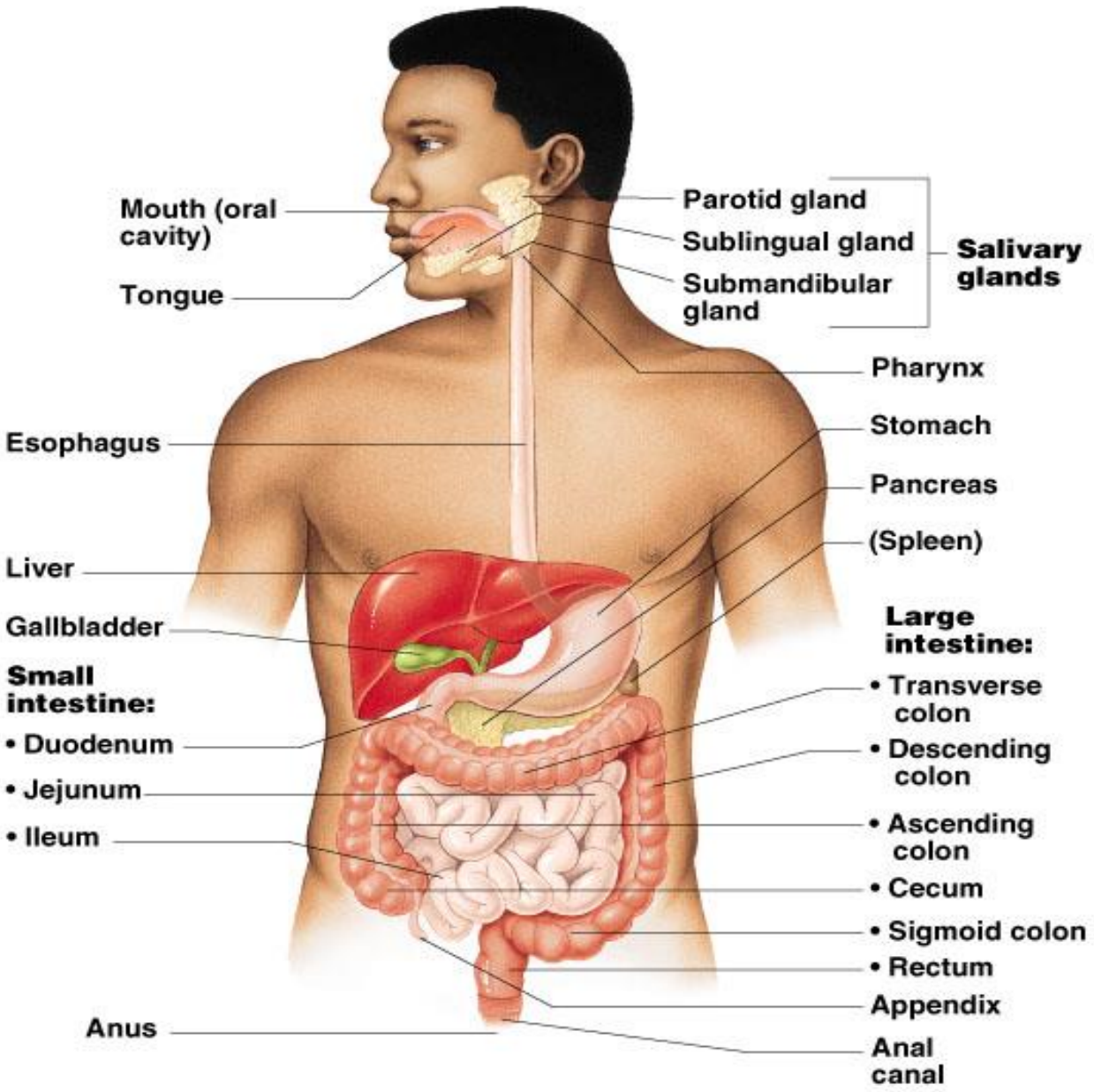


Anterior view

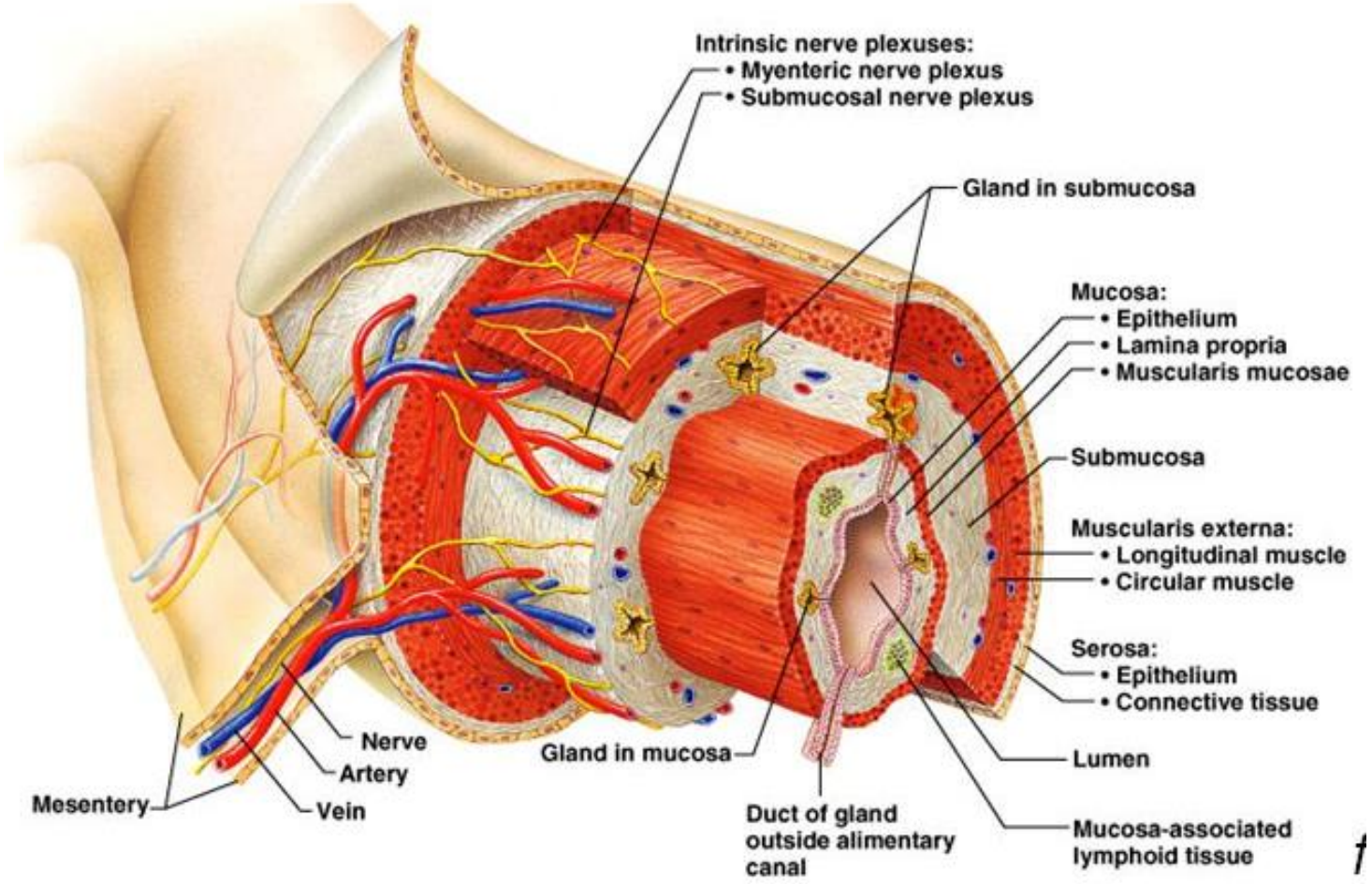
The **mesentery** is an organ that attaches the intestines to the posterior abdominal wall in humans

Organs of the Digestive System

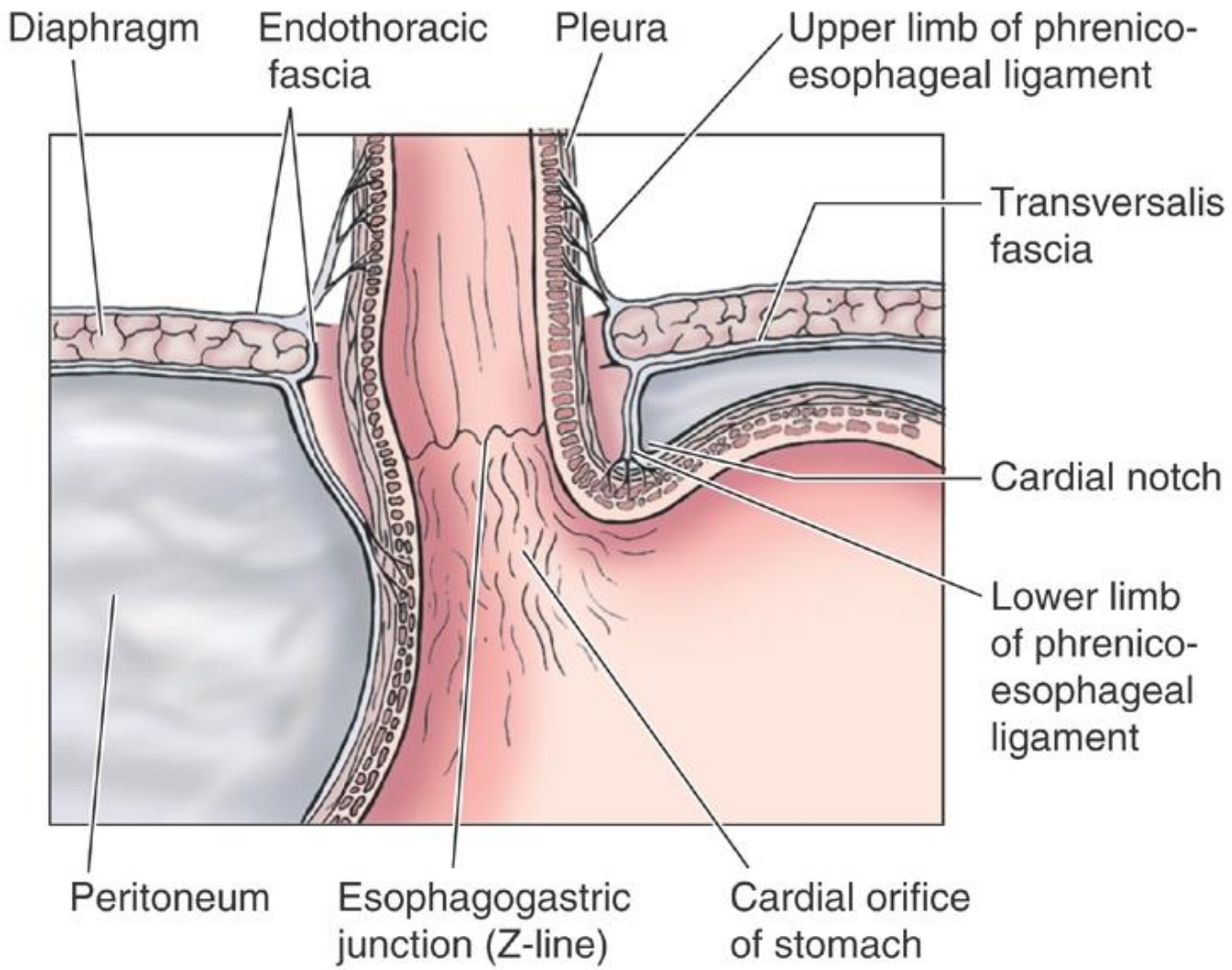
- Mouth
- teeth
- Salivary glands
- Pharynx
- Esophagus
- Stomach
- Liver
- Gallbladder (GB)
- Pancreas
- Small intestine
- Large intestine
- Rectum
- Anus



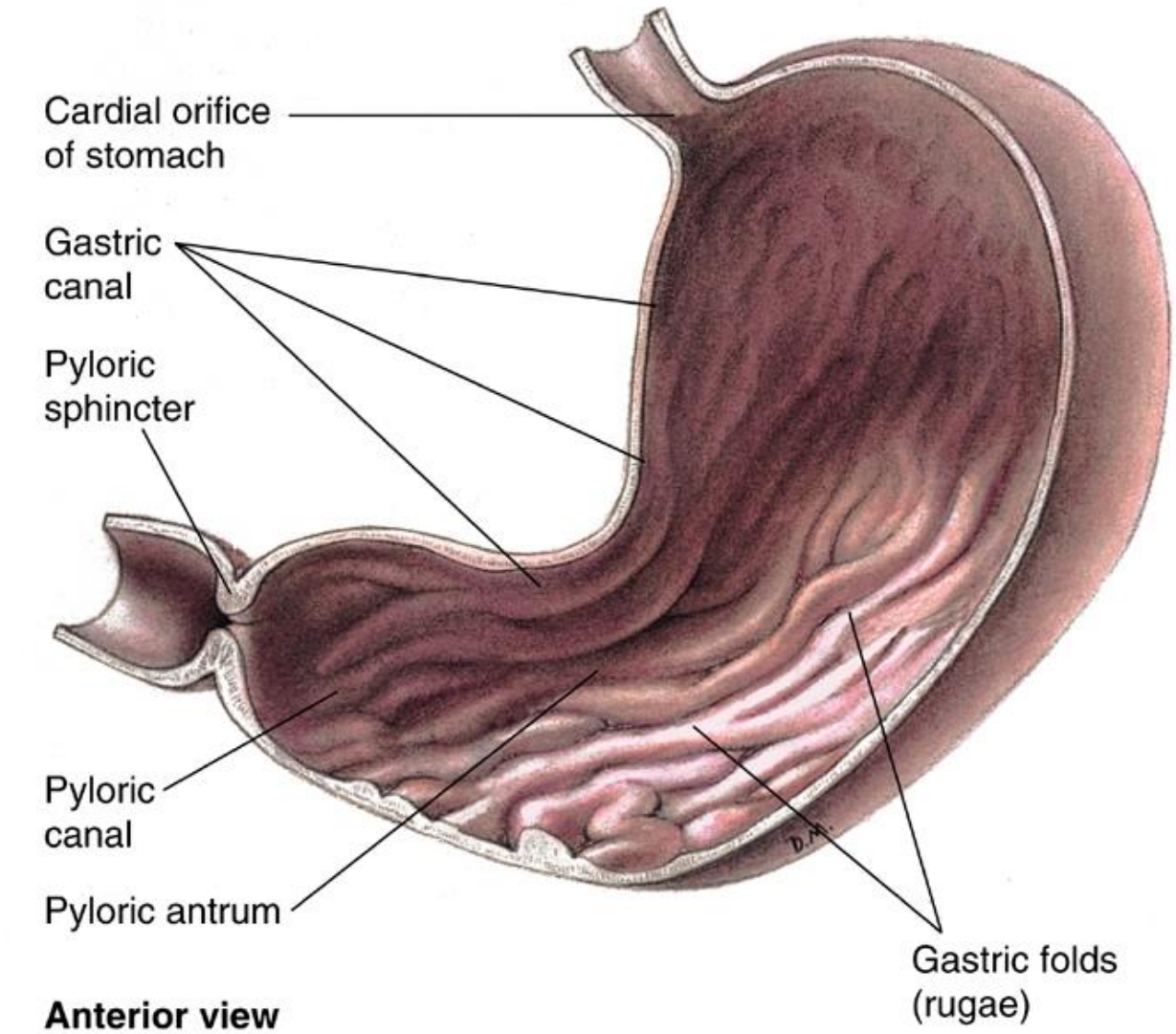
- From esophagus to the anal canal the walls of the GI tract have the same four tunics
- From the lumen to outward they are the:
  - Mucosa
  - Sub Mucosa
  - Muscularis externa
  - Serosa

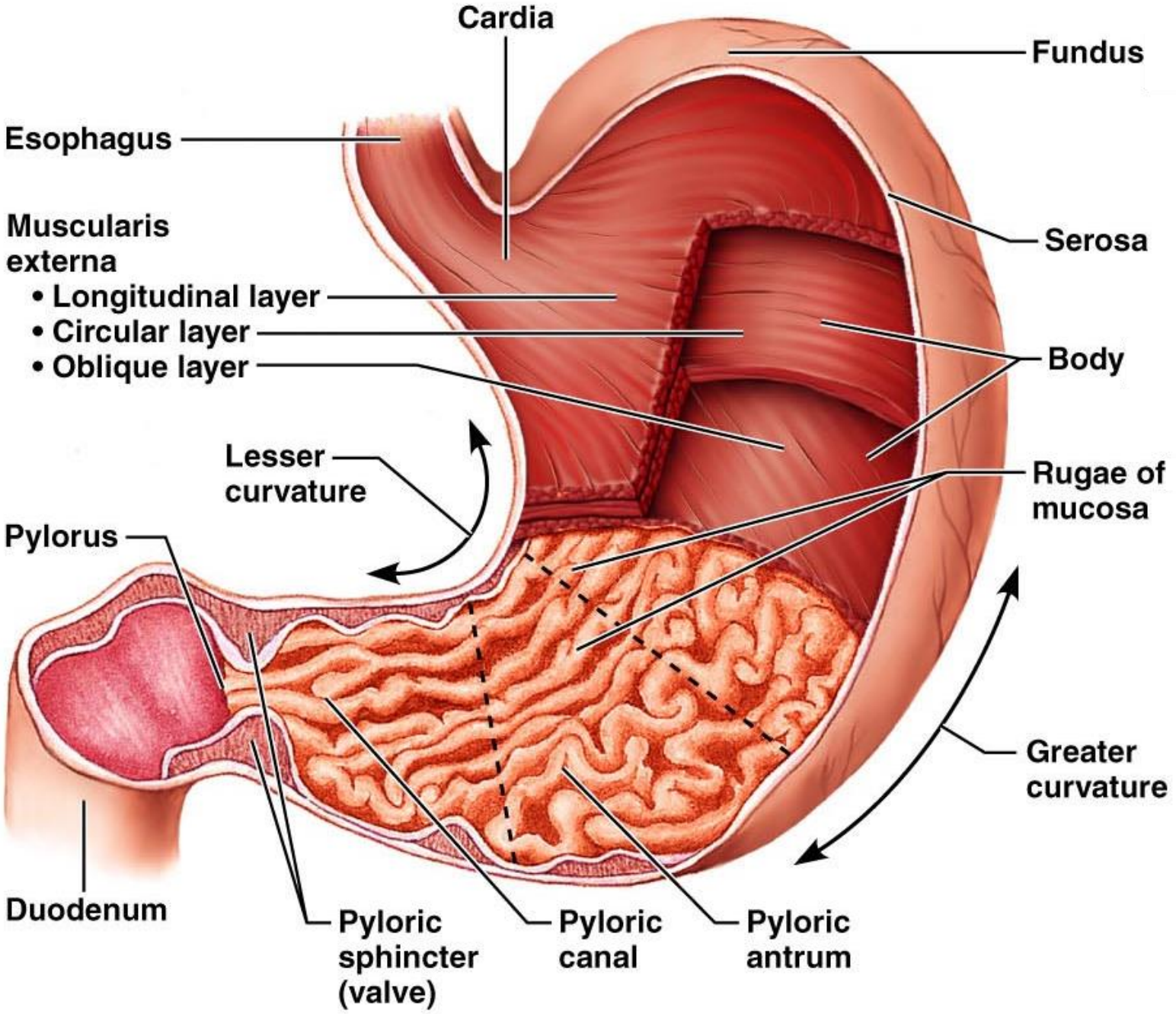


Entrance to Stomach (Cardiac Sphincter)

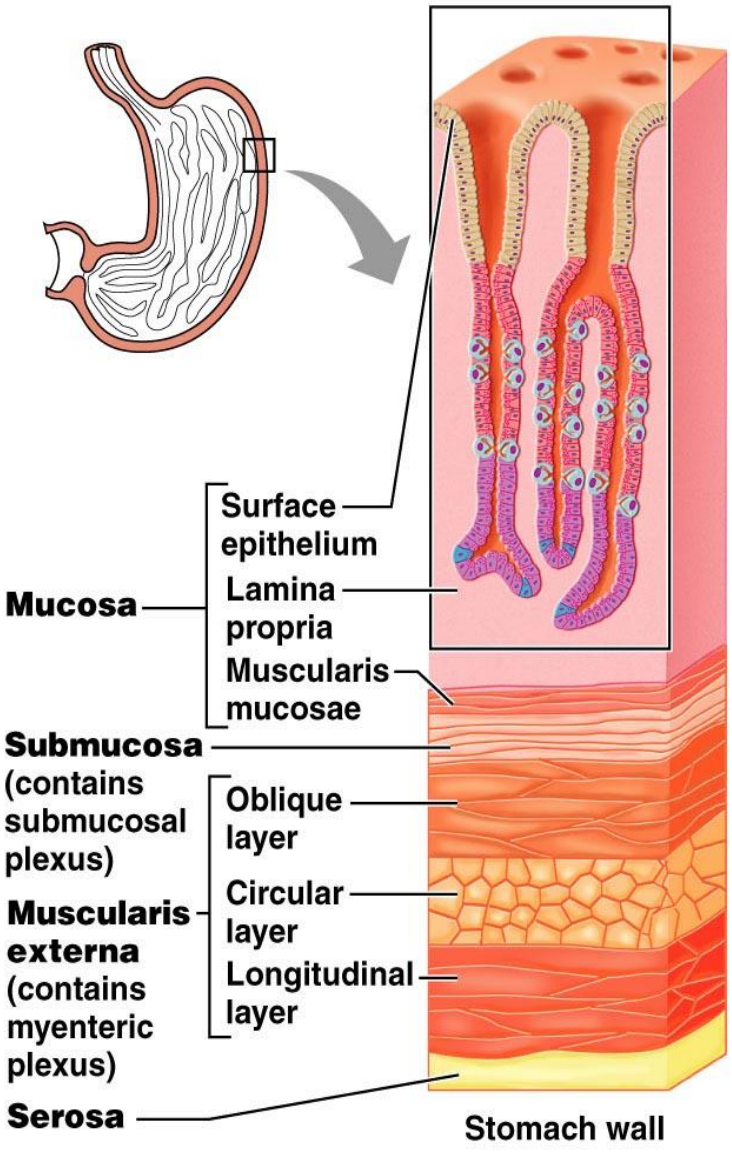


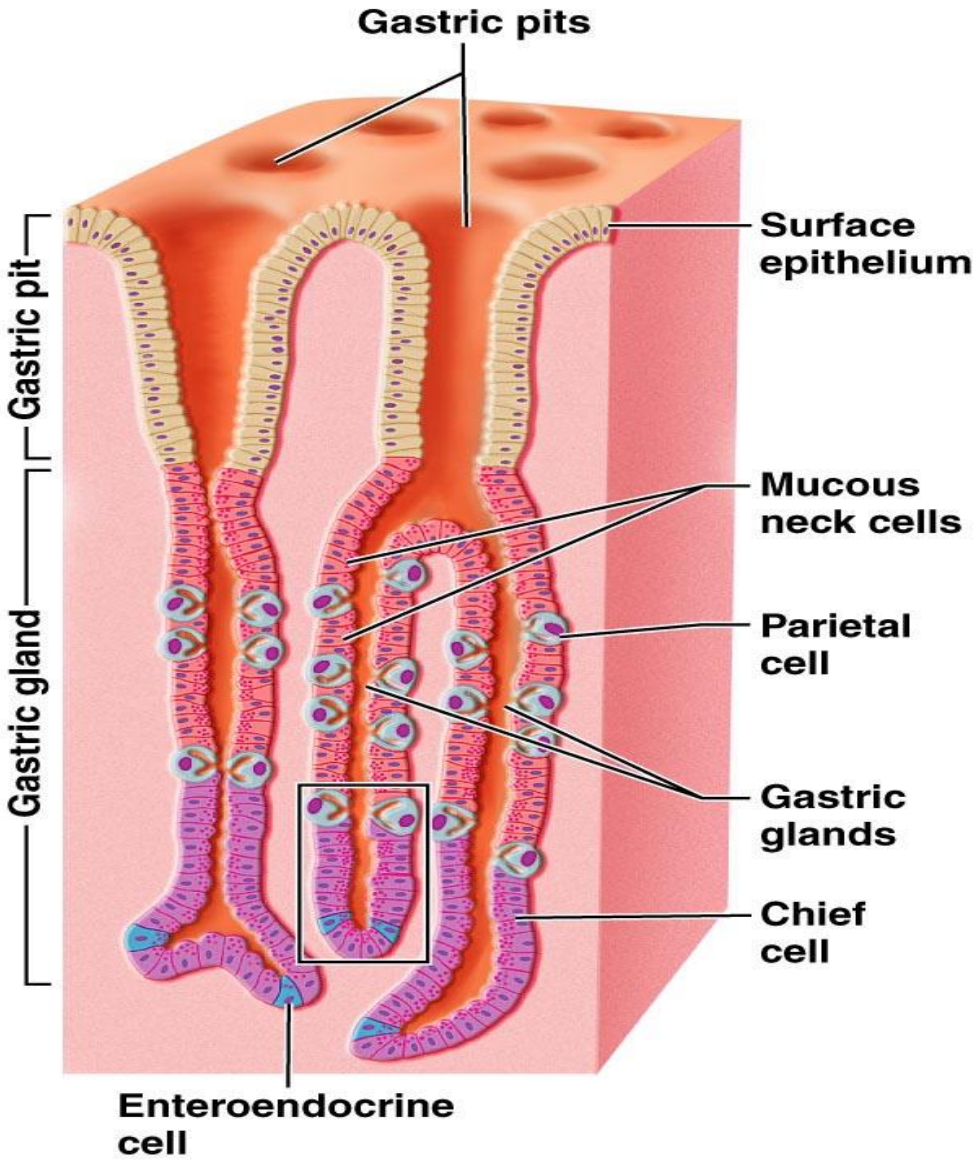
Anatomy of the Stomach



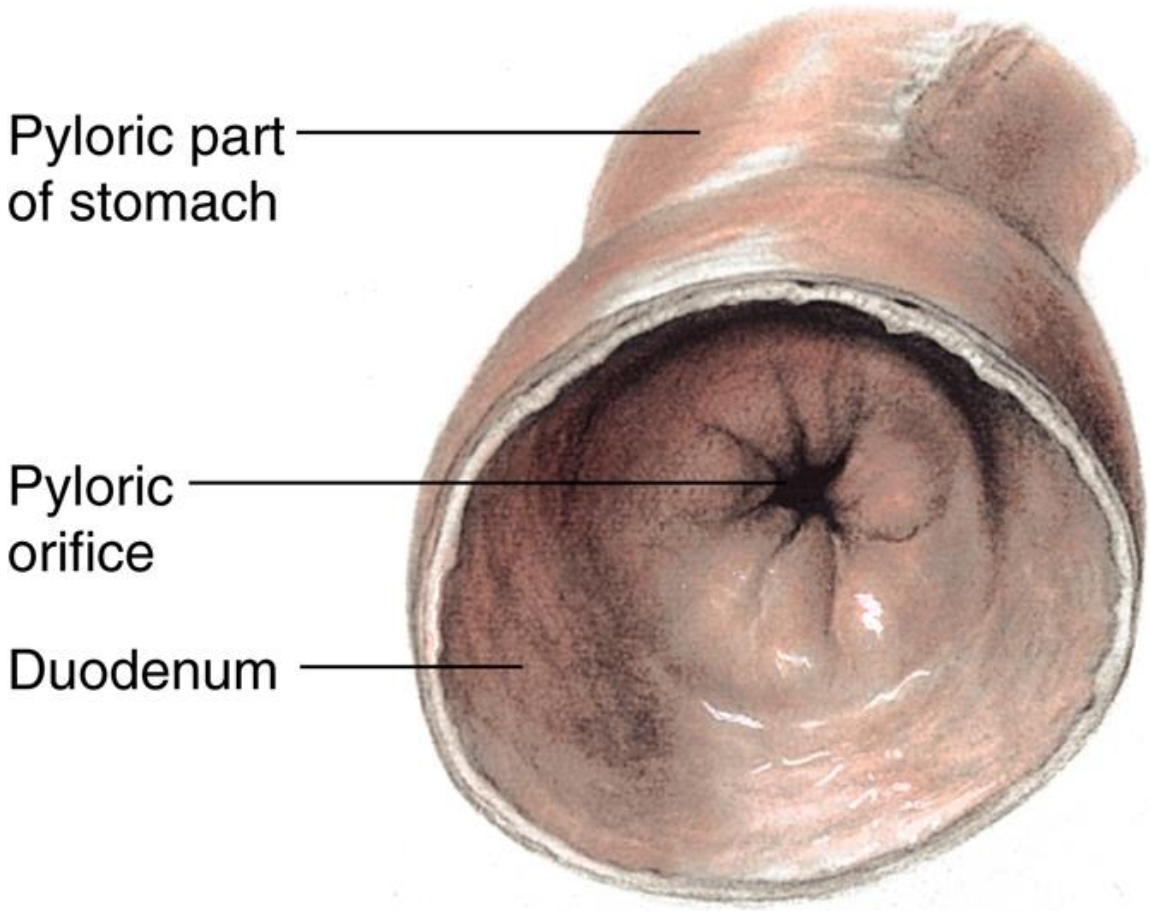

Cardia
Fundus
Esophagus
Muscularis externa
• Longitudinal layer
• Circular layer
• Oblique layer
Serosa
Body
Lesser curvature
Rugae of mucosa
Pylorus
Greater curvature
Duodenum
Pyloric sphincter (valve)
Pyloric canal
Pyloric antrum

Microscopic Anatomy of the Stomach

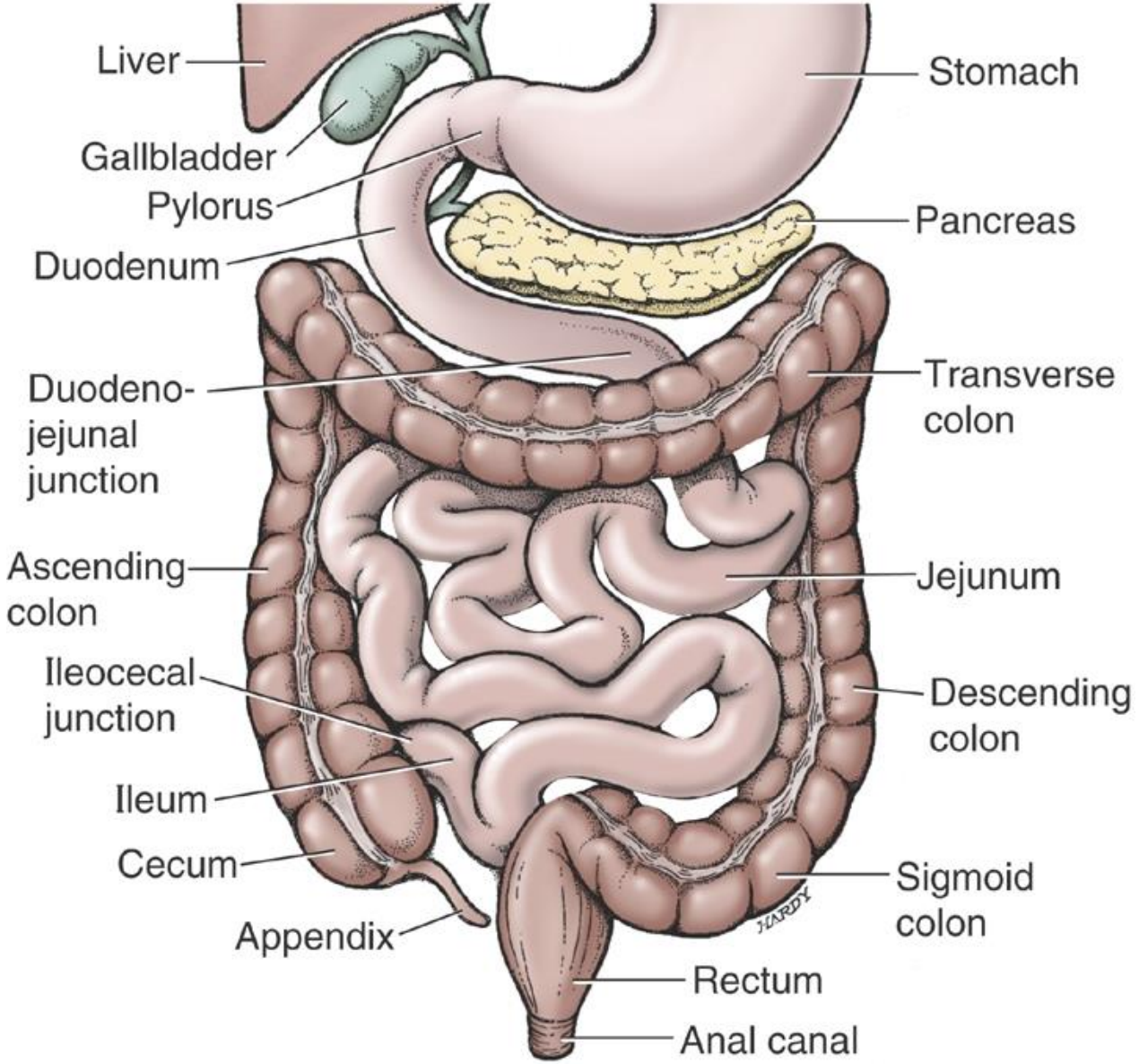




Pyloric Sphincter

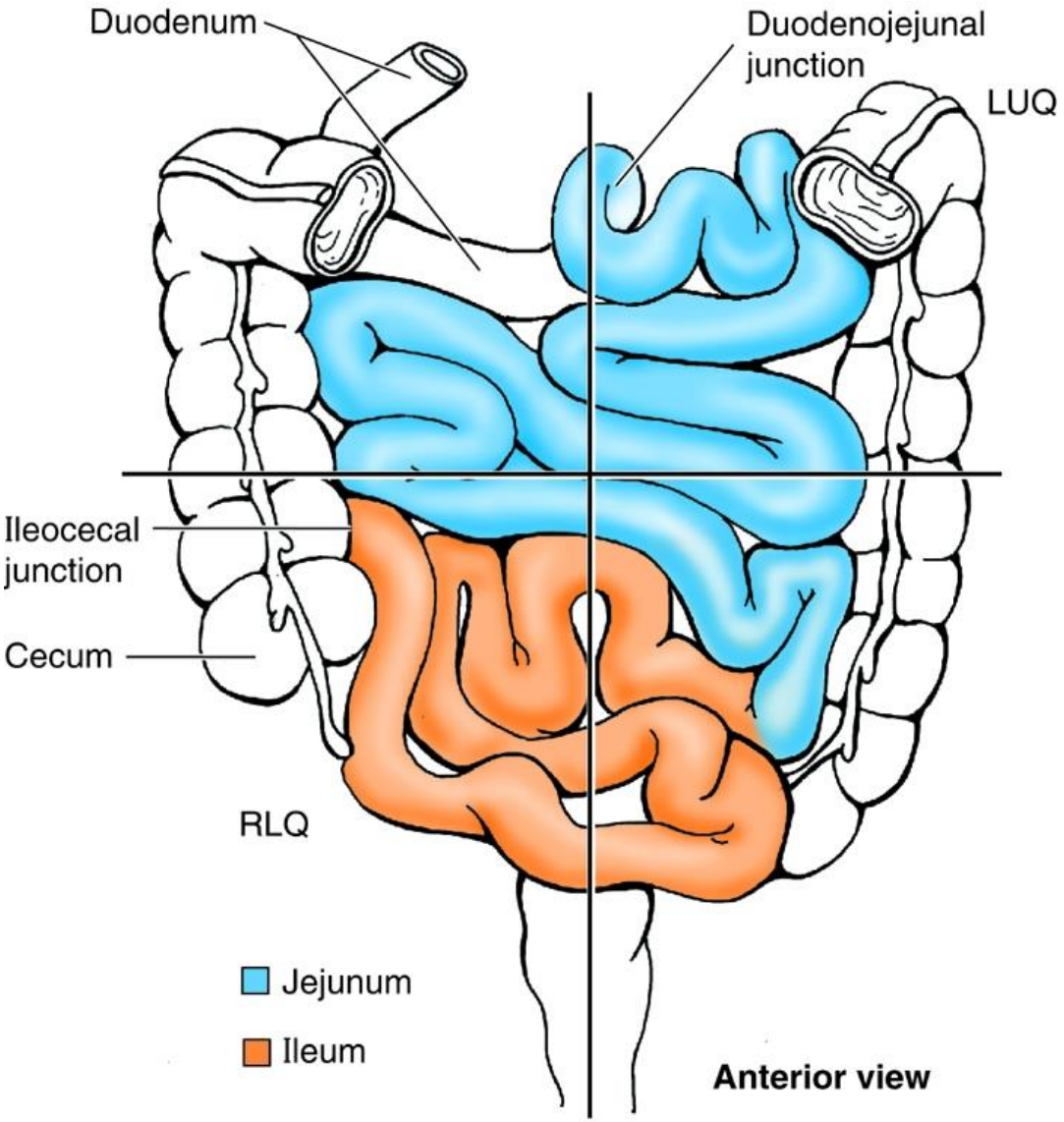


Internal (lateral) view from duodenum

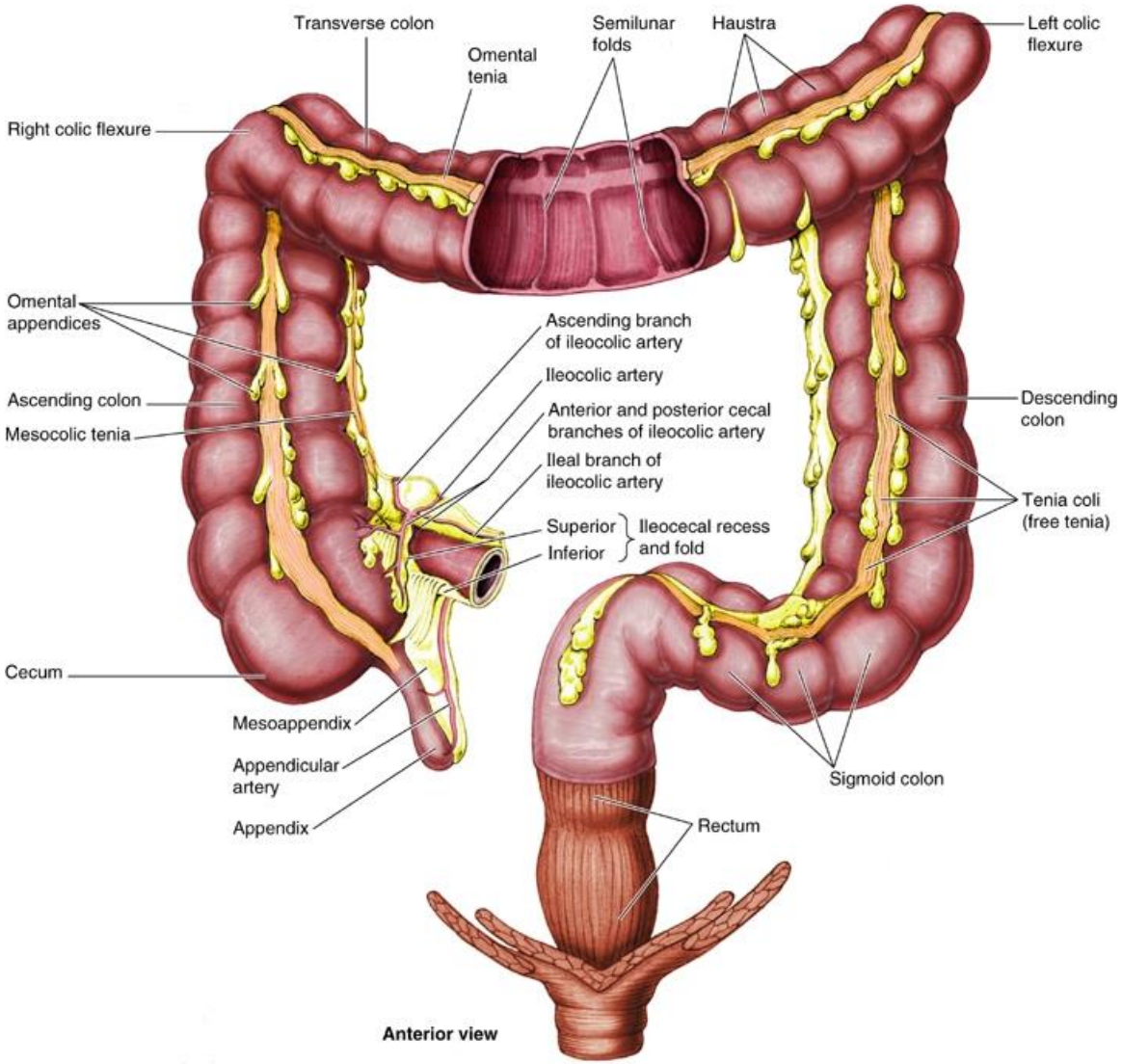


Anterior view

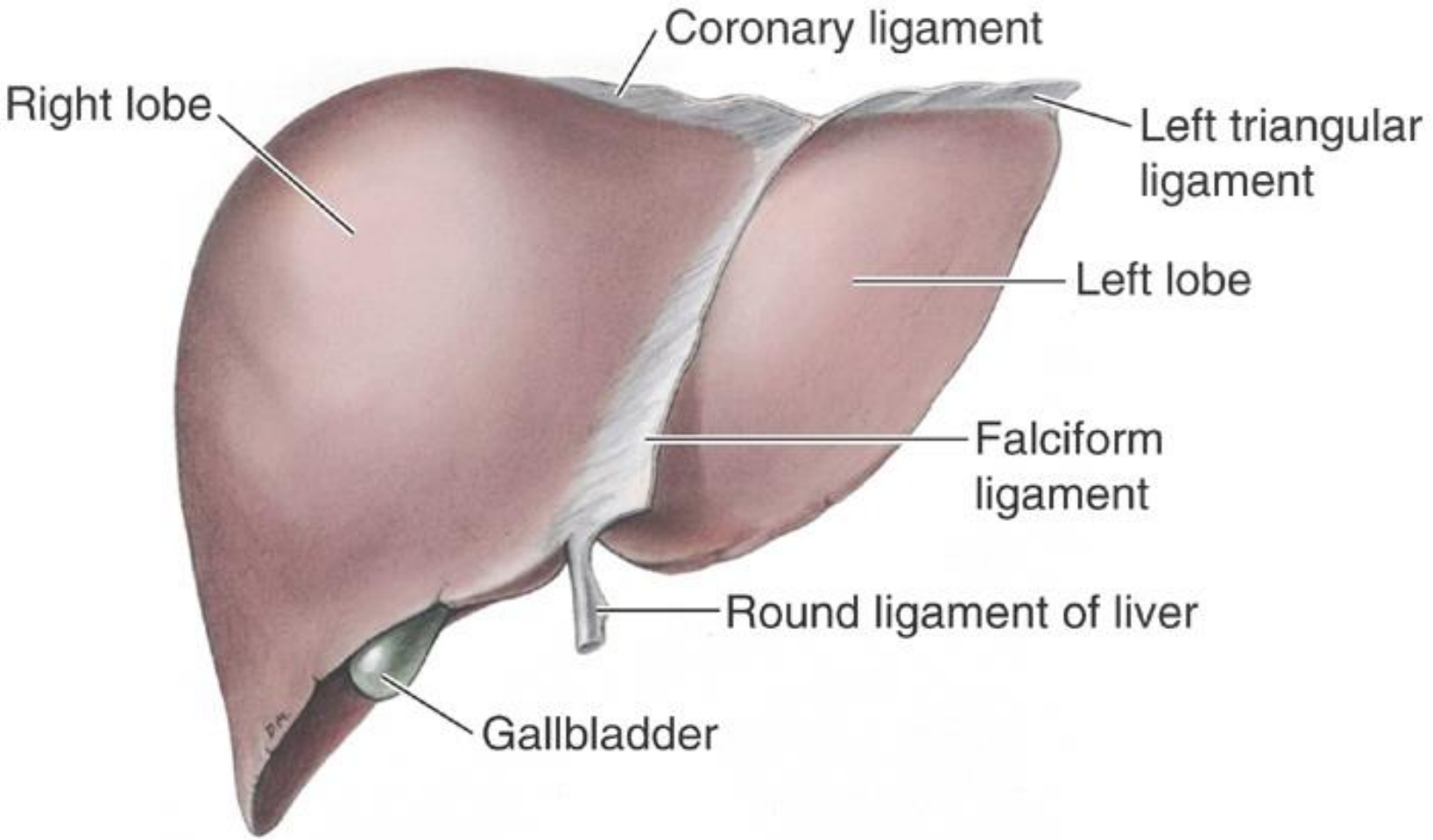
Ileum/Jejunum



Large Intestine

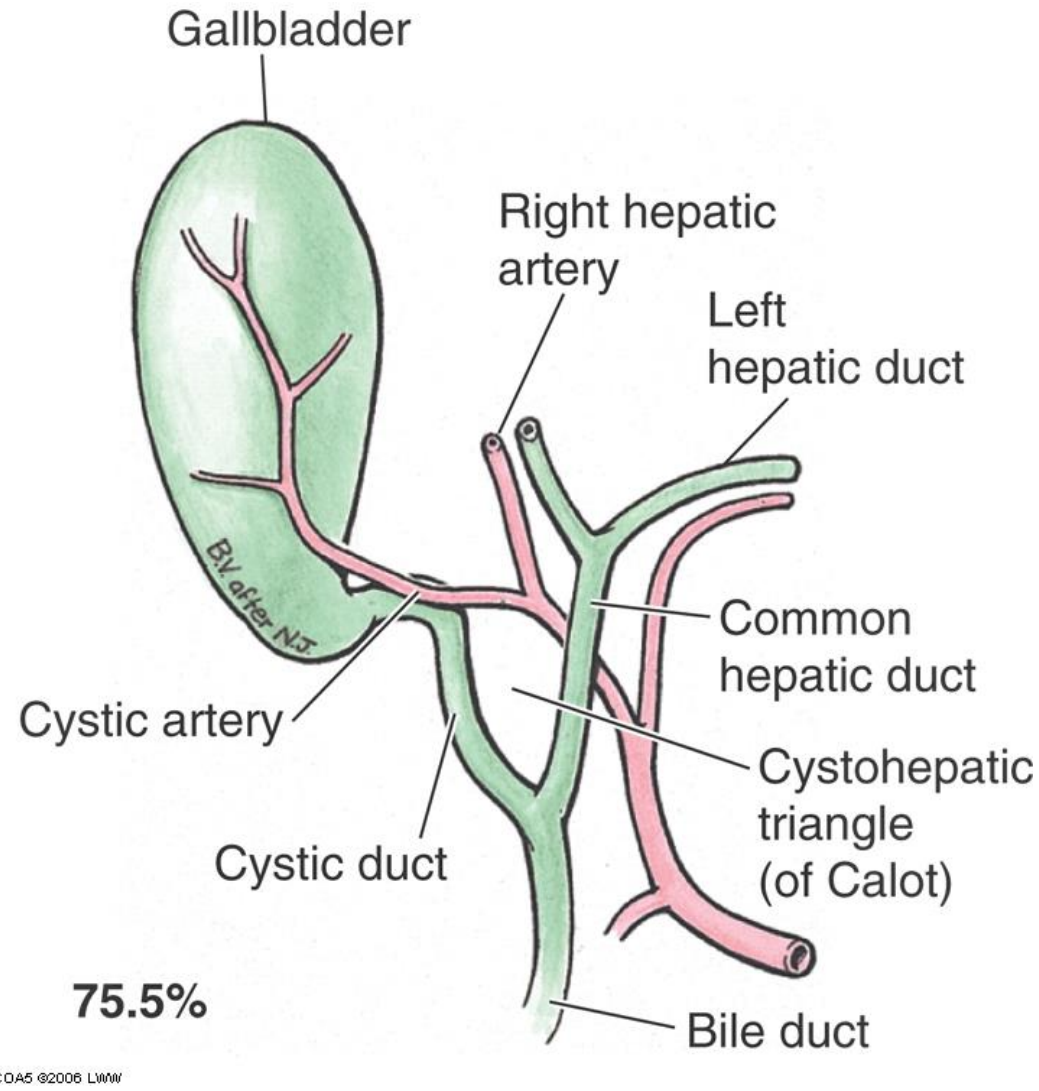


Liver - anterior

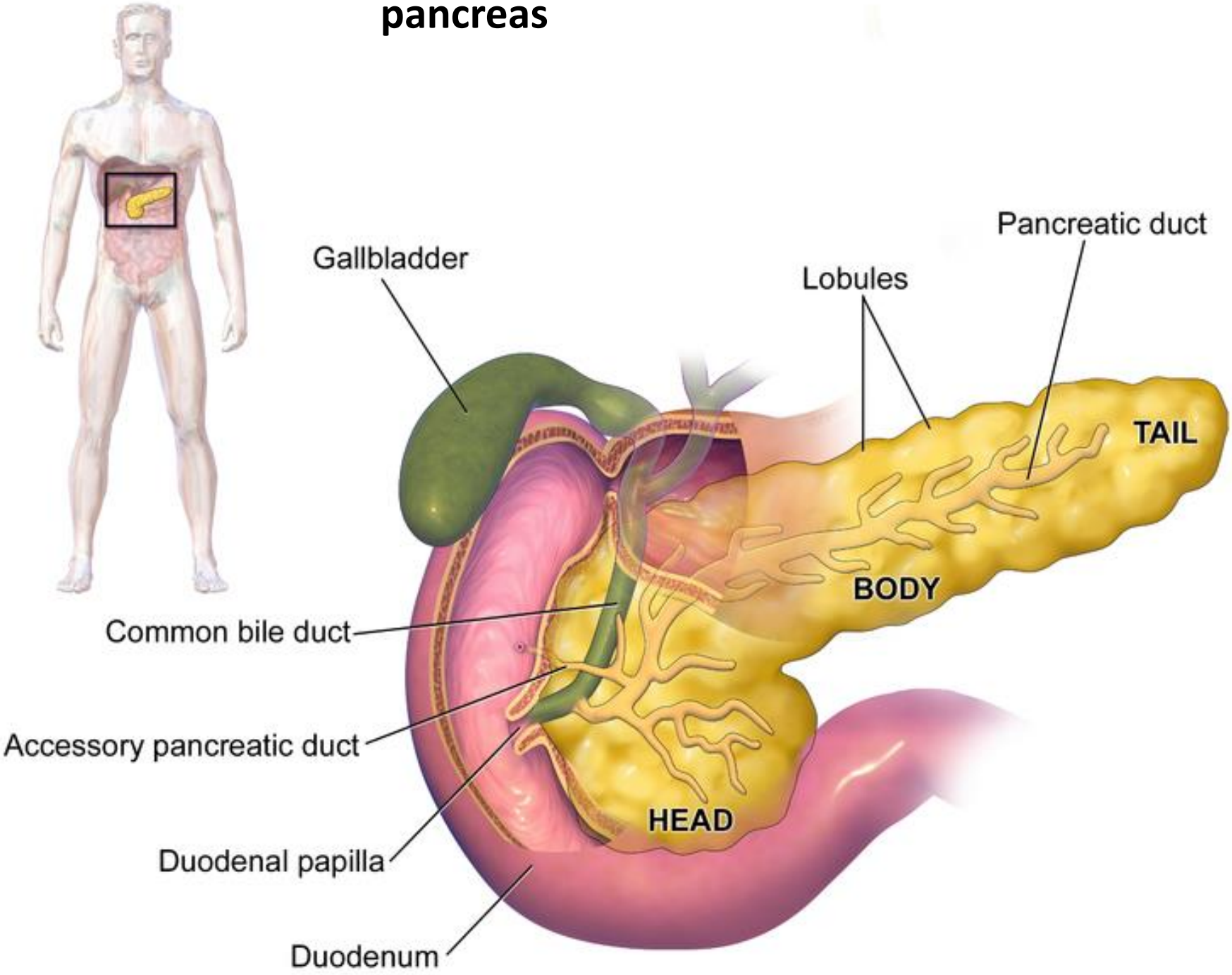


Diaphragmatic surface (Anterior view)

Biliary tree



pancreas


Gallbladder
Lobules
Pancreatic duct
TAIL
BODY
Common bile duct
Accessory pancreatic duct
HEAD
Duodenal papilla
Duodenum


Watch video #
D1-D4

Digestive Physiology (chapter 64)

Types of Secretory Glands

- Single Cell - mucous cells or goblet cells
- Simple - indentations in epithelium (crypts of Lieberkühn)
- Tubular - acid secreting oxyntic gland
- Complex - salivary, pancreas

Control of Secretions

- Local - tactile, distention, irritation
- Reflex- nervous input
- Hormonal - gastrointestinal (G.I.) hormones

Digestive Enzymes

Salivary glands

- α-amylase
- ptyalin
- lingual lipase

Stomach

- pepsin

Pancreas

- amylase
- trypsin
- chymotrypsin
- carboxypeptidase
- elastase
- lipase-colipase
- phospholipase A_2
- cholesterol esterase

Intestinal Mucosa

- enterokinase
- sucrase
- maltase
- lactase
- α-dextrinase (isomaltase)
- amino-oligopeptidase
- dipeptidase

- Daily Secretion of Intestinal Juices

	Daily Volume (ml)	pH
Saliva	1000	6.0-7.0
Gastric secretion	1500	1.0-3.5
Pancreatic secretion	1000	8.0-8.3
Bile	1000	7.8
Small intestinal secretion	1800	7.5-8.0
Brunner's gland secretion	200	8.0-8.9
Large intestinal secretion	200	7.5-8.0
Total	6700	

Saliva

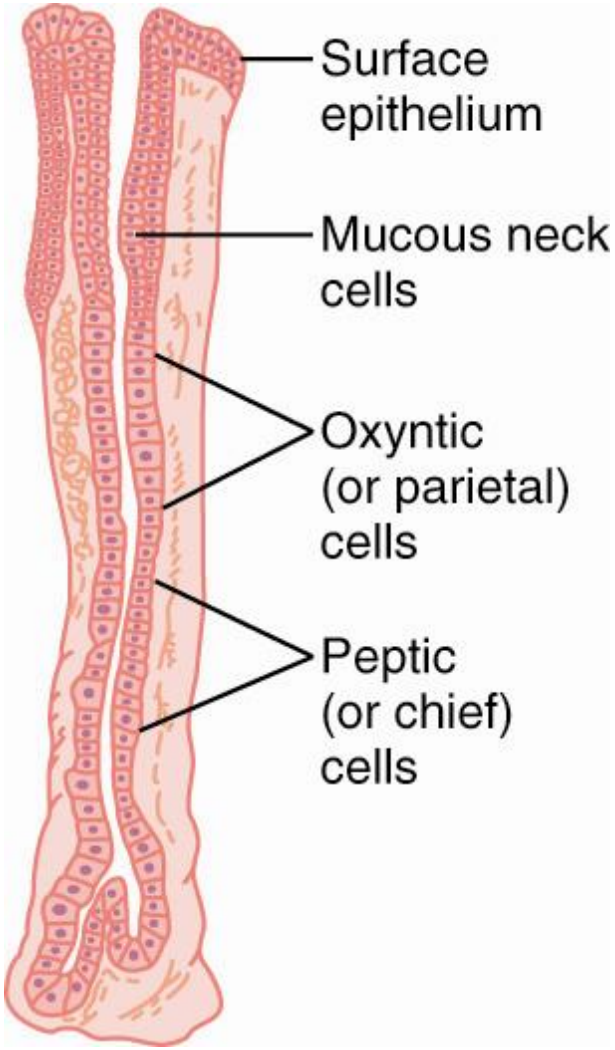
- Two types of secretion -
  - Serous - watery secretion, contains α-amylase (and ptyalin)
  - Mucous - contains mucin - lubrication
- Secrete 800-1500 ml/day of saliva
- Maximum rate of secretion: 4 ml/min

Salivary Glands

Watch video #D6

Gland	Type of saliva	% of total Secreted
Parotid	Serous	90%
Submandibular	Mucous/ Serous	
Sublingual	Mucous/ Serous	10%
Buccal	Mucous	<1%

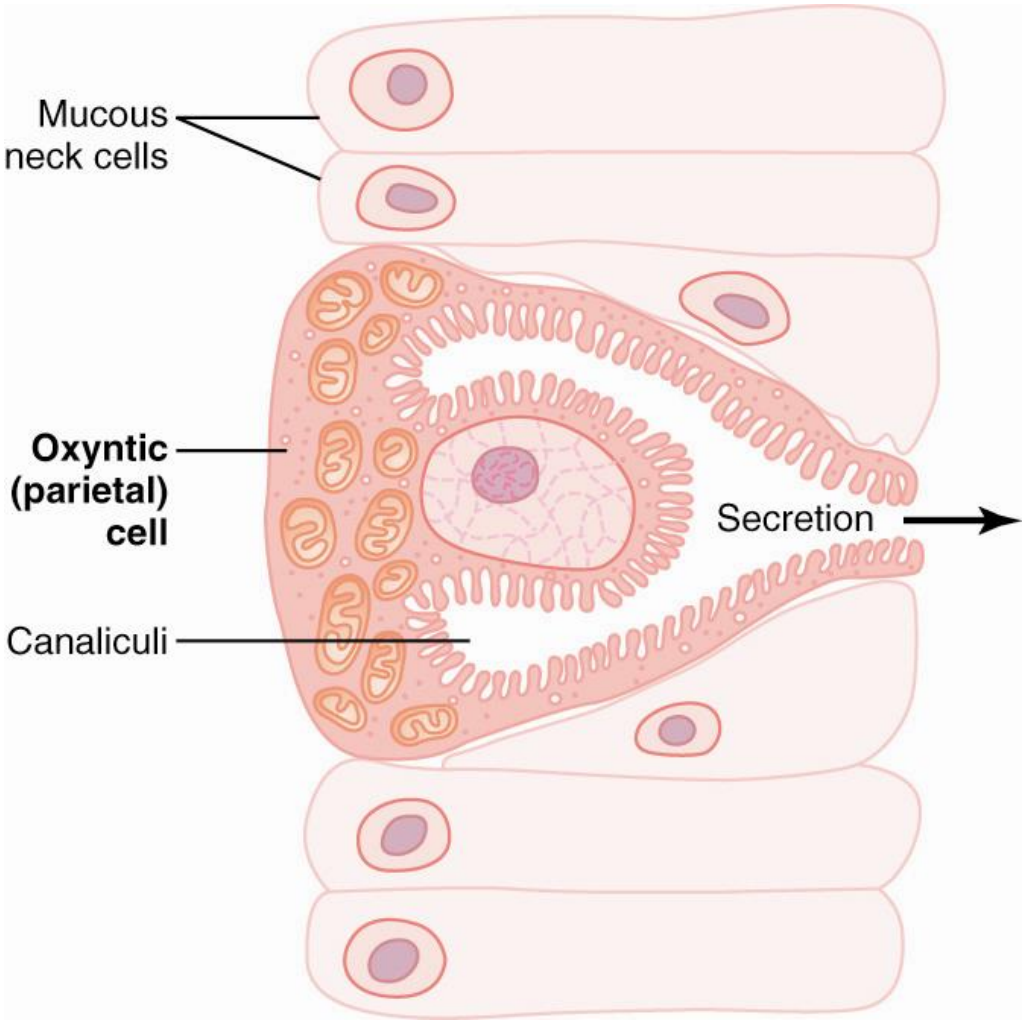
Gastric Secretion



Oxyntic gland from the body of the stomach

Oxyntic gland composed of three types of cells: (1) mucous neck cells, which secrete mainly mucus; (2) peptic (or chief) cells, which secrete large quantities of pepsinogen; and (3) parietal (or oxyntic) cells, which secrete hydrochloric acid and intrinsic factor.

Figure 64-4 :Oxyntic gland from the body of the stomach.



Oxyntic gland from the body of the stomach

Figure 64-5; Schematic anatomy of the canaliculi in a parietal (oxyntic) cell

Watch video #D8

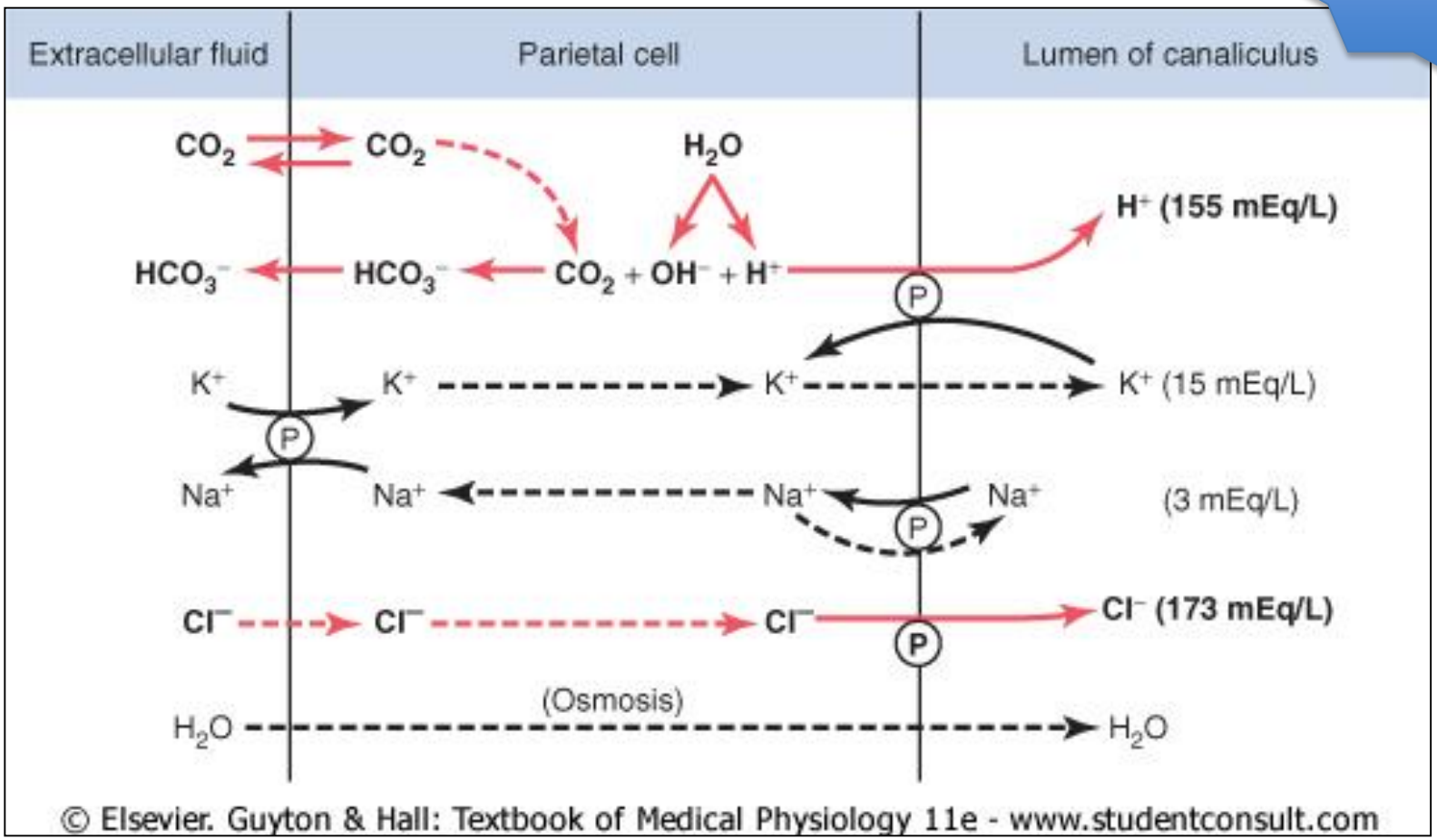


Figure 64–6

Postulated mechanism for secretion of hydrochloric acid. (The points labeled “P” indicate active pumps, and the dashed lines represent free diffusion and osmosis.)

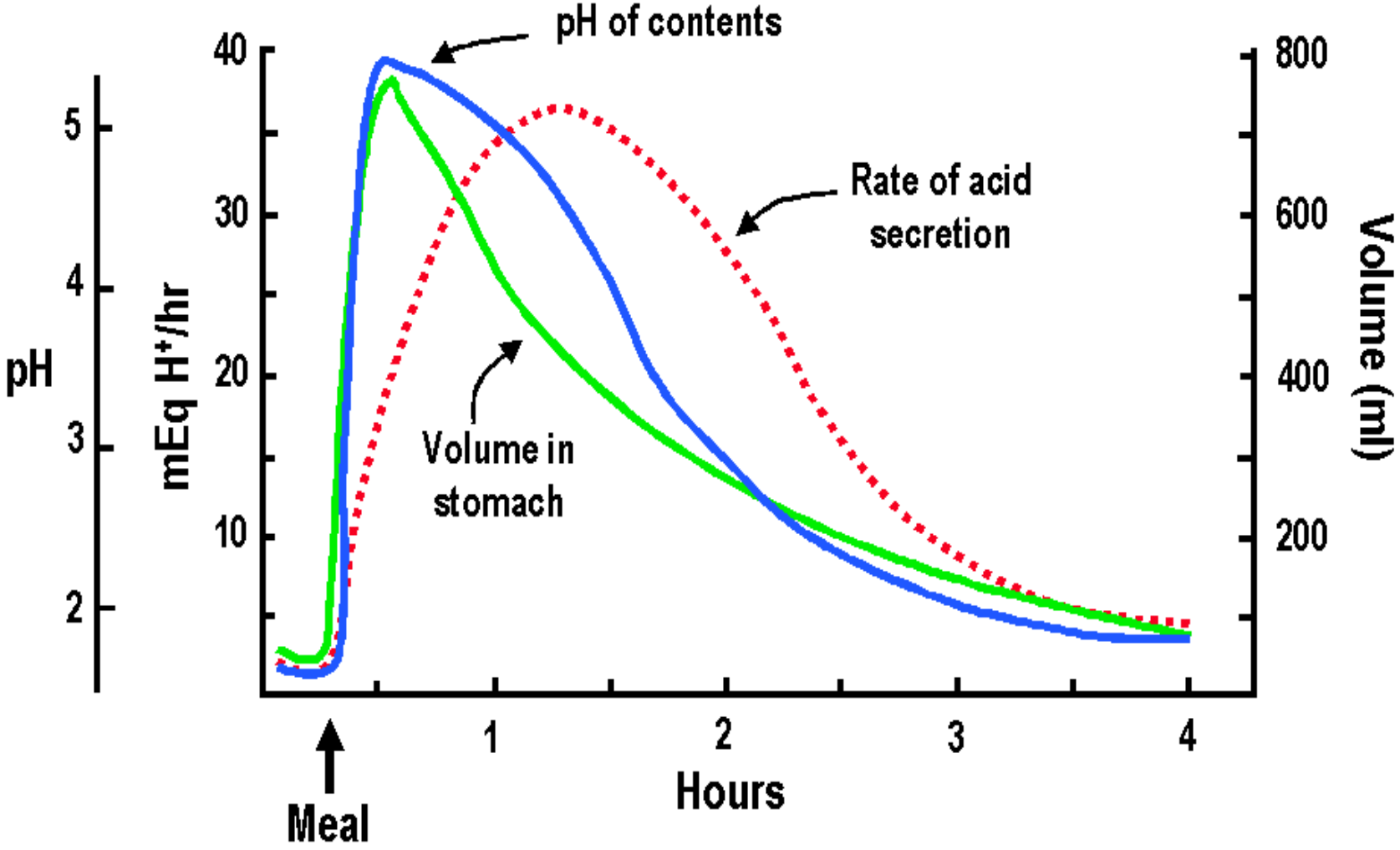
Gastric Acid

- Three major functions -
  - Bacteriostatic
  - Converts pepsinogen to pepsin
  - Begins protein digestion (with pepsin)

Pepsinogen

- Pepsinogen is an inactive, secreted form of pepsin -
  - Acid converts pepsinogen to pepsin
  - Pepsin (35 kDa) converts more pepsinogen to pepsin

- proteolytic enzyme
- optimal pH 1.8 - 3.5
- reversibly inactivated > pH 5.0
- irreversibly inactivated > pH 7-8



➢ Peptic Ulcers

- Peptic ulcers occur when damaging effects of acid and pepsin overcome ability of mucosa to protect itself
  - Gastric ulcers - main problem is decreased ability of mucosa to protect itself
  - Duodenal ulcers - main problem is exposure to increased amounts of acid and pepsin

Pancreas

- As chyme floods into small intestine two things must happen:
  - Acid must be neutralized to prevent damage to duodenal mucosa
  - Macromolecular nutrients - proteins, fats and starch must be broken down much further so their constituents can be absorbed

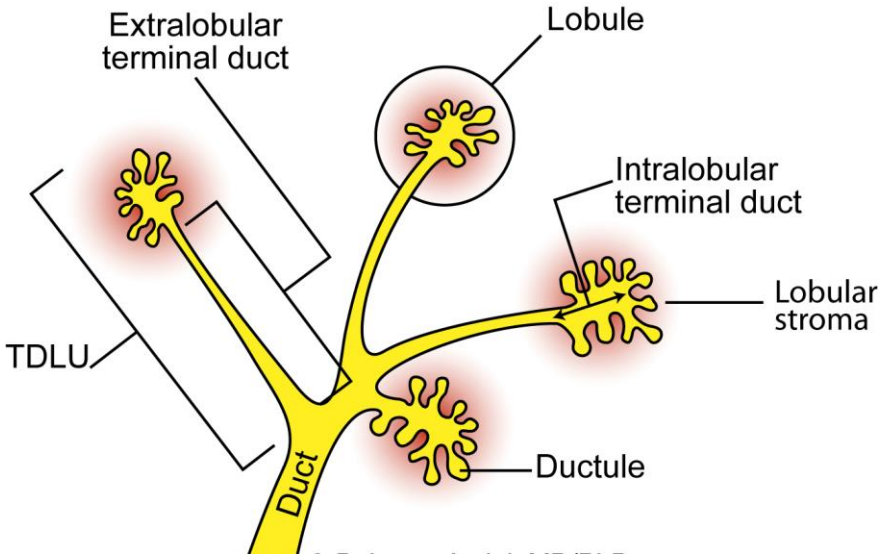
Pancreas – (cont.)

- Pancreas plays vital role in accomplishing both objectives
  - Digestive enzymes for all food types
  - Bicarbonate solution to neutralize acid chyme

Internal Structure of Pancreas

Watch video #D9-D10

- Compound gland with structure similar to salivary gland
- Acini - grape-like clusters of cells that store and secrete digestive enzymes
- Ducts - secrete bicarbonate
  - Intercalated ducts - receive secretions from acini
  - Intralobular ducts - receive fluid from intercalated ducts



Enzymes for Protein Digestion

- Proteolytic enzymes

  - Trypsin
  - Chymotrypsin

  } Cleaves proteins to polypeptides

  - Carboxypeptidase

  } Cleaves polypeptides to AA

Enzymes for Carbohydrate Digestion

- Pancreatic amylase
  - starches
  - glycogen

  } to disaccharides

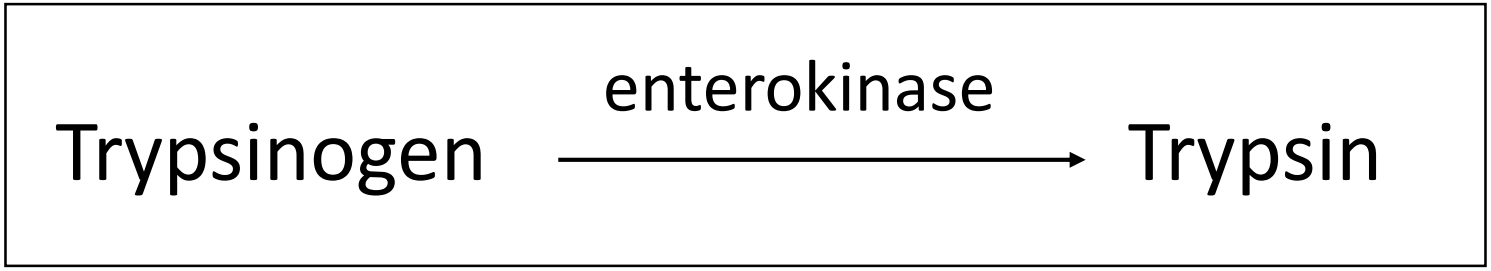
Enzymes for Fat Digestion

- Pancreatic lipase -
  - fat → fatty acids +monoglycerides
- Phospholipase -
  - phospholipids → fatty acid
- Cholesterol esterase -
  - cholesterol esters → fatty acid

Why Doesn't the Pancreas Digest Itself?

- Pancreatic proteolytic enzymes are stored and secreted in an inactive form - (also, a trypsin inhibitor is present in cells)
  - trypsinogen → trypsin
  - chymotrypsinogen → chymotrypsin
  - procarboxypeptidase → carboxypeptidase

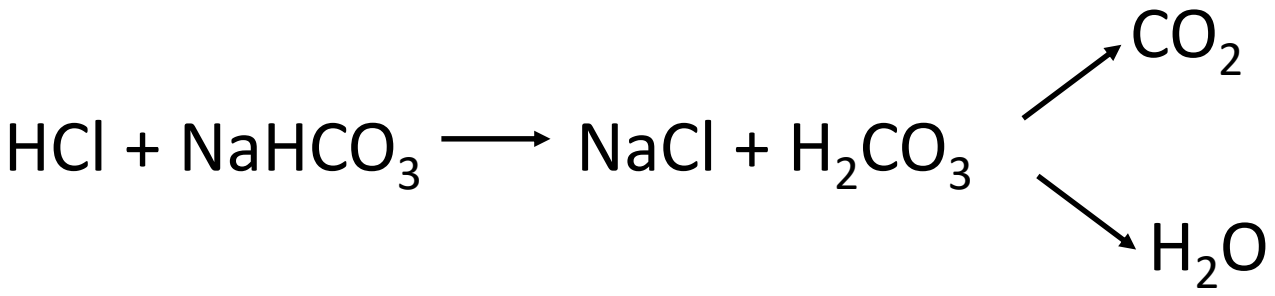
Activation of Proteolytic Enzymes



- Enterokinase - located on intestinal mucosal cells
- Trypsin - autocatalytic activation
  - activates → chymotrypsinogen,
    - procarboxypeptidase
    - trypsinogen

Bicarbonate Neutralizes Acid Chyme

- Secretin induced bicarbonate secretion neutralizes acid chyme creating optimal conditions (pH = 7-8) for digestive enzymes -



Secretin is nature's antiacid

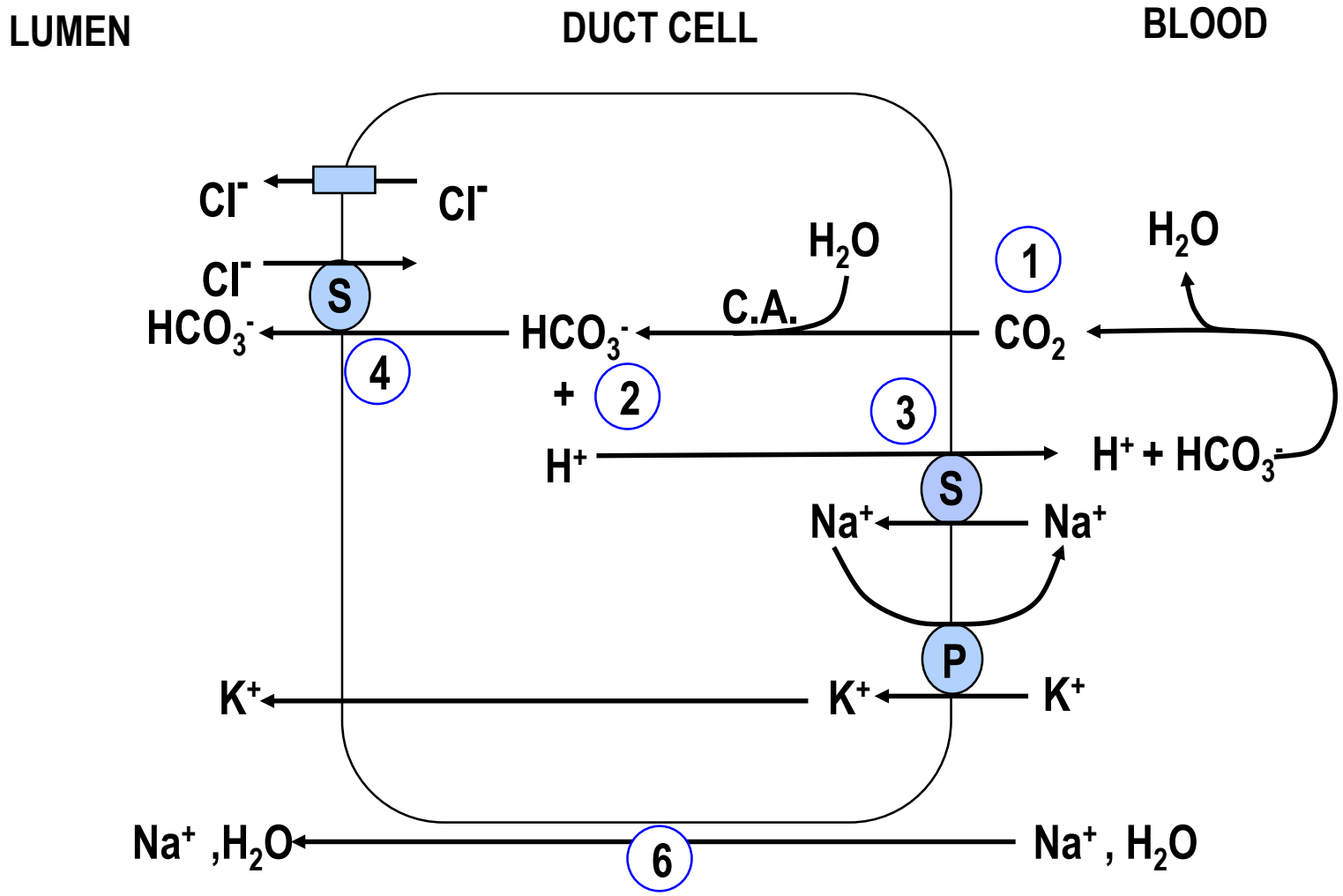
Model of Bicarbonate Secretion

1. CO_2 combines with H_2O in presence of C.A. in cell

2. Carbonic acid dissociates into HCO_3^- and H^+ ions

3. H^+ ions are transported through apical membrane by secondary transport mechanism that requires Na^+ gradient. Na^+ gradient is established by usual Na^+-K^+ ATPase pump.

4. HCO_3^- moves out of cell in exchange for Cl^-.


LUMEN
DUCT CELL
BLOOD
Cl-
Cl-
Cl-
S
HCO3-
4
H2O
C.A.
HCO3-
+
2
1
CO2
H2O
3
H+
H+ + HCO3-
S
Na+
Na+
P
K+
K+
K+
Na+ ,H2O
6
Na+ , H2O

Model of Bicarbonate Secretion - (cont)

5. Rate of HCO_3^- secretion is dependent upon luminal Cl^- concentration.

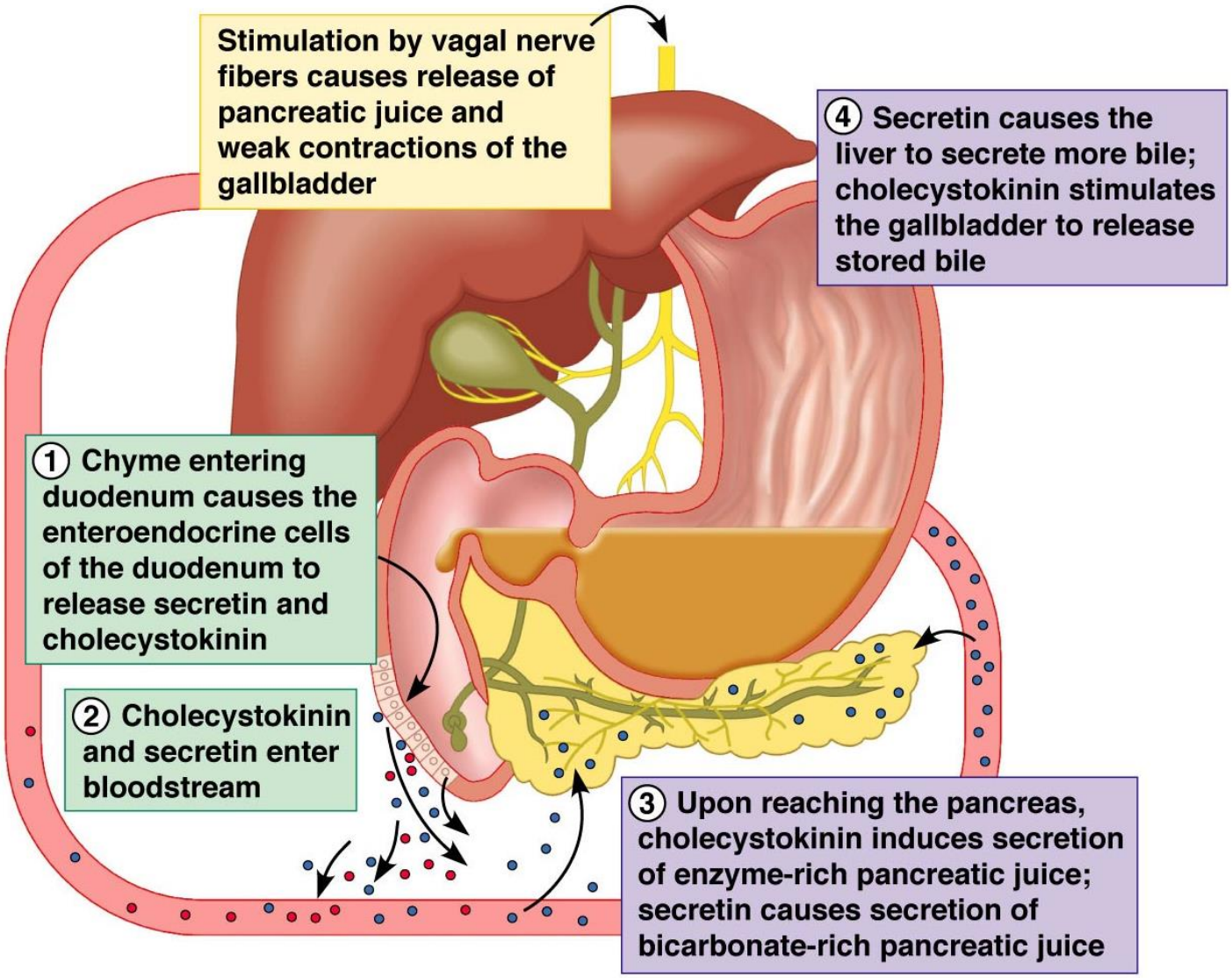
6. Na^+ moves down electrochemical gradient. Water moves into lumen establishing osmotic equilibrium.

<u>Secretin</u> - acts to open Cl^- channels and thus increase secretion of bicarbonate.

Effect of Secretion Rate on Ionic Composition of Pancreatic Juice

- Low secretion rates -
  - bicarbonate concentration is low
  - chloride concentration is high
- High secretion rates -
  - bicarbonate concentration is high
  - chloride concentration is low
- Sodium and potassium concentrations always same as plasma

Regulation of pancreatic secretion



Hormones & Hormonelike Products that Act in Digestion

TABLE 14.1 Hormones and Hormonelike Products That Act in Digestion

Hormone	Source	Stimulus for secretion	Action
Gastrin	Stomach	Food in stomach (chemical stimulus); ACH released by nerve fibers	• Stimulates release of gastric juice • Stimulates stomach emptying
Intestinal gastrin	Duodenum	Acidic food in stomach	• Stimulates gastric secretion and emptying
Histamine	Stomach	Food in stomach	• Activates parietal cells to secrete hydrochloric acid.
Somatostatin	Stomach and duodenum	Food in stomach; stimulated by sympathetic nerve fibers	• Inhibits secretion of gastric juice and pancreatic juice • Inhibits emptying of stomach and gallbladder.

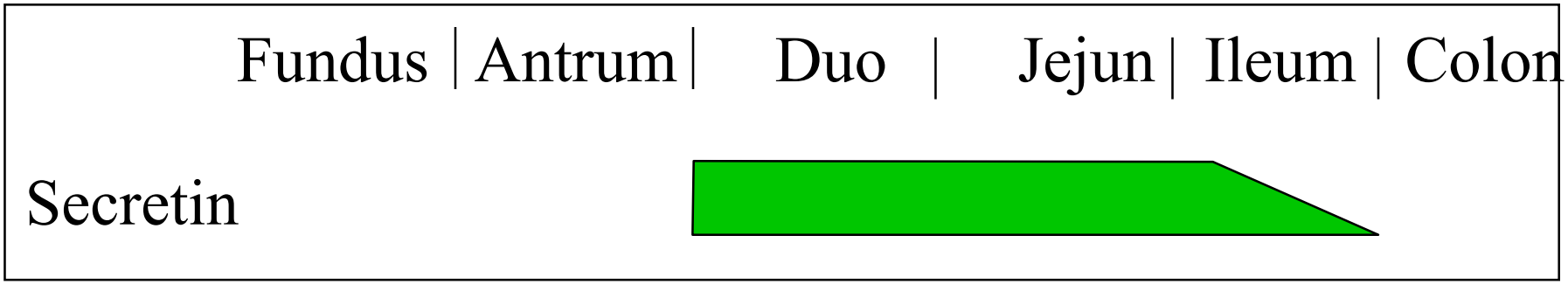
Hormones & Hormonelike Products that Act in Digestion

TABLE 14.1 Hormones and Hormonelike Products That Act in Digestion *(continued)*

Hormone	Source	Stimulus for secretion	Action
Secretin	Duodenum	Acidic chyme and partially digested foods in duodenum	• Increases output of pancreatic juice rich in bicarbonate ions • Increases bile output by liver • Inhibits gastric mobility and gastric gland secretion.
Cholecystokinin (CCK)	Duodenum	Fatty chyme and partially digested proteins in duodenum	• Increases output of enzyme-rich pancreatic juice • Stimulates gallbladder to expel stored bile • Relaxes sphincter of duodenal papilla to allow bile and pancreatic juice to enter the duodenum.
Gastric inhibitory peptide (GIP)	Duodenum	Fatty chyme in duodenum	• Inhibits secretion of gastric juice.

Distribution of GI Hormones

- Digestive products are equally effective in releasing secretin when applied to any part of duodenum or jejunum.



Pancreatic Failure

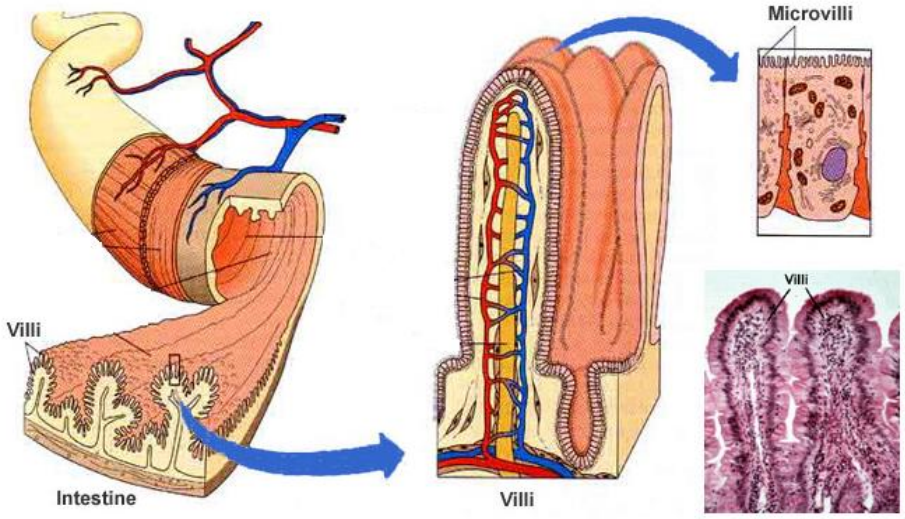
- Digestion is abnormal when pancreas fails to secrete normal amounts of enzymes.

- Without pancreatic enzymes -
  - 60% fat not absorbed
  - 30-40% protein and carbohydrates not absorbed

Absorption and Neural Control of Digestion

Absorption in the Small Intestine

- The small intestine is specially adapted for absorption of nutrients.
  - The folded surfaces of the small intestine are covered with fingerlike projections called villi.
  - Villi increases the surface area for absorption of nutrients



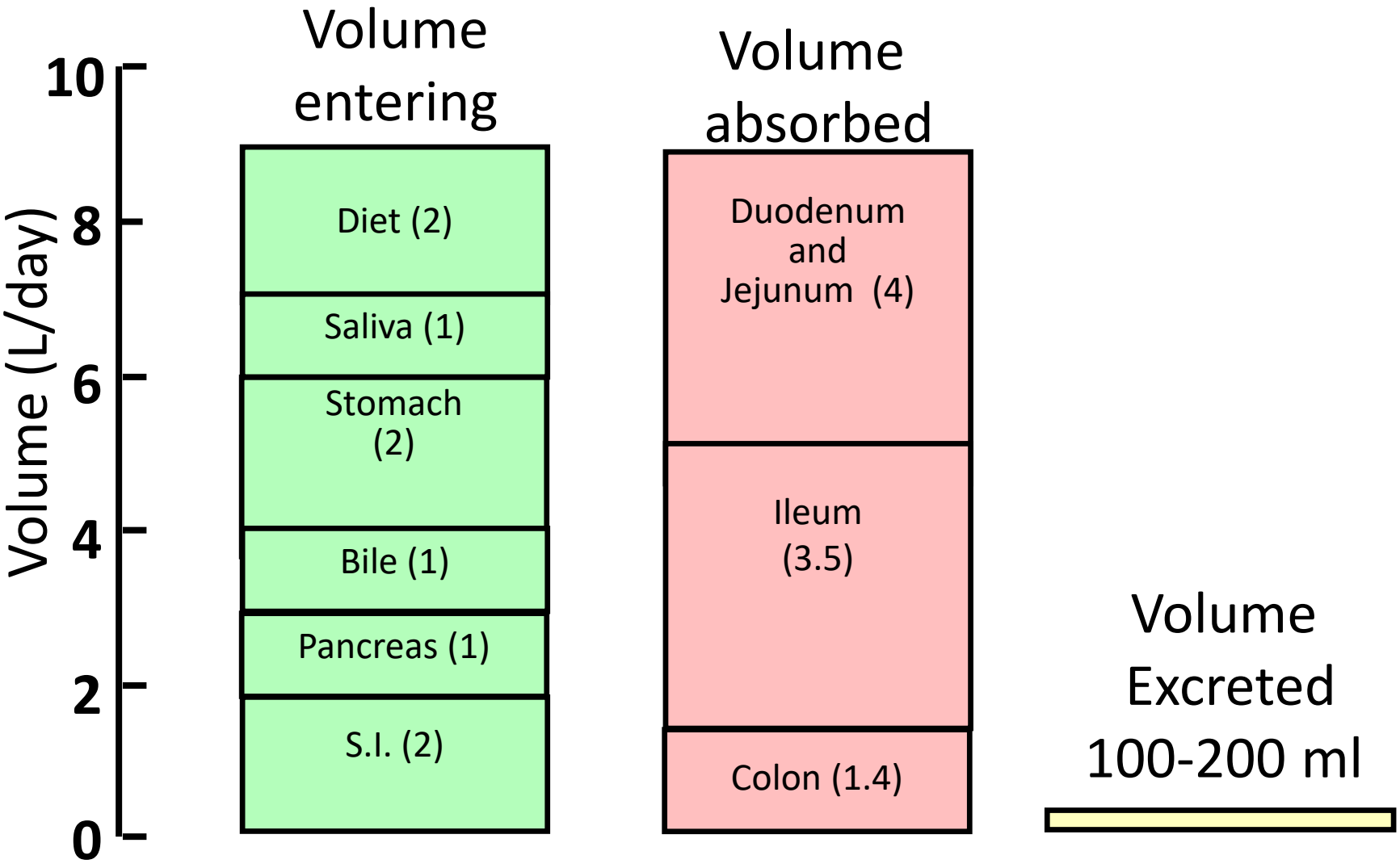
Absorption in the Small Intestine

- By the time food is ready to leave the small intestine, it is basically nutrient-free.
  - The complex organic molecules have been digested and absorbed, leaving only water, cellulose, and other undigestible substances behind.

Mechanisms of Absorption

- Four mechanisms are important in transport of substances across intestinal cell membrane
  - Active Transport -
    - primary
    - secondary (co-transport, counter-transport)
  - Passive Diffusion
  - Facilitated Diffusion - carrier mediated
  - Endocytosis

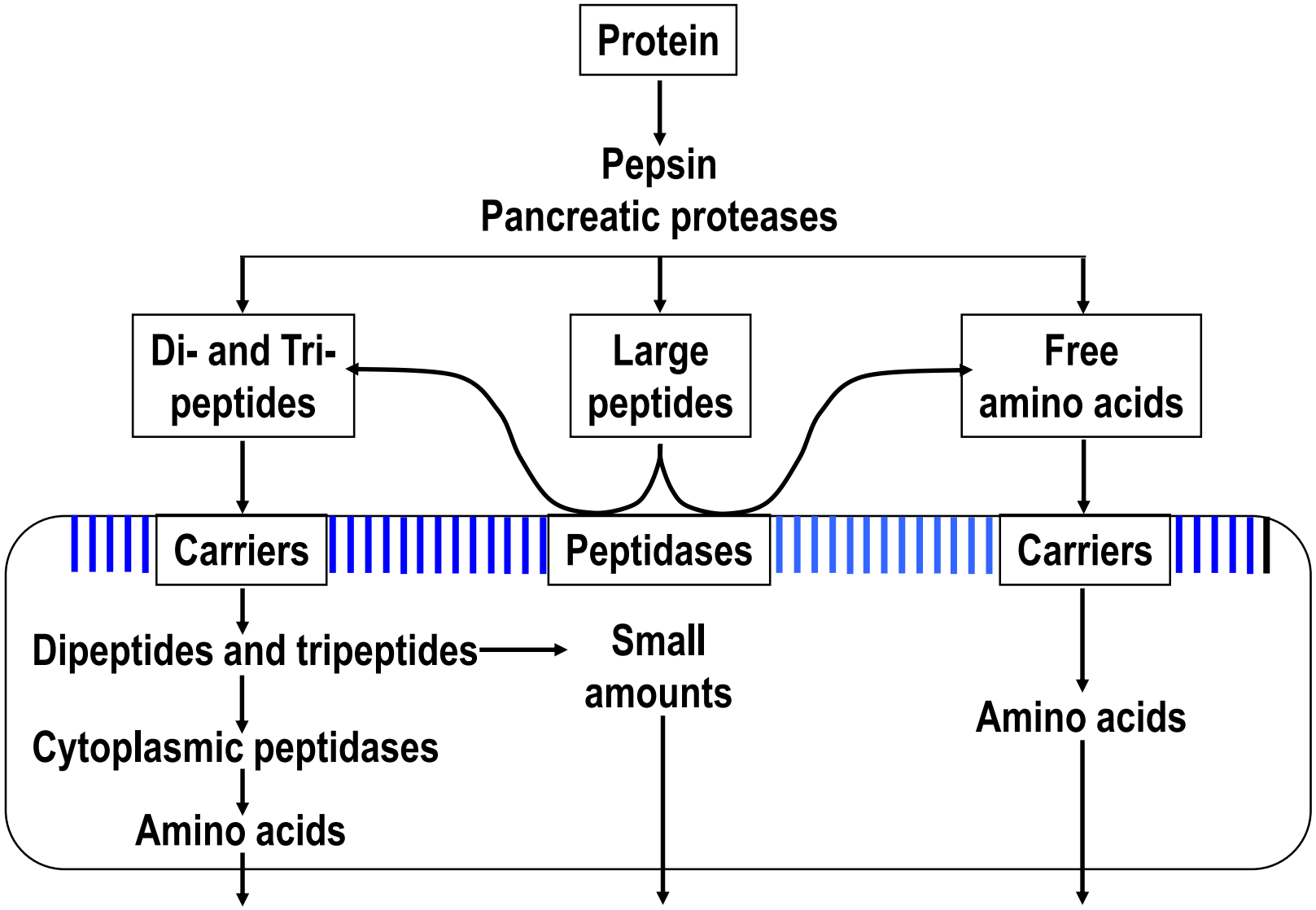
Fluid Entering and Exiting the Gut



Carbohydrate Digestion and Assimilation

- Begins in the mouth via our saliva, with help from an enzyme - salivary amylase
- Digestive enzymes released by the pancreas into the small intestine (in response to eating carbohydrates) allows the absorption of carbonhydrates throughout the small intestine

Protein Digestion and Absorption

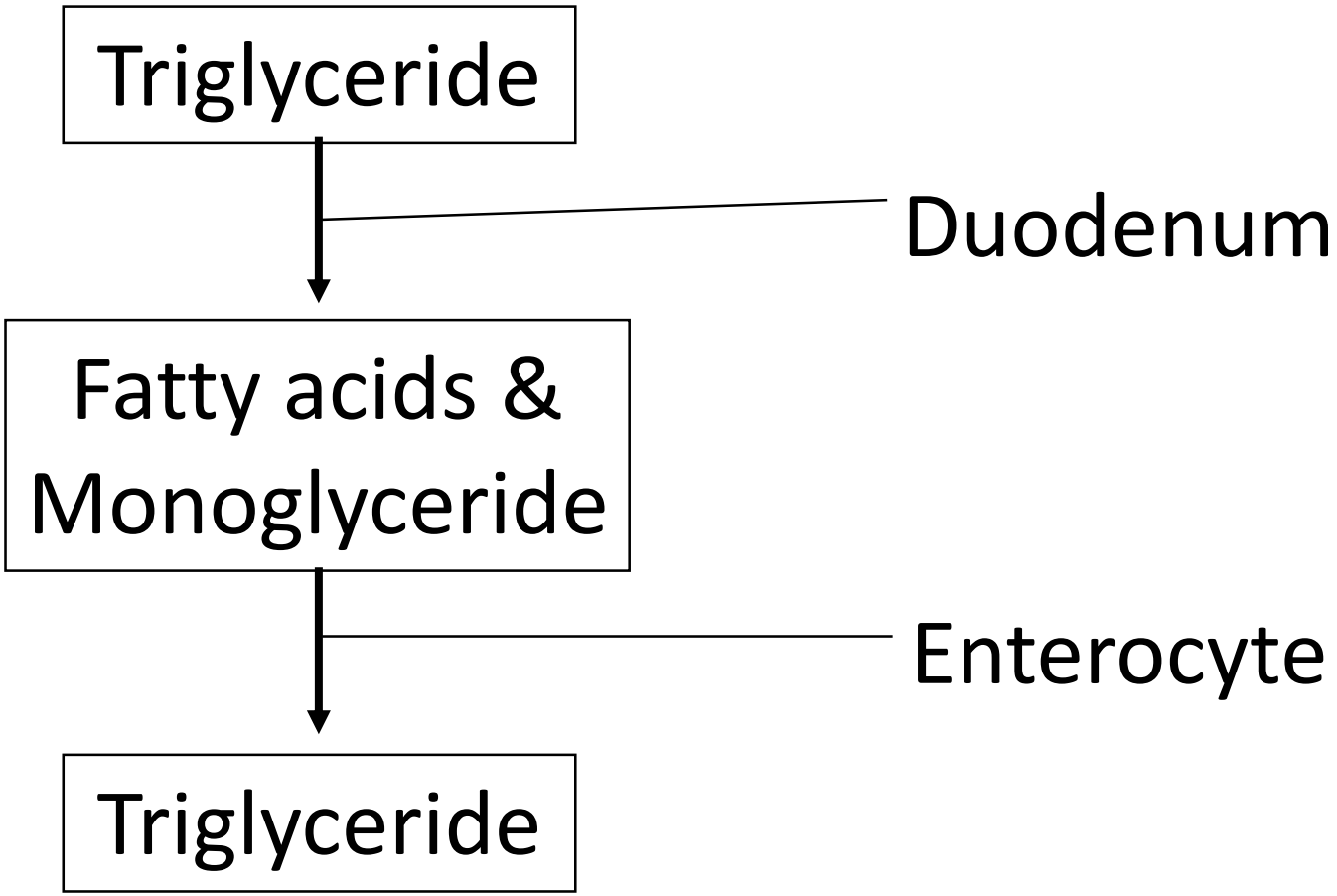


Basic Steps of Lipid Assimilation

- Most dietary lipid is neutral fat or triglyceride. Three main processes must occur for triglyceride to be absorbed into blood:
  - Emulsification - large aggregates of dietary triglyceride are broken down.
  - Enzymatic digestion - to yield monoglyceride and fatty acids. Both can diffuse into enterocyte.
  - Reconstitution of triglyceride and chylomicron formation

Assimilation of Lipids – Overall Scheme

Watch video #D15-D16-17



Neural Control of GI Tract

- Intrinsic Control - Enteric nervous system
  - Myenteric (Auerbach's) plexus
  - Submucosal (Meissner's) plexus

- Extrinsic Control - Autonomic nervous system
  - Parasympathetic - mainly stimulates (Ach)
  - Sympathetic - mainly inhibits (NE)

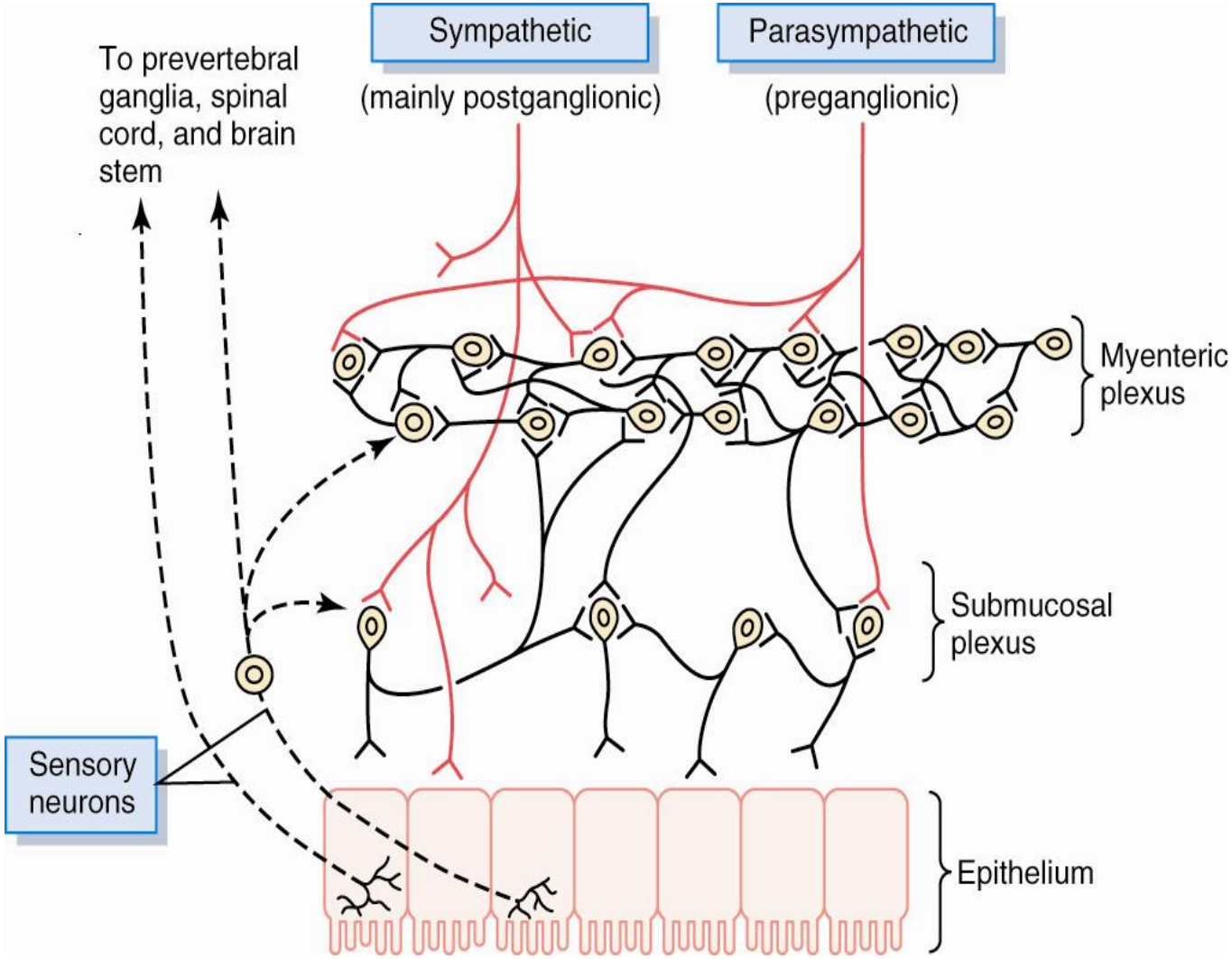


Figure 62-4Neural control of the gut wall, showing (1) the myenteric and submucosal plexuses (black fibers); (2) extrinsic control of these plexuses by the sympathetic and parasympathetic nervous systems (red fibers); and (3) sensory fibers passing from the luminal epithelium and gut wall to the enteric plexuses, then to the prevertebral ganglia of the spinal cord and directly to the spinal cord and brain stem (dashed fibers)