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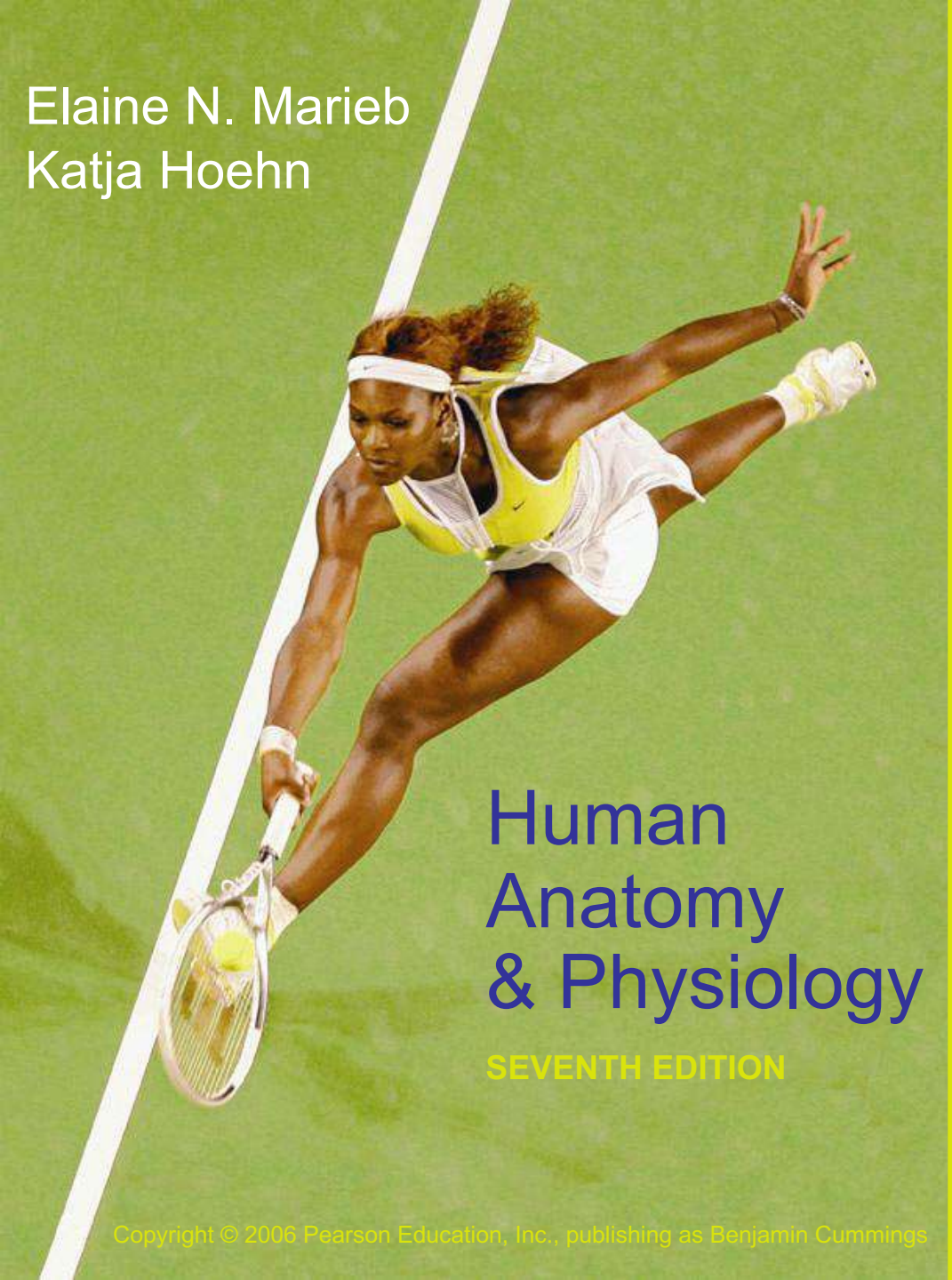

Human Anatomy & Physiology

SEVENTH EDITION

PowerPoint® Lecture Slides
prepared by Vince Austin,
Bluegrass Technical
and Community College

CHAPTER 23

The Gastrointestinal System

Gastrointestinal System: Overview

- The gastrointestinal (GI) tract digests and absorbs food
- GI– mouth, pharynx, esophagus, stomach, small intestine, and large intestine
- Accessory digestive organs – teeth, tongue, gallbladder, salivary glands, liver, and pancreas

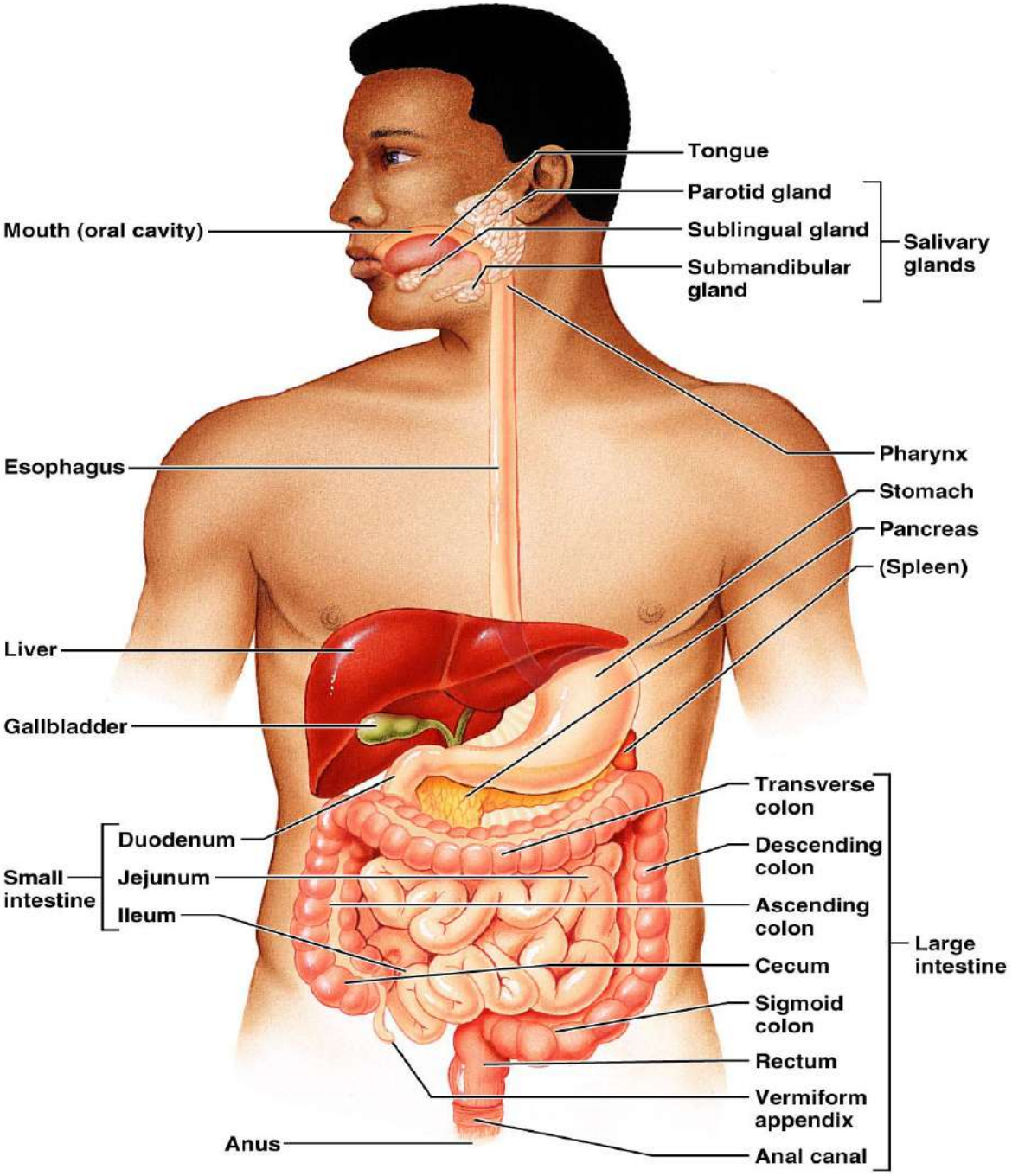

Figure 23.1

Gastrointestinal Tract Activities

- Mechanical digestion – food breakdown to smaller particles
- Chemical digestion – catabolic breakdown of food
- Motility – movement of chyme down GIT
- Absorption – movement of nutrients from the GI tract to the blood or lymph
- Defecation – elimination of indigestible solid wastes

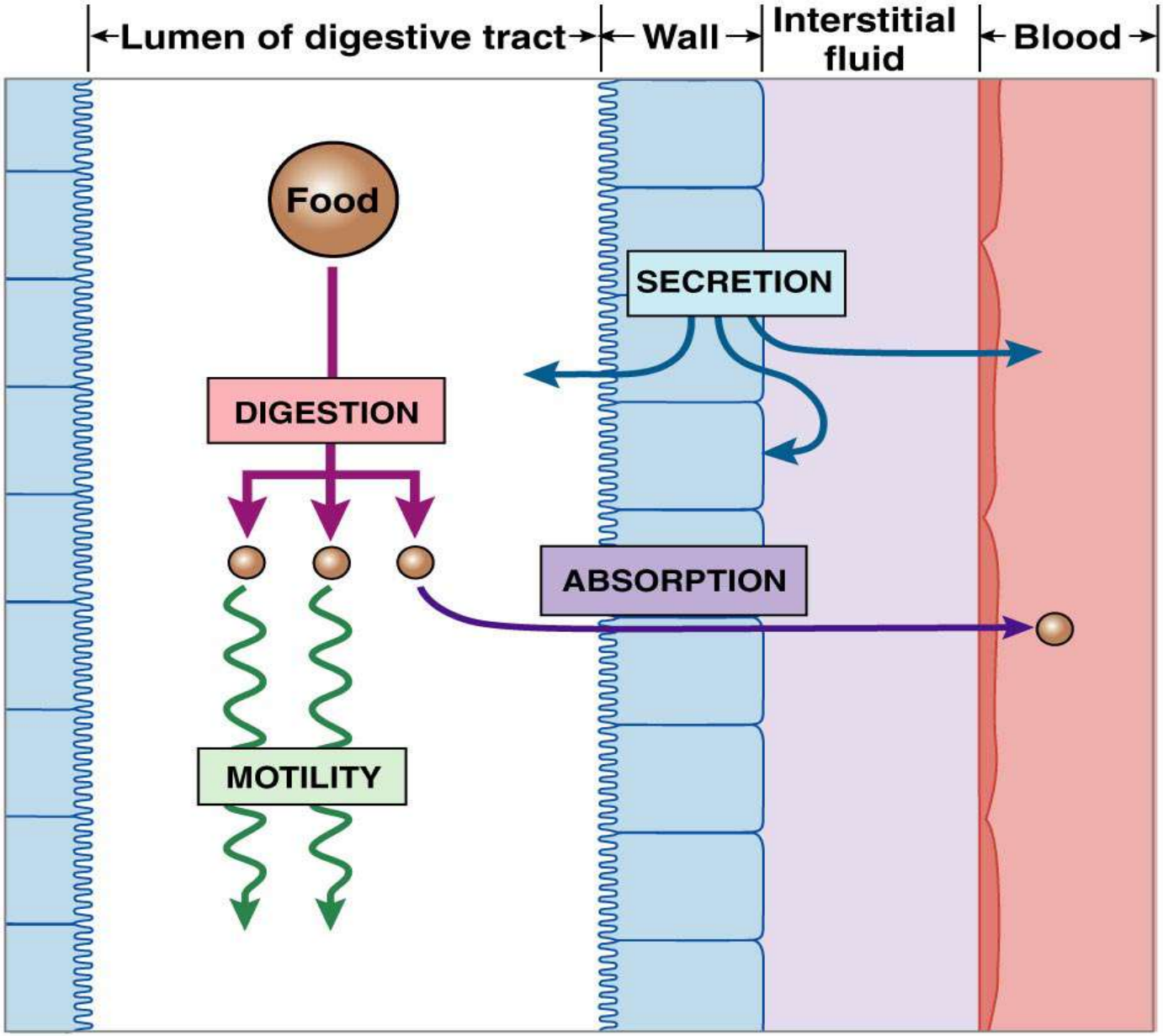

Figure 21-1

GI Tract Regulation

- External environment for the digestive process
- Regulation of digestion involves:
  - Mechanical and chemical stimuli – stretch receptors, osmolarity, and presence of substrate in the lumen
  - Extrinsic control by CNS centers
  - Intrinsic control by local centers (ENS)

Receptors of the GI Tract

- Mechano- and chemoreceptors respond to:
  - Stretch, osmolarity, and pH
  - Presence of substrate, and end products of digestion
- They initiate reflexes that:
  - Activate or inhibit digestive glands
  - Mix lumen contents and move them along

Peritoneum and Peritoneal Cavity

- Peritoneum – serous membrane of the abdominal cavity
  - Visceral – covers external surface of most digestive organs
  - Parietal – lines the body wall
- Peritoneal cavity
  - Lubricates digestive organs
  - Allows them to slide across one another

Peritoneum and Peritoneal Cavity

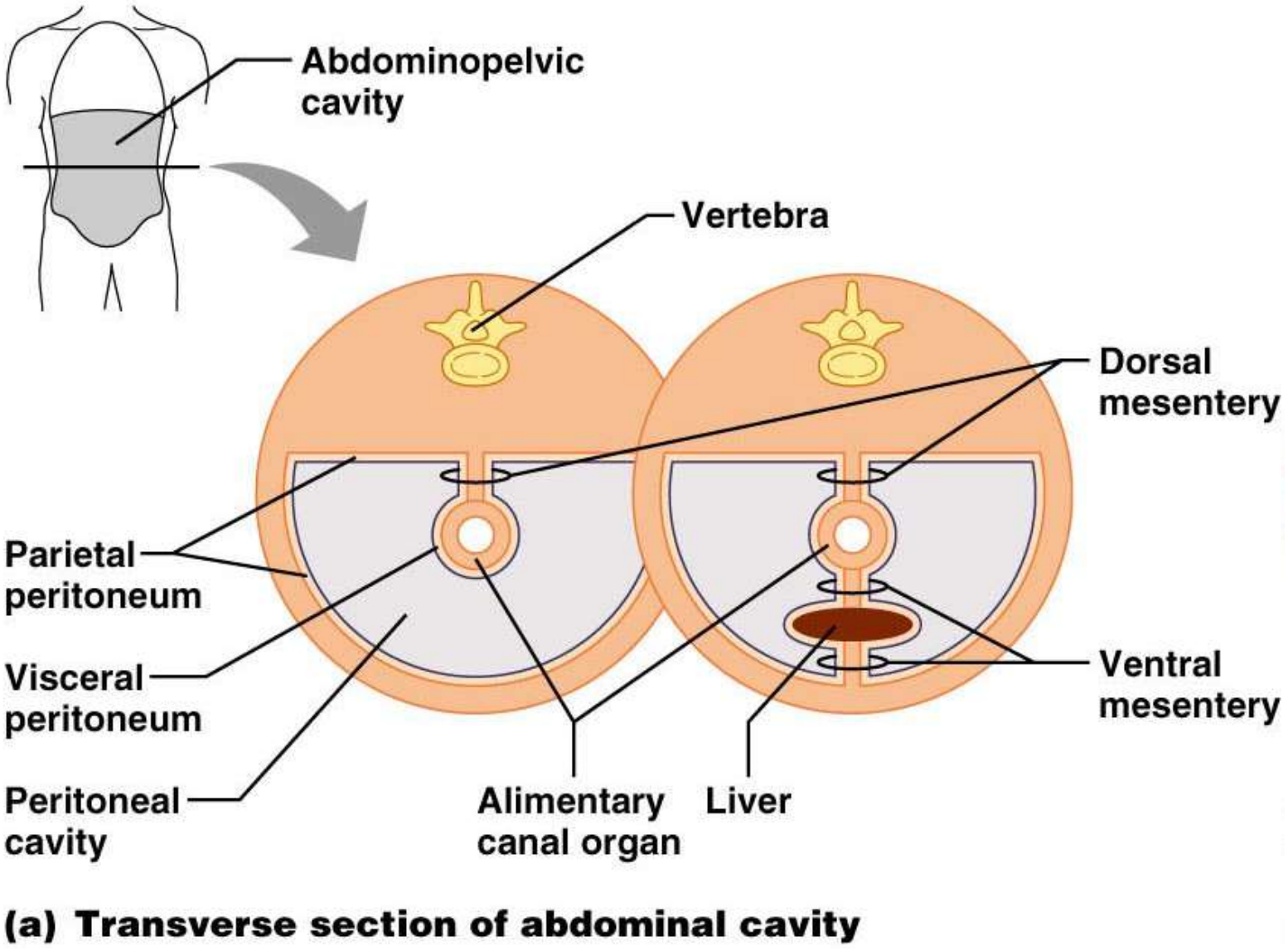

Figure 23.5a

Peritoneum and Peritoneal Cavity

- Mesentery – double layer of peritoneum that provides:
  - Vascular and nerve supplies to the viscera
  - Hold digestive organs in place and store fat
- Retroperitoneal organs – organs outside the peritoneum
- Peritoneal organs (intraperitoneal) – organs surrounded by peritoneum

Blood Supply: Splanchnic Circulation

- Arteries and the organs they serve include
  - The hepatic, splenic, and left gastric: spleen, liver, and stomach
  - Inferior and superior mesenteric: small and large intestines

Blood Supply: Splanchnic Circulation

- Hepatic portal circulation:
  - Collects nutrient-rich venous blood from the digestive viscera
  - Delivers this blood to the liver for metabolic processing and storage

Histology of the Alimentary Canal

- From esophagus to the anal canal the walls of the GI tract have the same four tunics
  - From the lumen outward they are **mucosa, submucosa, muscularis, and serosa**
- Each tunic has a predominant tissue type and a specific digestive function

Histology of the Alimentary Canal

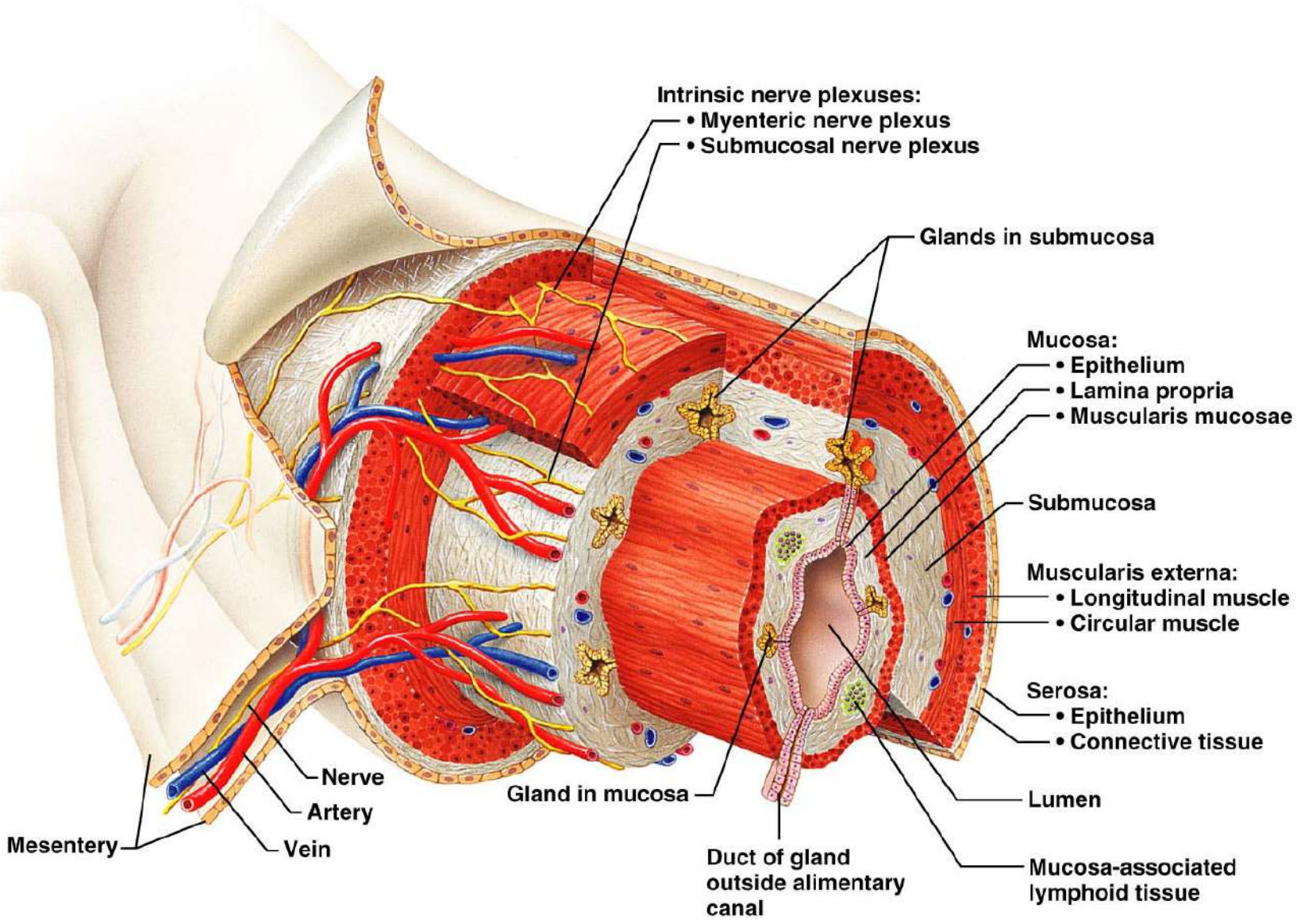

Figure 23.6

(c) In the stomach, surface area is increased by invaginations called gastric glands.

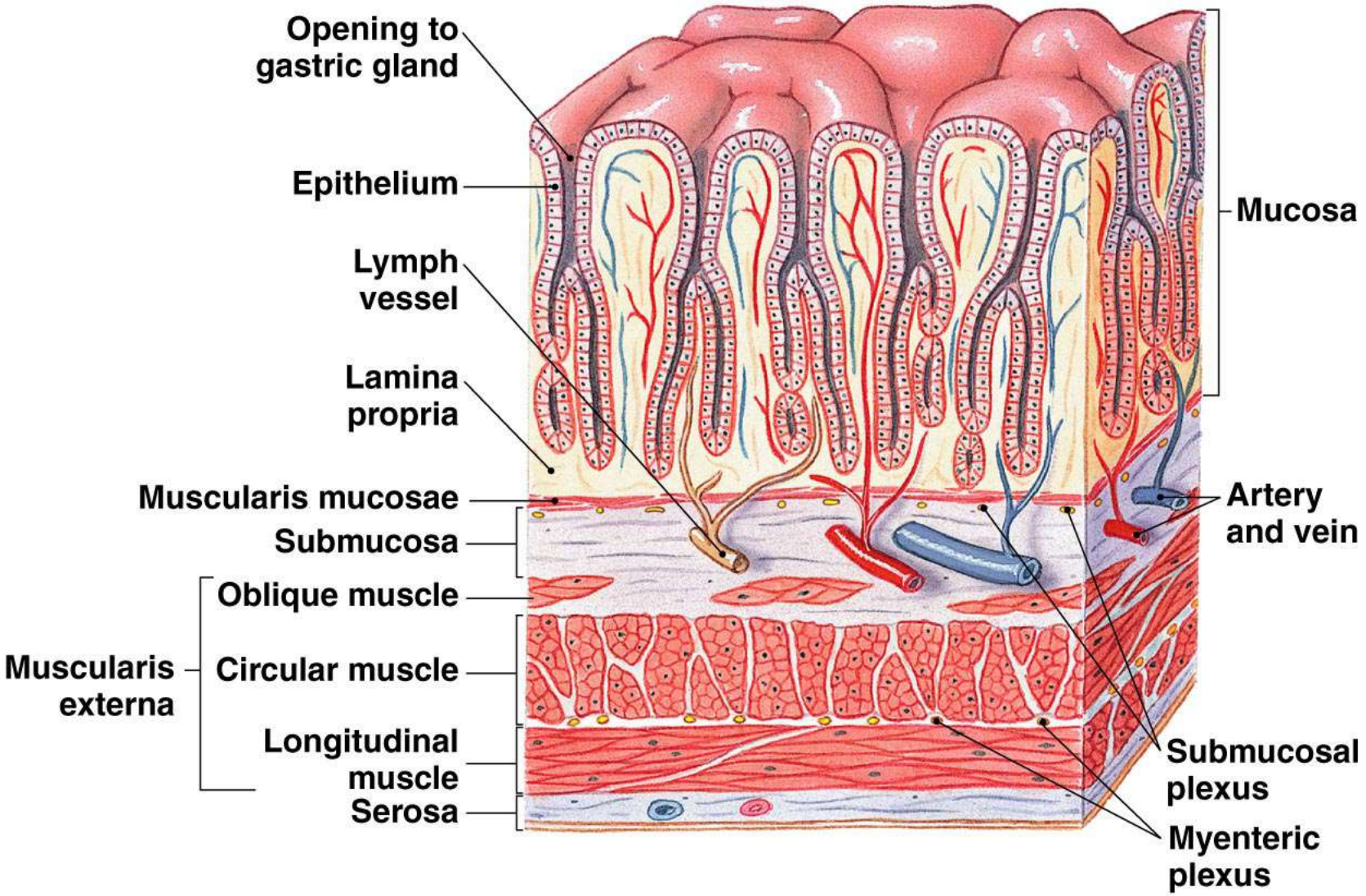

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Figure 21-2c

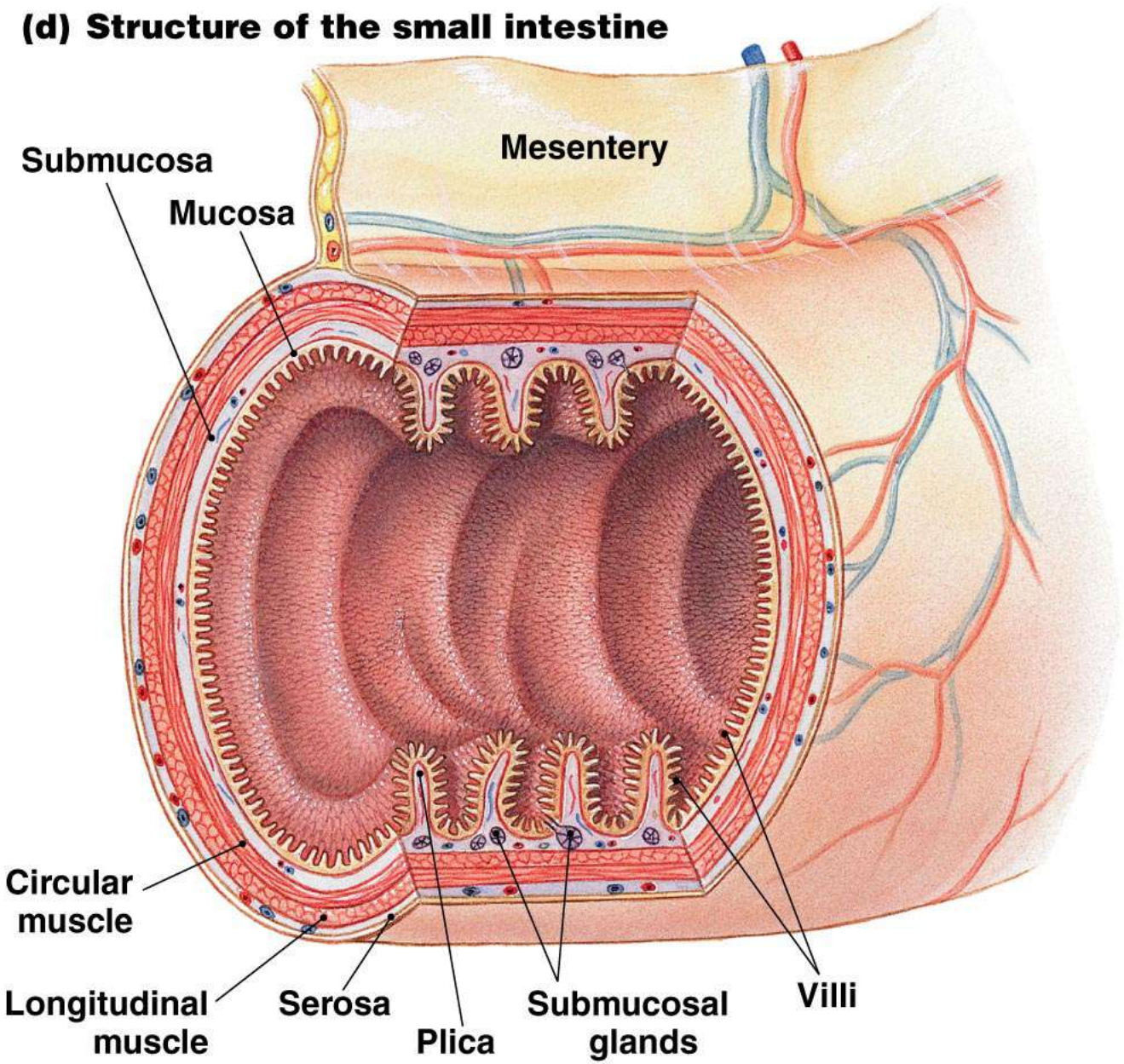


Figure 21-2d

(e) Intestinal surface area is enhanced by finger-like villi and invaginations called crypts.

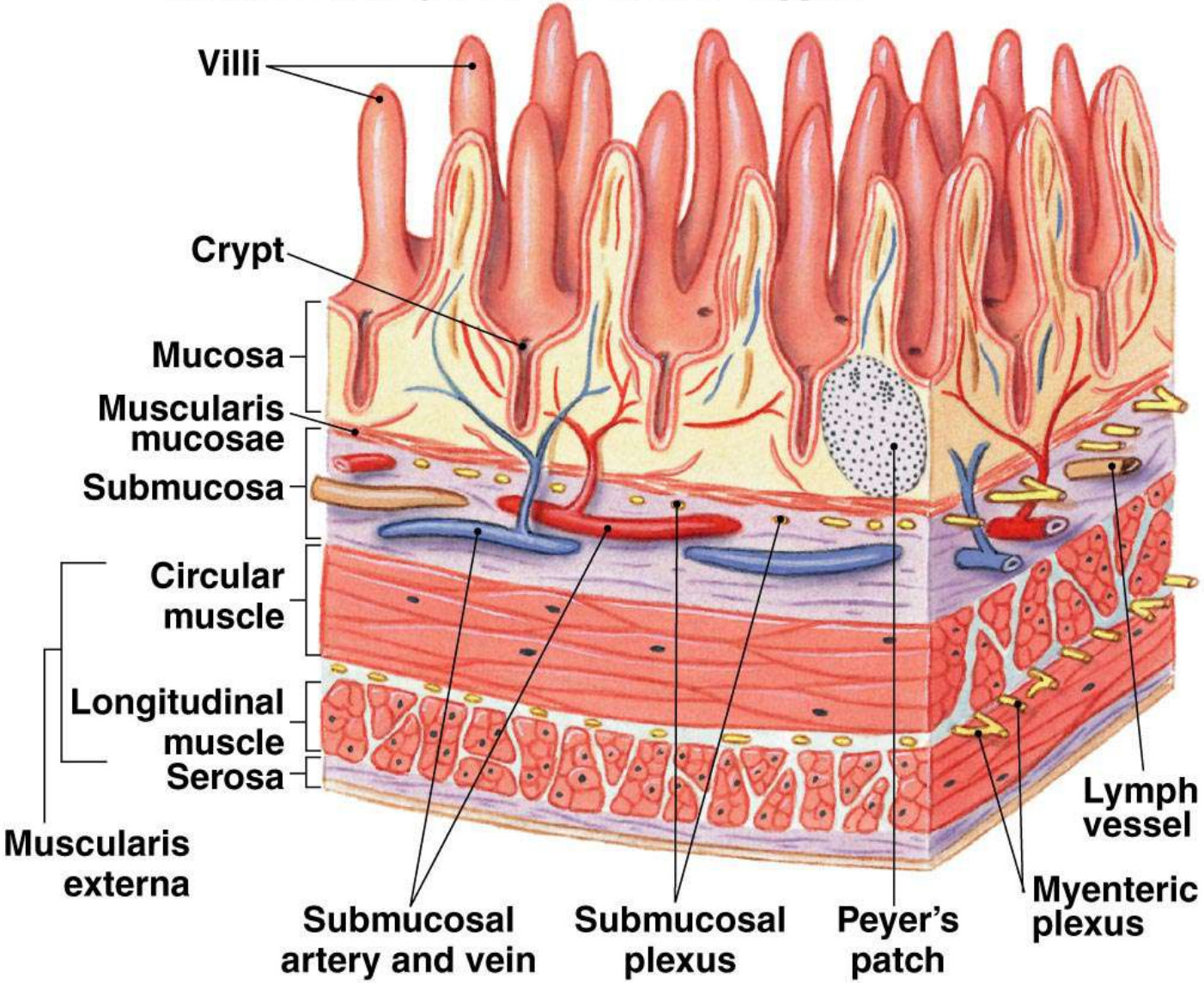


Figure 21-2e

Mucosa

- Moist epithelial layer that lines the lumen of the alimentary canal
- Three major functions:
  - Secretion of mucus
  - Absorption of end products of digestion
  - Protection against infectious disease
- Consists of three layers: a lining epithelium, lamina propria, and muscularis mucosae

Enteric Nervous System (ENS)

- Composed of two major intrinsic nerve plexuses:
  - Submucosal nerve plexus – regulates glands and smooth muscle in the mucosa
  - Myenteric nerve plexus – Major nerve supply that controls GI tract mobility
- Segmentation and peristalsis are largely automatic involving local reflex arcs
- Linked to the CNS via long autonomic reflex arc

Anatomy of the Oral Cavity: Mouth

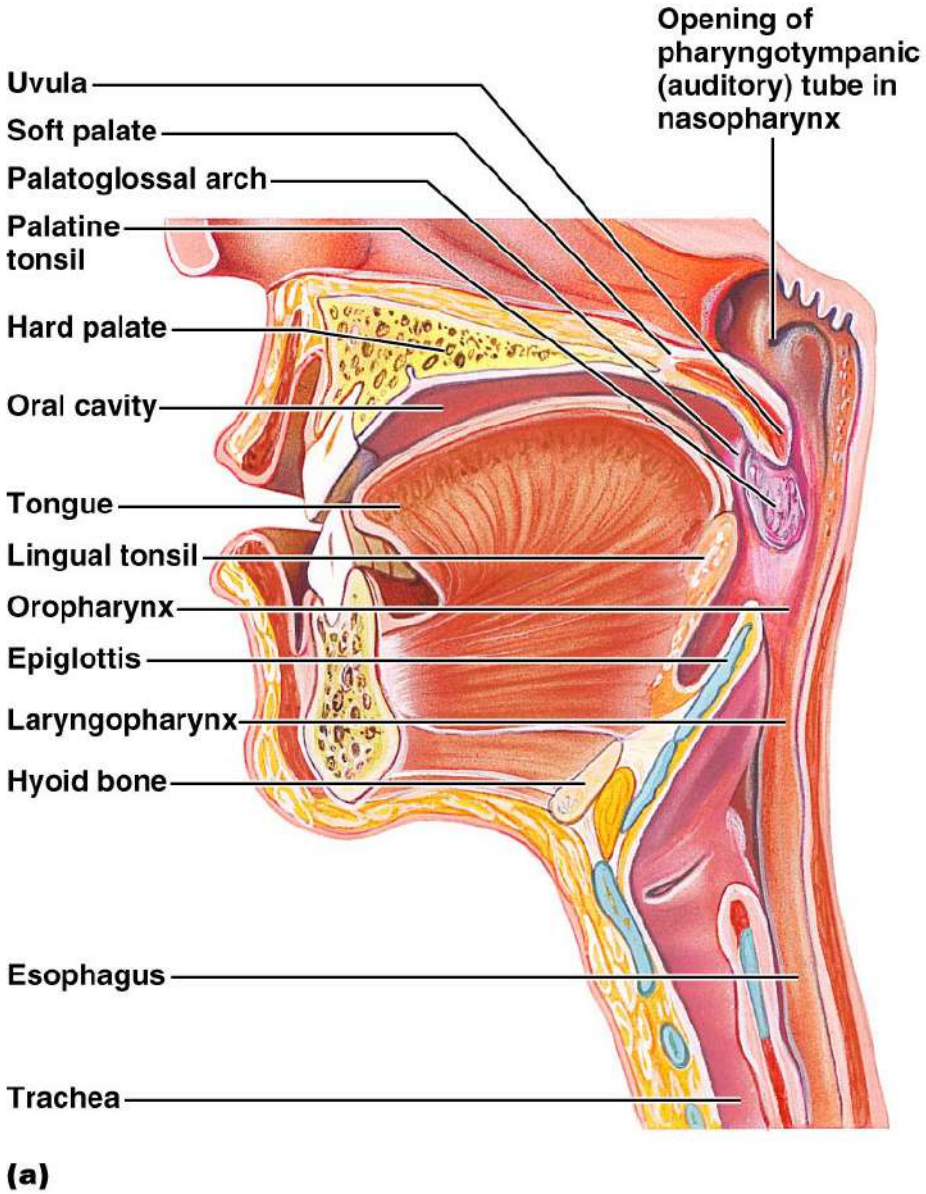


Figure 23.7a

Oral Cavity and Pharynx: Anterior View

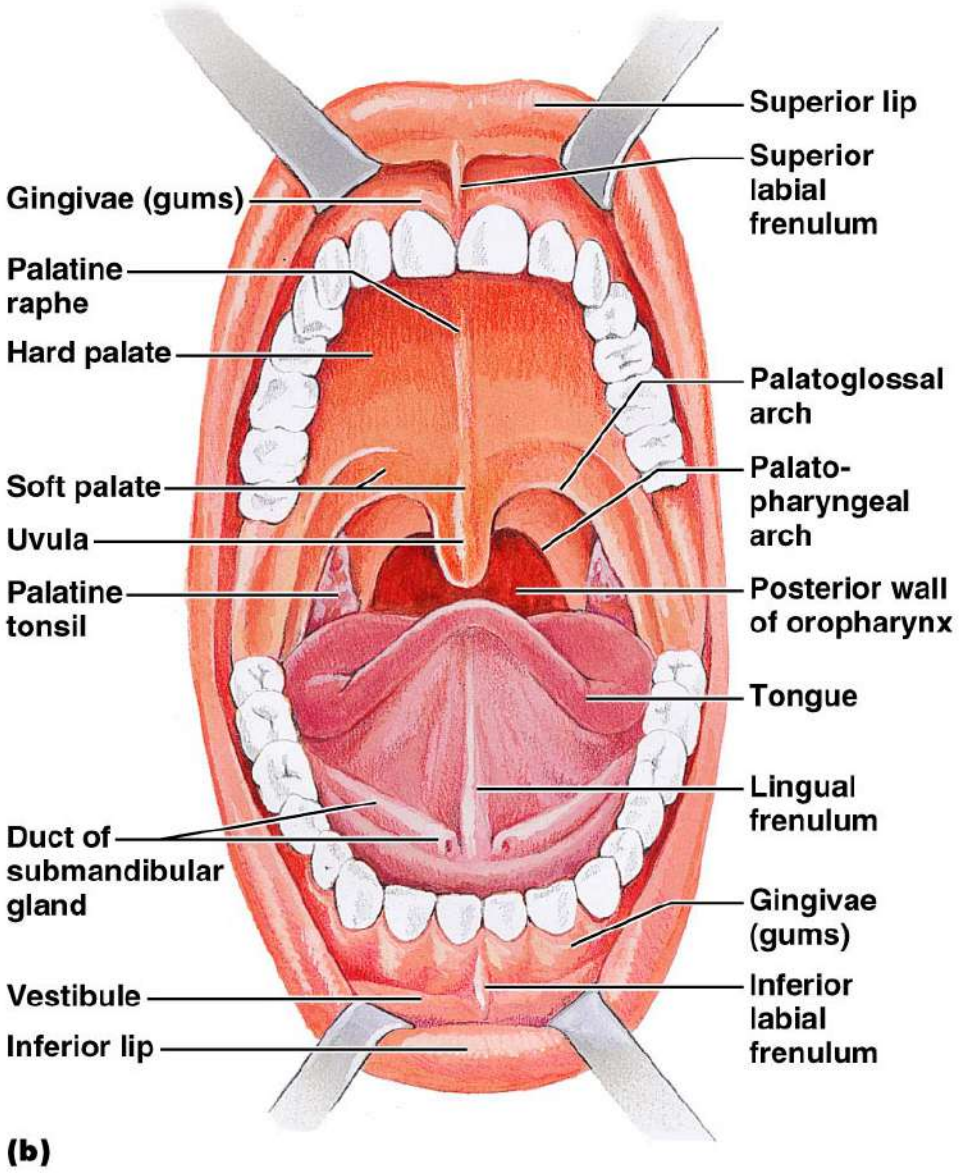


Figure 23.7b

Palate

- Hard palate – underlain by palatine bones
  - Assists the tongue in chewing
- Soft palate – mobile fold formed mostly of skeletal muscle
  - Closes off the nasopharynx during swallowing
  - Uvula projects downward from its free edge

Tongue

- Occupies the floor of the mouth and fills the oral cavity when mouth is closed
- Functions include:
  - Gripping and repositioning food during chewing
  - Mixing food with saliva and forming the bolus
  - Initiation of swallowing, and speech

Tongue

- Intrinsic muscles change the shape of the tongue
- Extrinsic muscles alter the tongue's position
- Lingual frenulum secures the tongue to the floor of the mouth
- Superior surface bears three types of papillae
  - Filiform, Fungiform and Circumvallate

Tongue

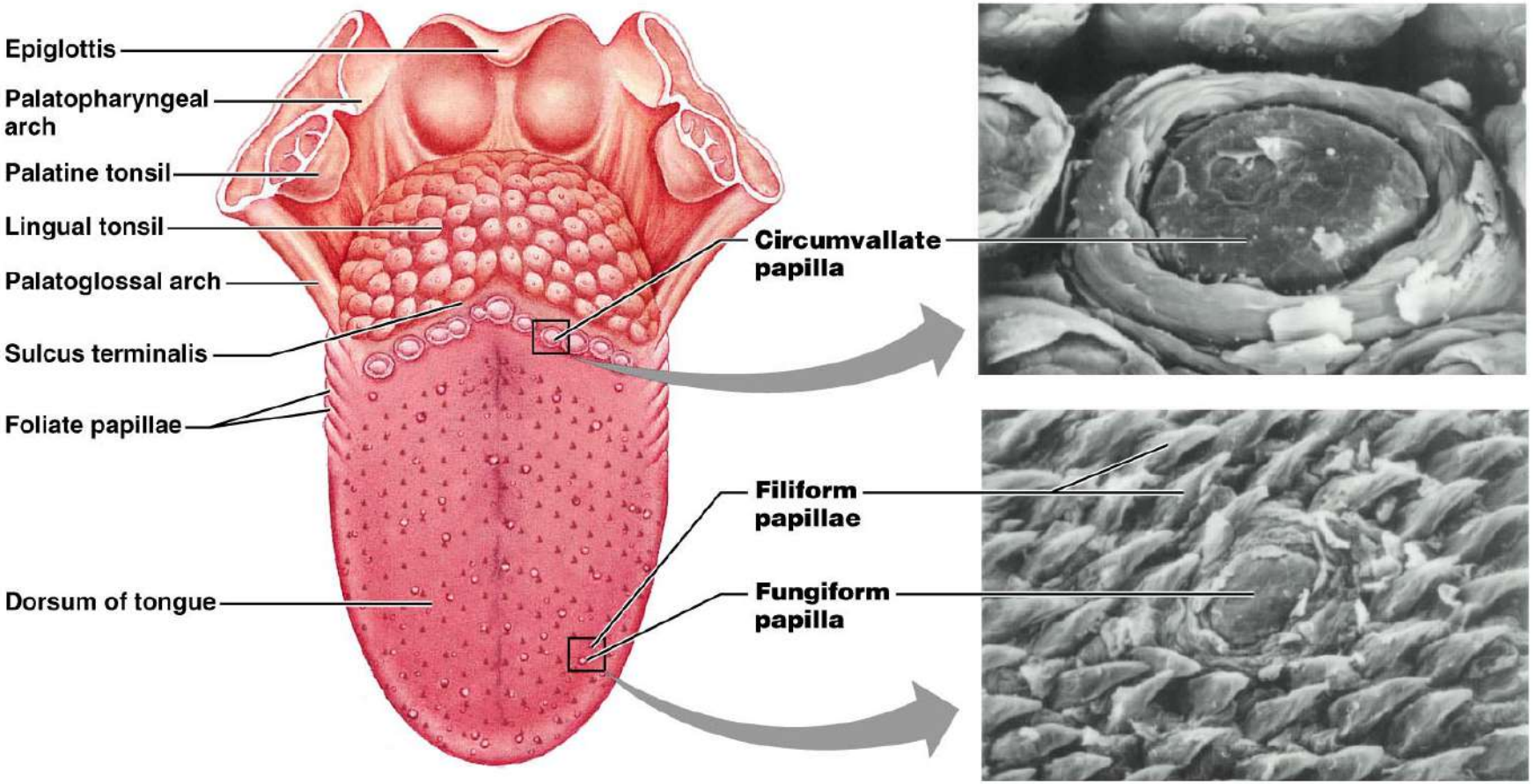


Figure 23.8

Salivary Glands

- Produce and secrete saliva that:
  - Cleanses the mouth
  - Moistens and dissolves food chemicals
  - Aids in bolus formation
  - Contains enzymes that break down starch

Salivary Glands

- Parotid – lies anterior to the ear between the masseter muscle and skin
- Submandibular – lies along the medial aspect of the mandibular body
- Sublingual – lies anterior to the submandibular gland under the tongue
- Intrinsic salivary glands (buccal glands) – scattered throughout the oral mucosa

Salivary Glands

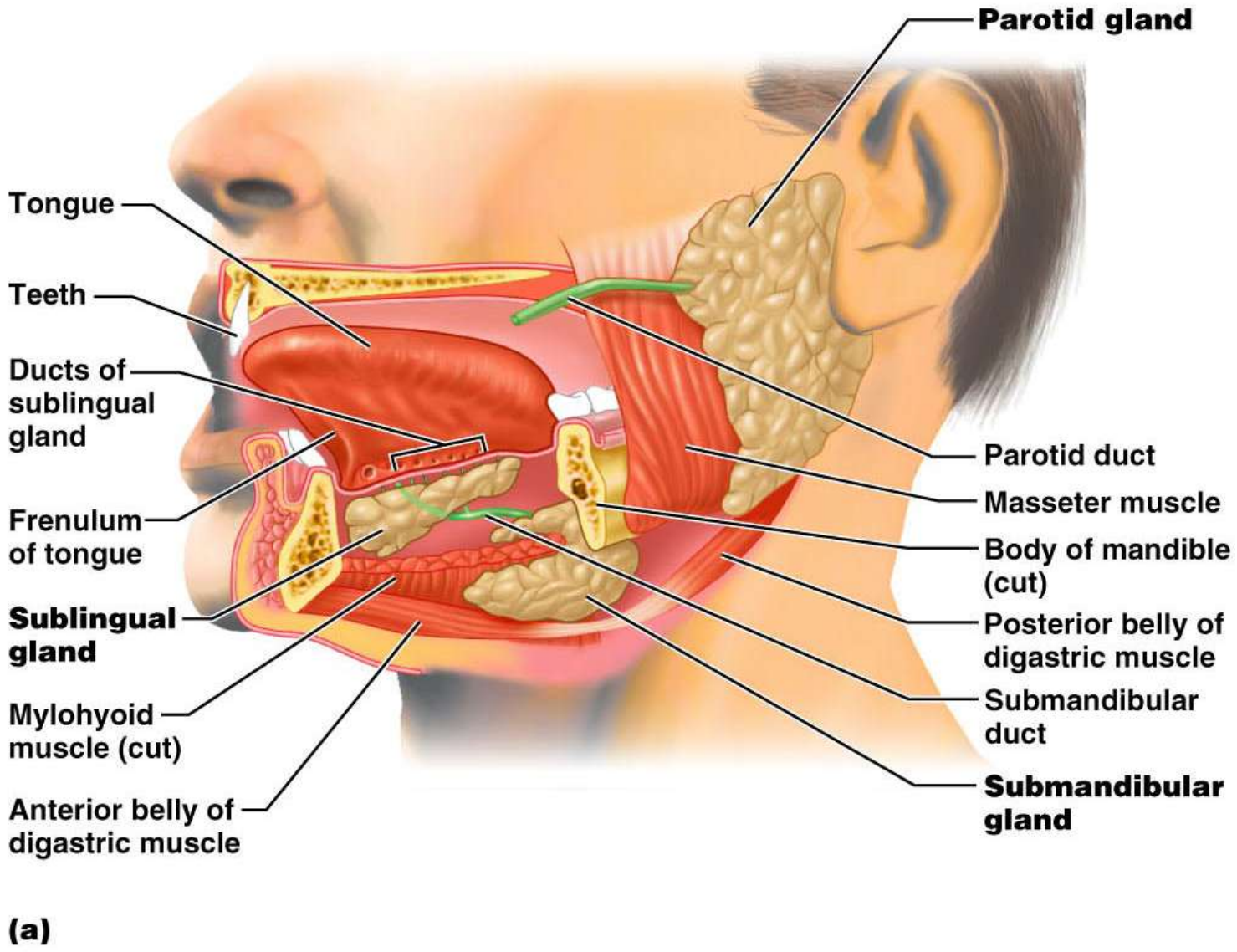


Figure 23.9a

Saliva: Source and Composition

- Secreted from serous and mucous cells of salivary glands
- 97-99.5% water, hypo-osmotic, slightly acidic solution containing
  - Electrolytes – Na^+, K^+, Cl^-, PO_4^{2-}, HCO_3^-
  - Digestive enzyme – salivary amylase
  - Proteins – mucin, lysozyme, defensins, and IgA
  - Metabolic wastes – urea and uric acid

Function and Control of Salivation

- Intrinsic glands keep the mouth moist
- Extrinsic glands secrete serous, enzyme-rich saliva in response to:
  - Ingested food which stimulates chemoreceptors and pressoreceptors
  - The thought of food
- **Strong sympathetic stimulation inhibits salivation and results in dry mouth**

Permanent Teeth

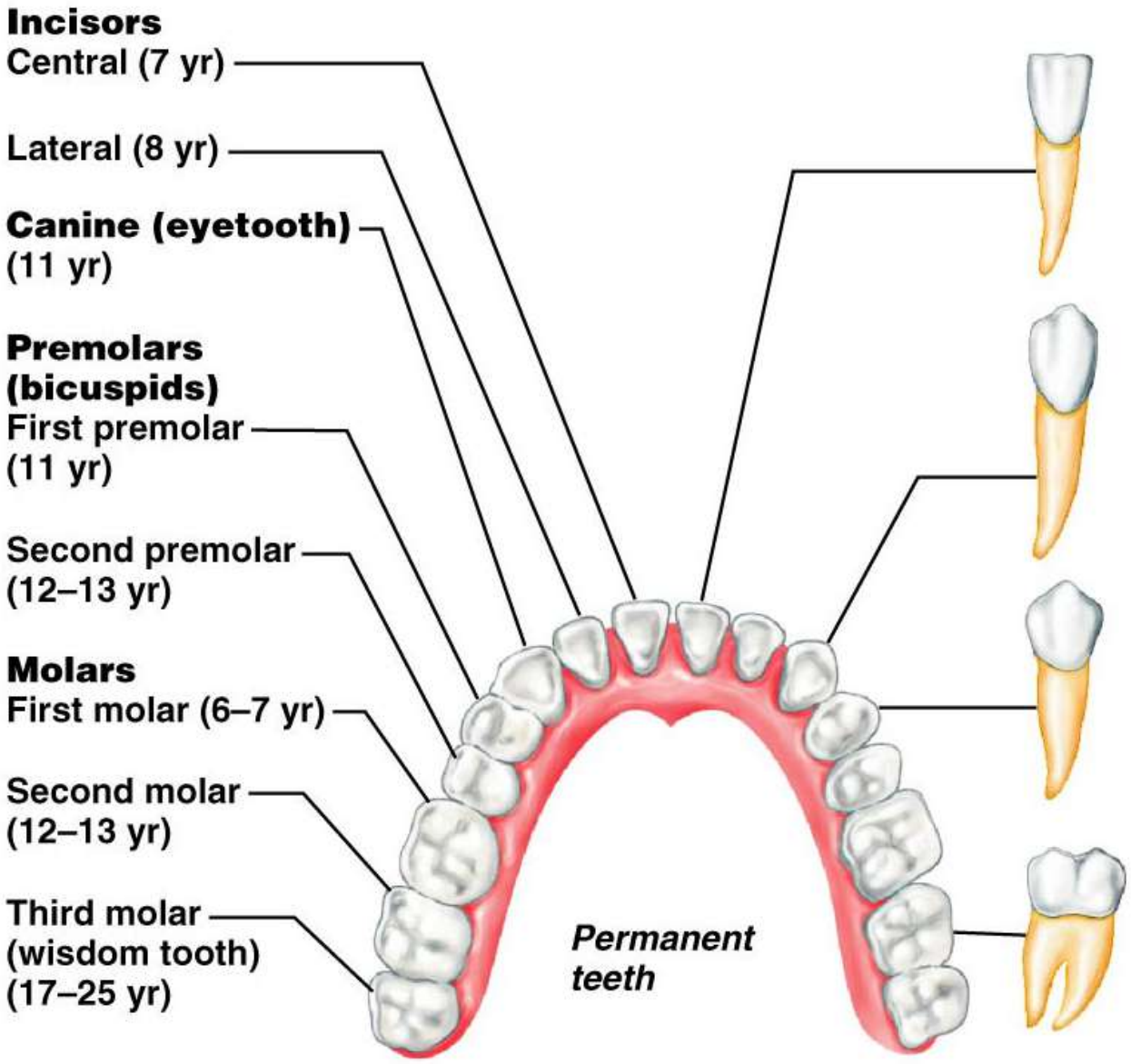


Figure 23.10.2

Tooth Structure

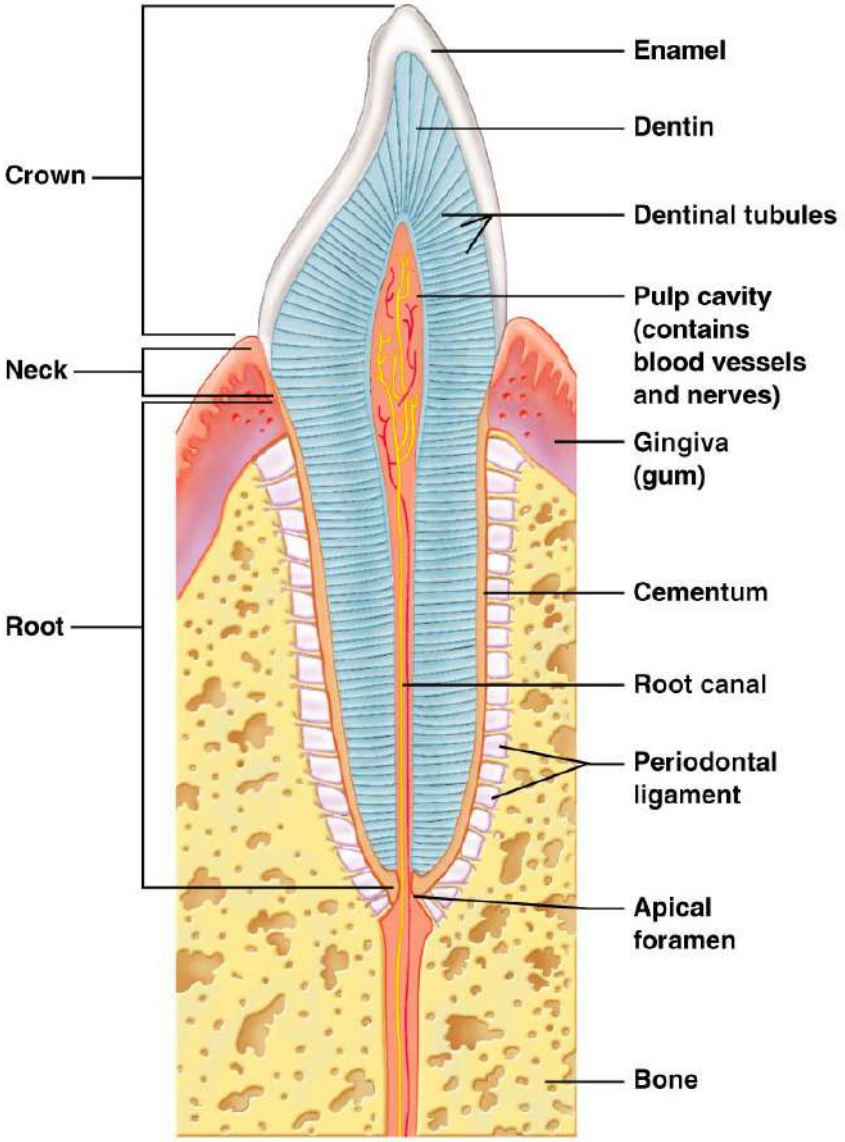


Figure 23.11

Pharynx

- From the mouth, the oro- and laryngopharynx allow passage of:
  - Food and fluids to the esophagus
  - Air to the trachea
- Lined with stratified squamous epithelium and mucus glands
- Has two skeletal muscle layers
  - Inner longitudinal
  - Outer pharyngeal constrictors

Esophagus

- Muscular tube going from the laryngopharynx to the stomach
- Travels through the mediastinum and pierces the diaphragm
- Joins the stomach at the cardiac orifice

Esophagus

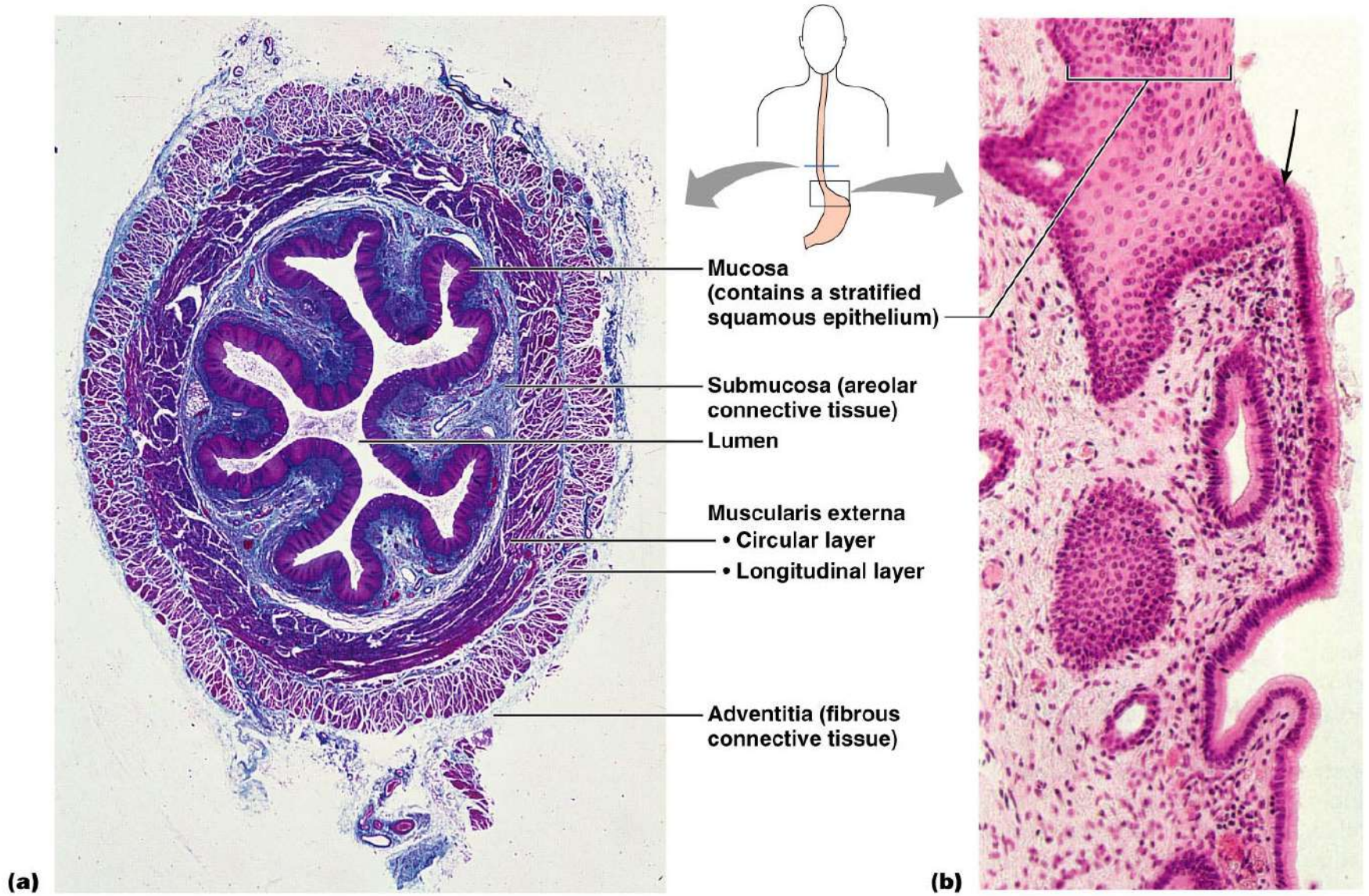
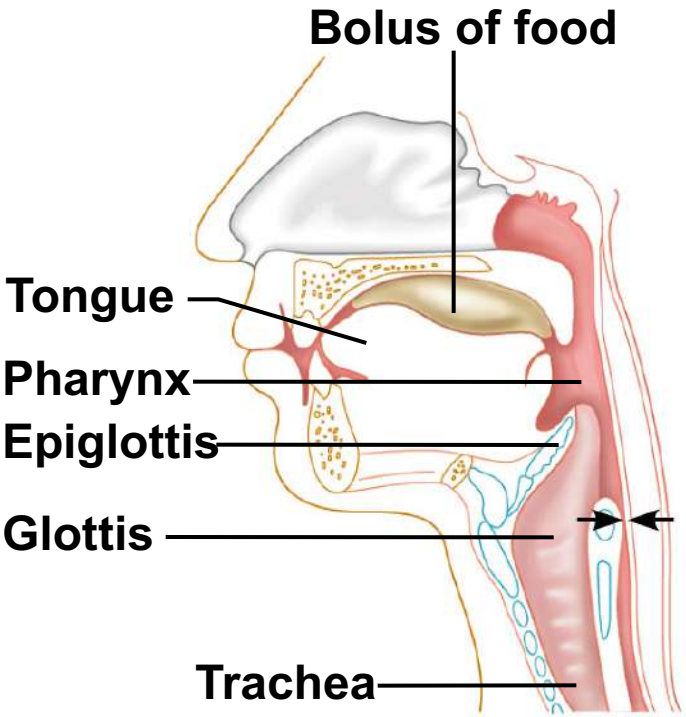


Figure 23.12

Digestive Processes in the Mouth

- Mechanical digestion begins (chewing)
- Salivary amylase begins chemical breakdown of starch
- Propulsion is initiated by swallowing
- The pharynx and esophagus serve as conduits to pass food from the mouth to the stomach

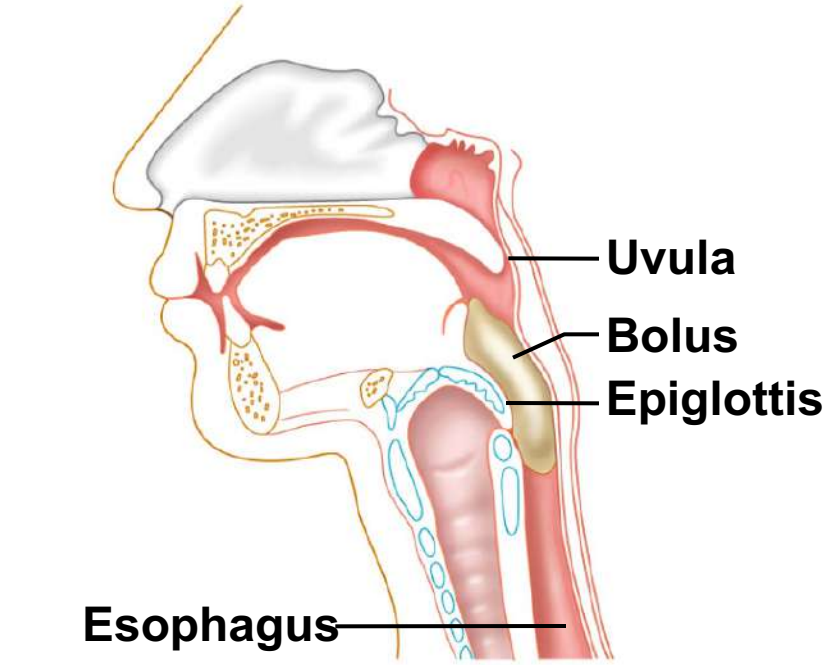
Deglutition (Swallowing)



(a) Upper esophagea sphincter contracted

Figure 23.13

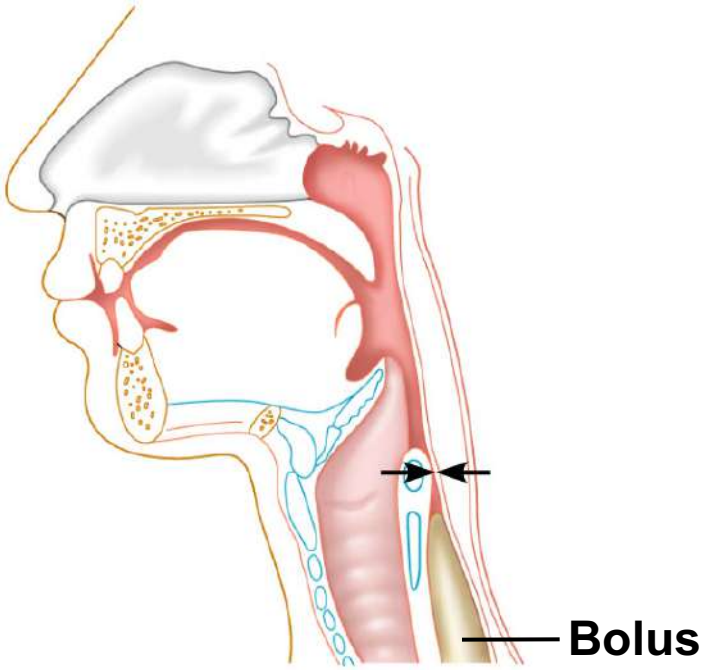
Deglutition (Swallowing)



(b) Upper esophageal sphincter relaxed

Figure 23.13

Deglutition (Swallowing)



(c) Upper esophageal sphincter contracted

Figure 23.13

Deglutition (Swallowing)

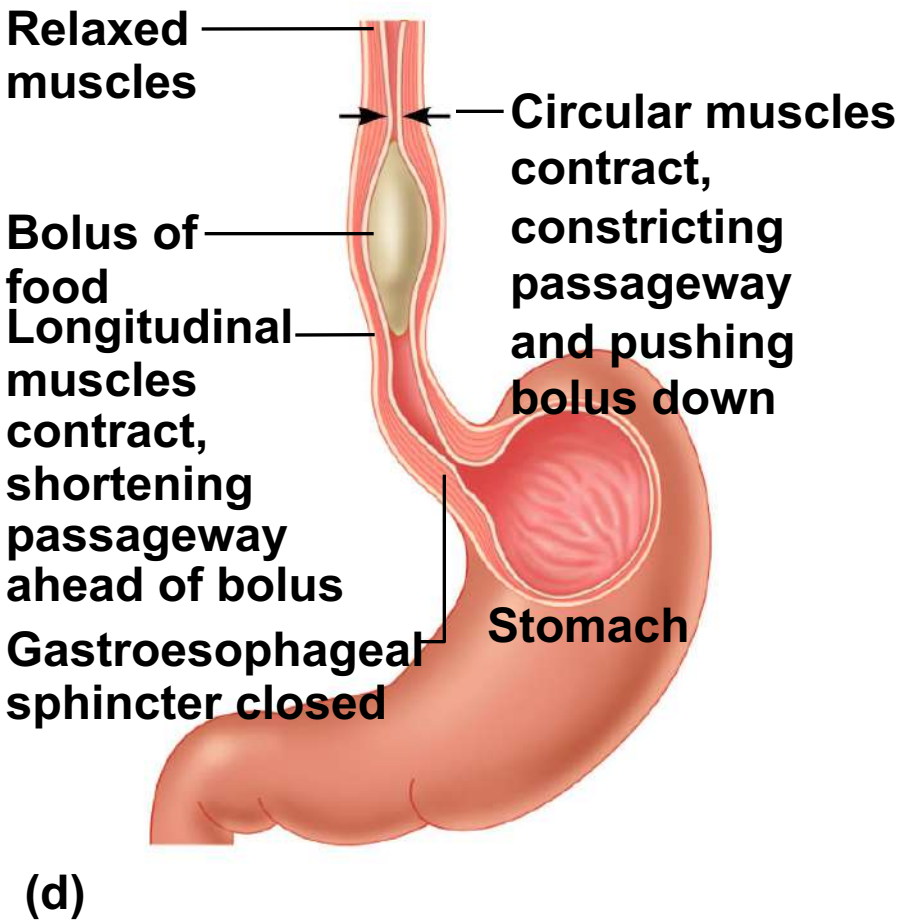


Figure 23.13

Deglutition (Swallowing)

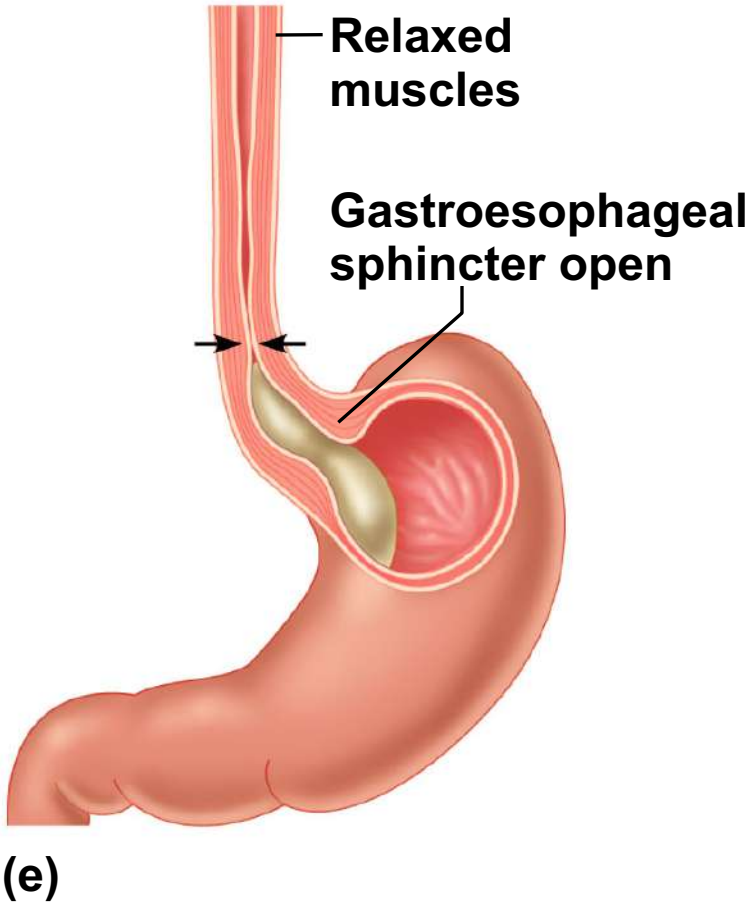


Figure 23.13

Stomach

- Chemical breakdown of proteins begins and food is converted to **chyme**
- Cardiac region – surrounds the cardiac orifice
- Fundus – dome-shaped region beneath the diaphragm
- Body – midportion of the stomach
- Pyloric region – made up of the antrum and canal which terminates at the pylorus
- The pylorus is continuous with the duodenum through the pyloric sphincter

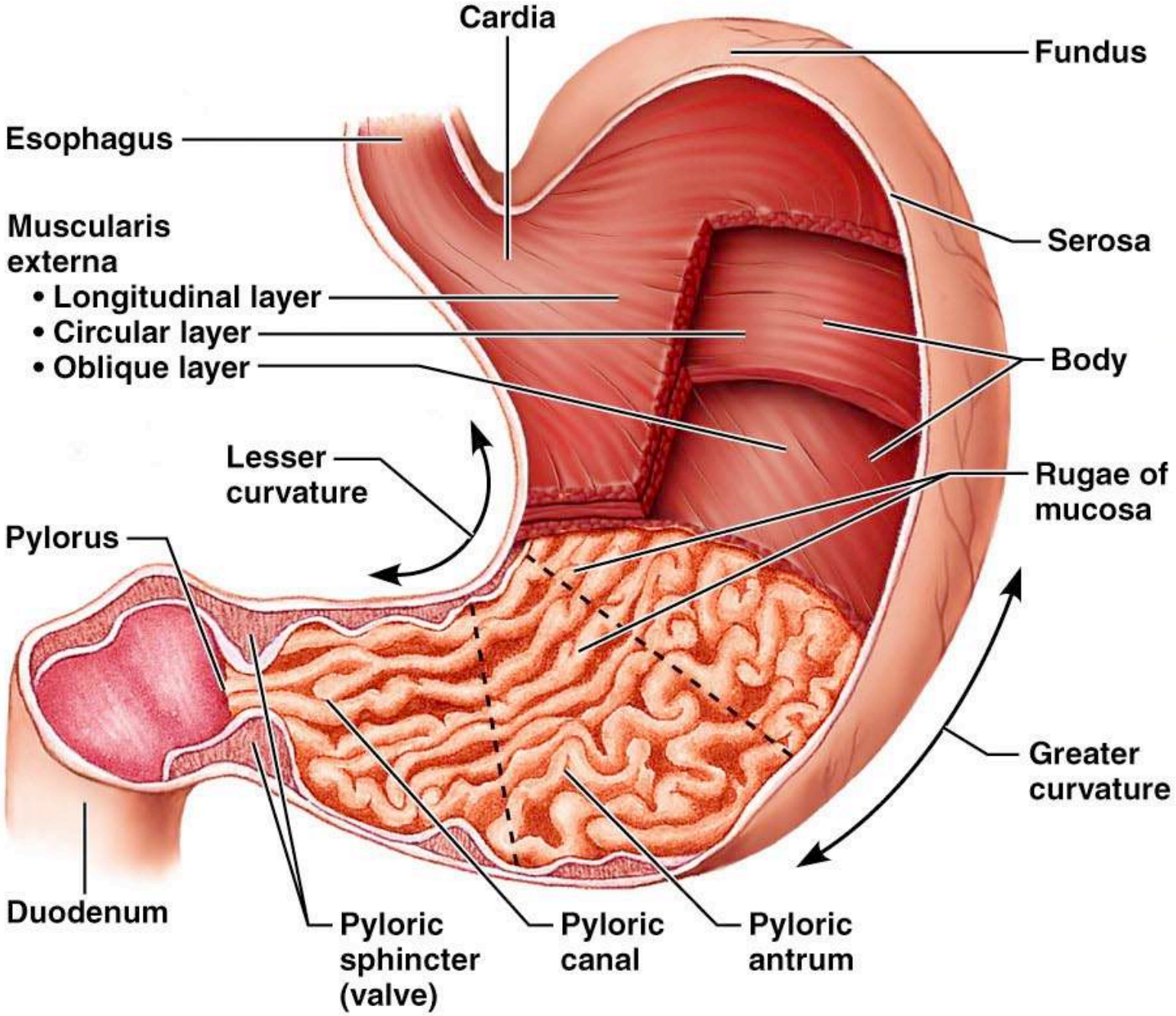


Figure 23.14a

(c) In the stomach, surface area is increased by invaginations called gastric glands.

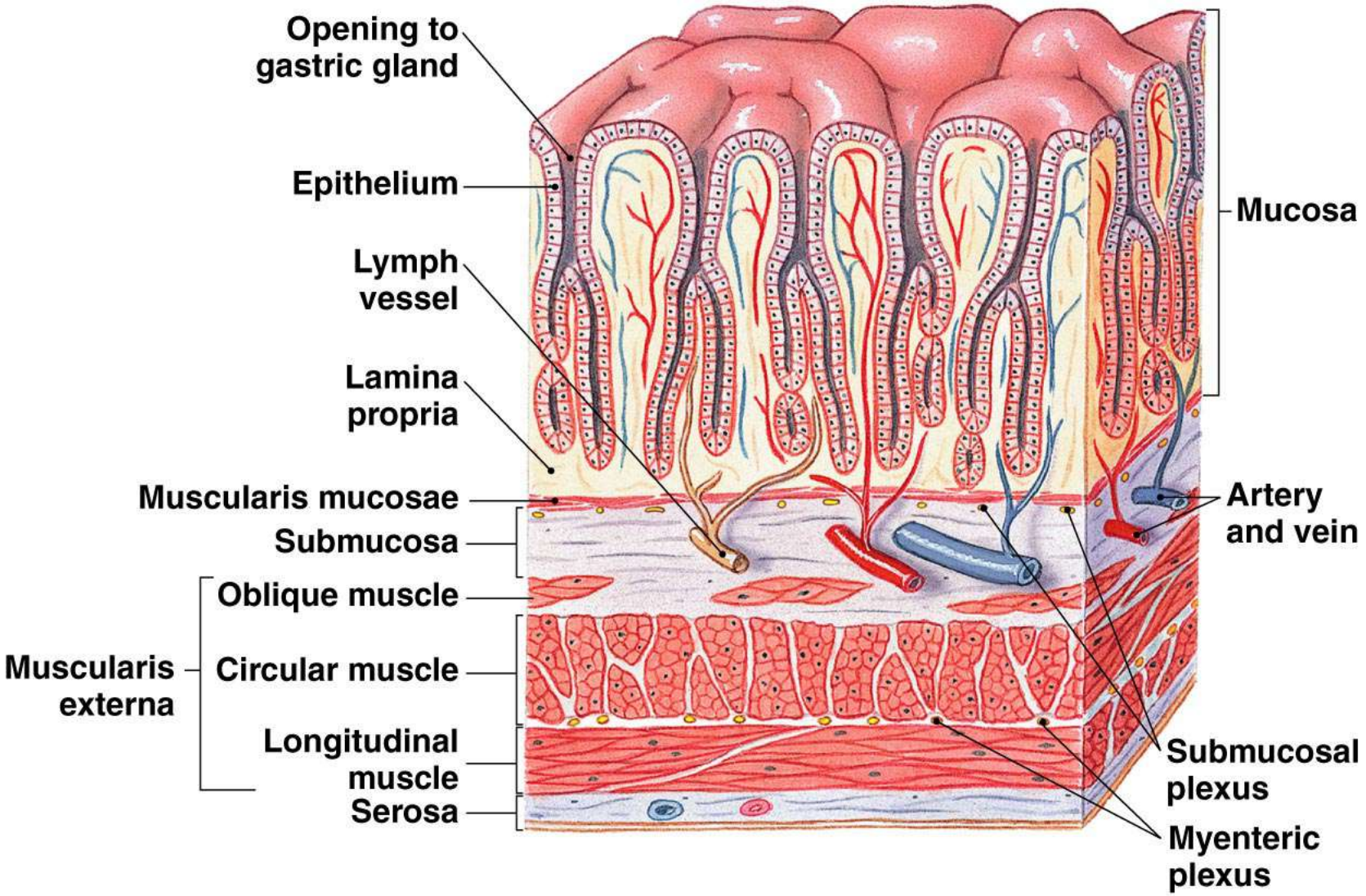


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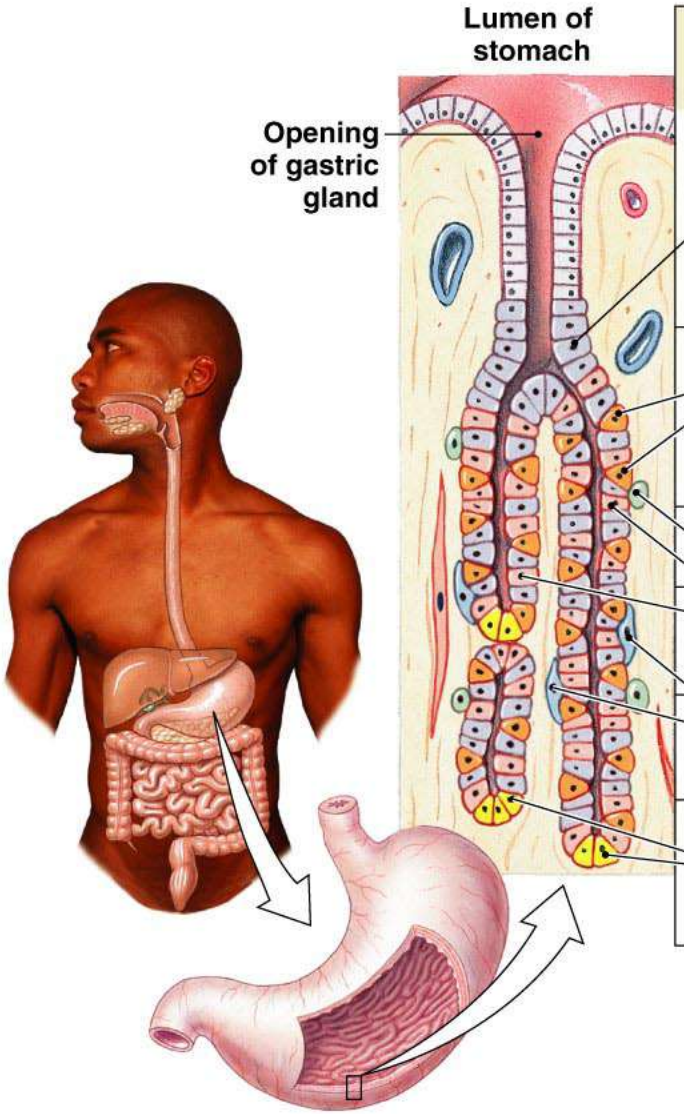
Figure 21-2c



Cell Types	Substance Secreted	Stimulus for Release	Function of Secretion
Mucous neck cell	Mucus	Tonic secretion; with irritation of mucosa	Physical barrier between lumen and epithelium
	Bicarbonate	Secreted with mucus	Buffers gastric acid to prevent damage to epithelium
Parietal cells	Gastric acid (HCl)	Acetylcholine, gastrin, histamine	Activates pepsin; kills bacteria
	Intrinsic factor		Complexes with vitamin B_{12} to permit absorption
Enterochromaffin-like cell	Histamine	Acetylcholine, gastrin	Stimulates gastric acid secretion
Chief cells	Pepsin(ogen)	Acetylcholine acid, secretin	Digests proteins
	Gastric lipase		Digests fats
D cells	Somatostatin	Acid in the stomach	Inhibits gastric acid secretion
G cells	Gastrin	Acetylcholine, peptides, and amino acids	Stimulates gastric acid secretion

Figure 21-25

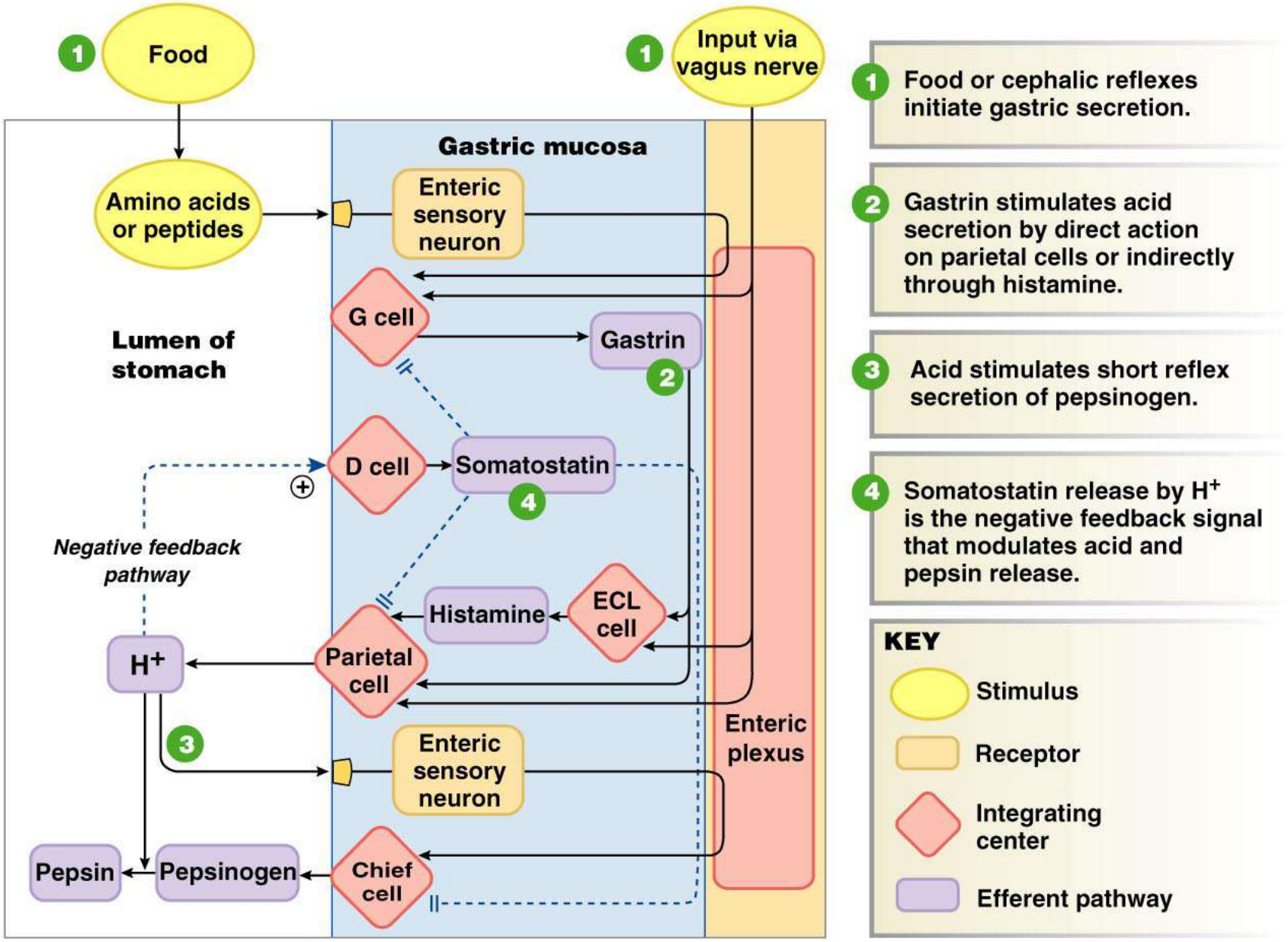


Figure 21-26

Regulation of Gastric Secretion

- Neural and hormonal mechanisms regulate the release of gastric juice
- Stimulatory and inhibitory events occur in three phases
  - Cephalic (reflex) phase: prior to food entry
  - Gastric phase: once food enters the stomach
  - Intestinal phase: as partially digested food enters the duodenum

Cephalic Phase

- Excitatory events include: (feedforward)
  - Sight or thought of food
  - Stimulation of taste or smell receptors
- Inhibitory events include:
  - Loss of appetite or depression
  - Decrease in stimulation of the parasympathetic division

Gastric Phase

- Excitatory events include:
  - 1. Stomach distension, 2. Activation of stretch receptors (neural activation), 3. Activation of chemoreceptors by peptides, caffeine, and rising pH and 4. Release of gastrin to the blood
- Inhibitory events include:
  - A pH lower than 2 and Emotional upset that overrides the parasympathetic division

Intestinal Phase

- Excitatory phase – low pH; partially digested food enters the duodenum and encourages gastric gland activity
- Inhibitory phase – distension of duodenum, presence of fatty, acidic, or hypertonic chyme, and/or irritants in the duodenum
  - Initiates inhibition of local reflexes and vagal nuclei
  - Closes the pyloric sphincter
  - Releases enterogastrones that inhibit gastric secretion

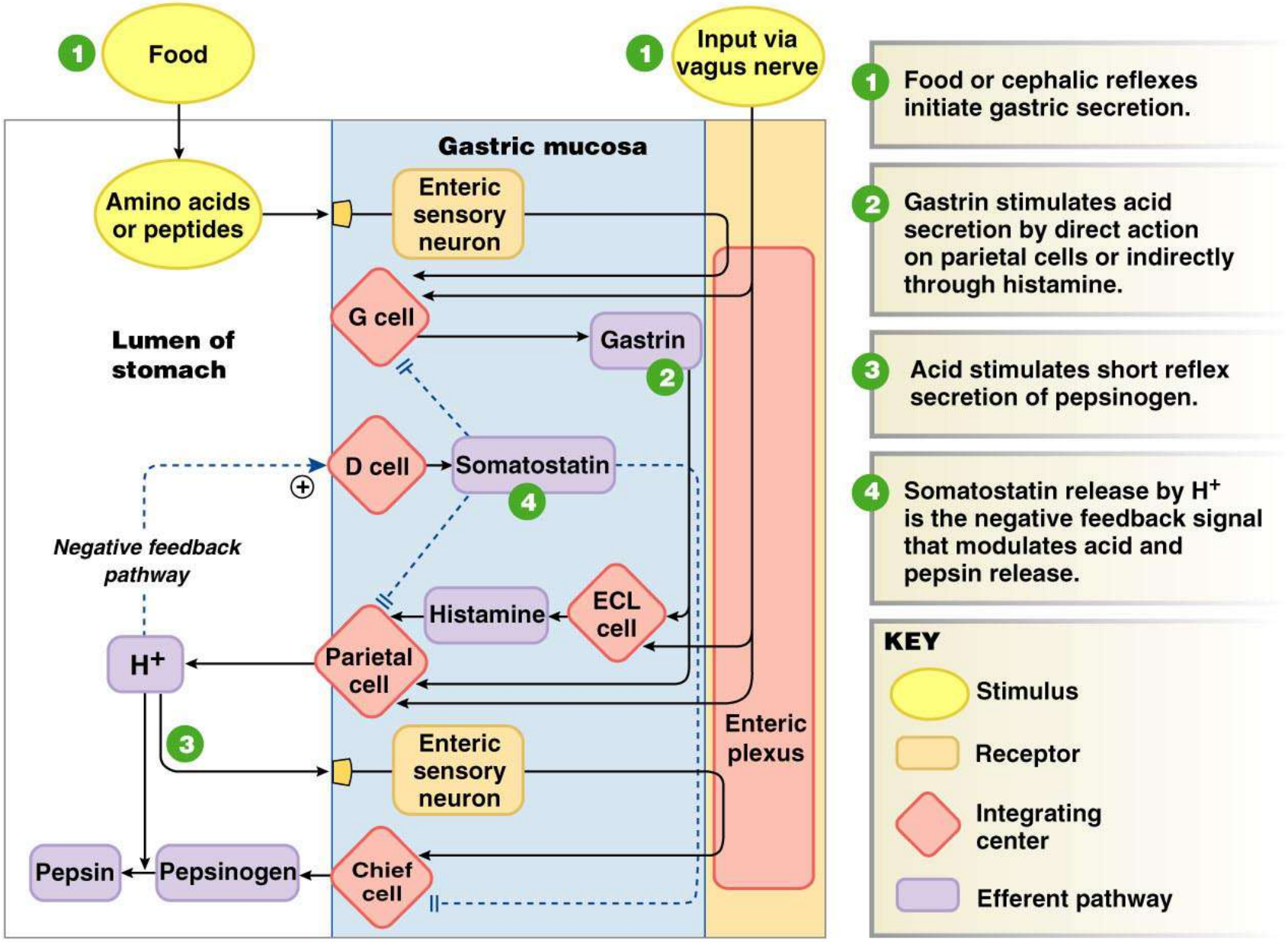


Figure 21-26

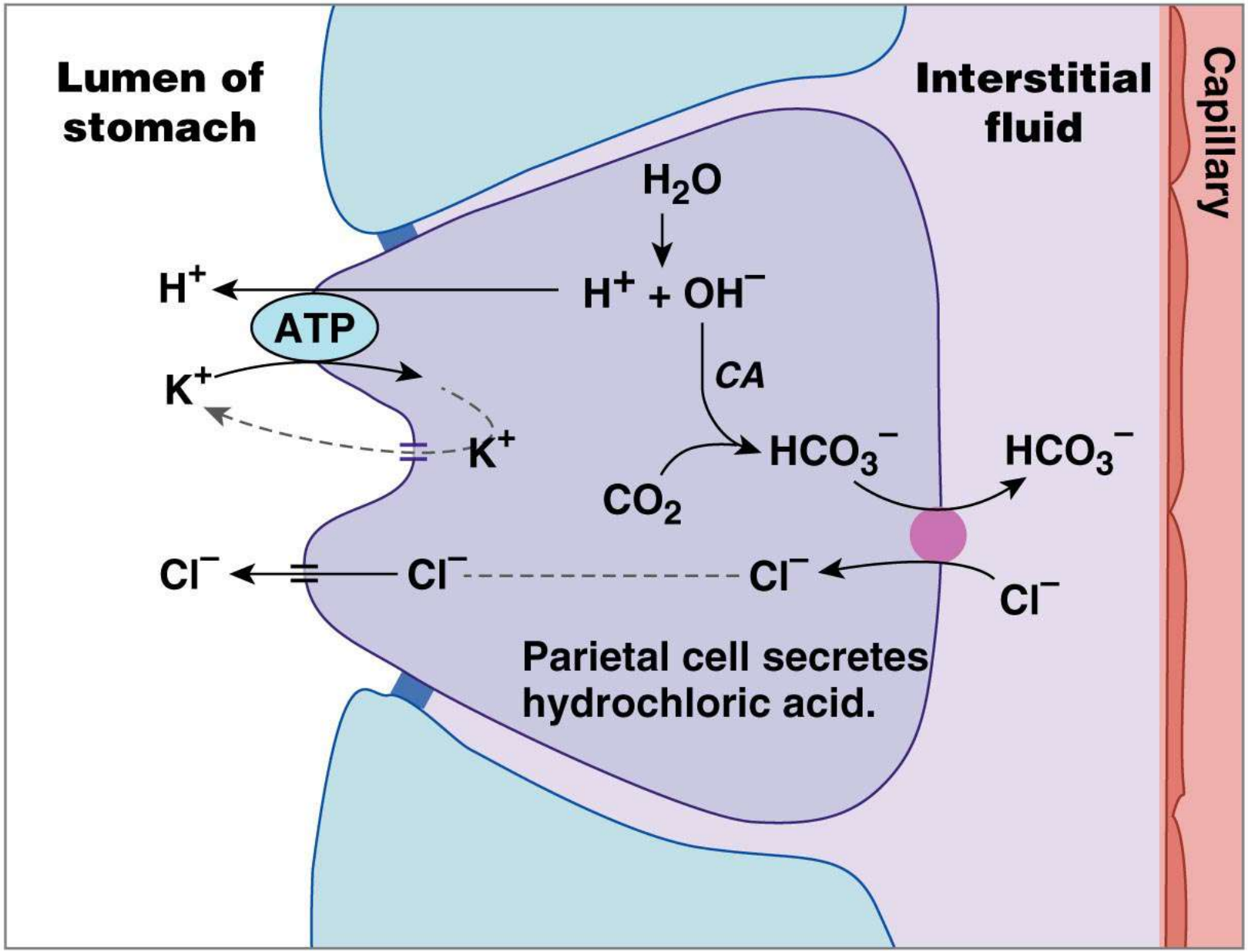


Figure 21-6

Gastric Contractile Activity

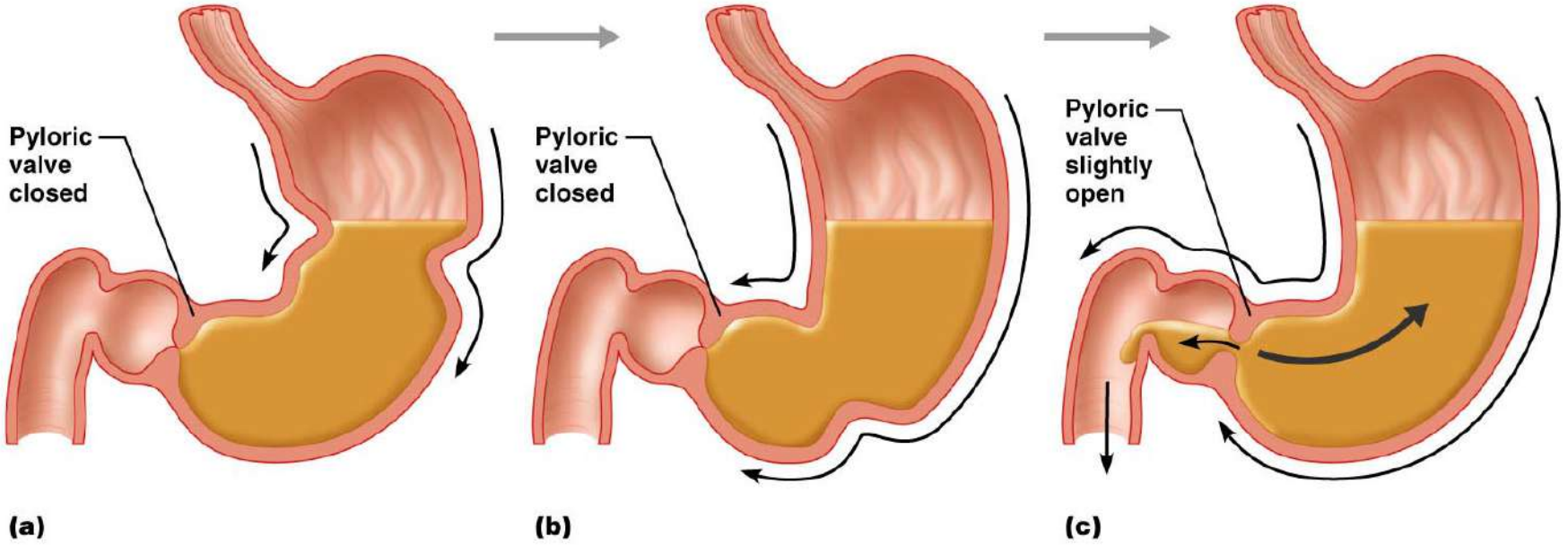


Figure 23.18

Small Intestine: Gross Anatomy

- Has three subdivisions: duodenum, jejunum, and ileum
- The bile duct and main pancreatic duct:
  - Join the duodenum at the hepatopancreatic ampulla
  - Are controlled by the sphincter of Oddi
- The jejunum extends from the duodenum to the ileum
- The ileum joins the large intestine at the ileocecal valve

Duodenum and Related Organs

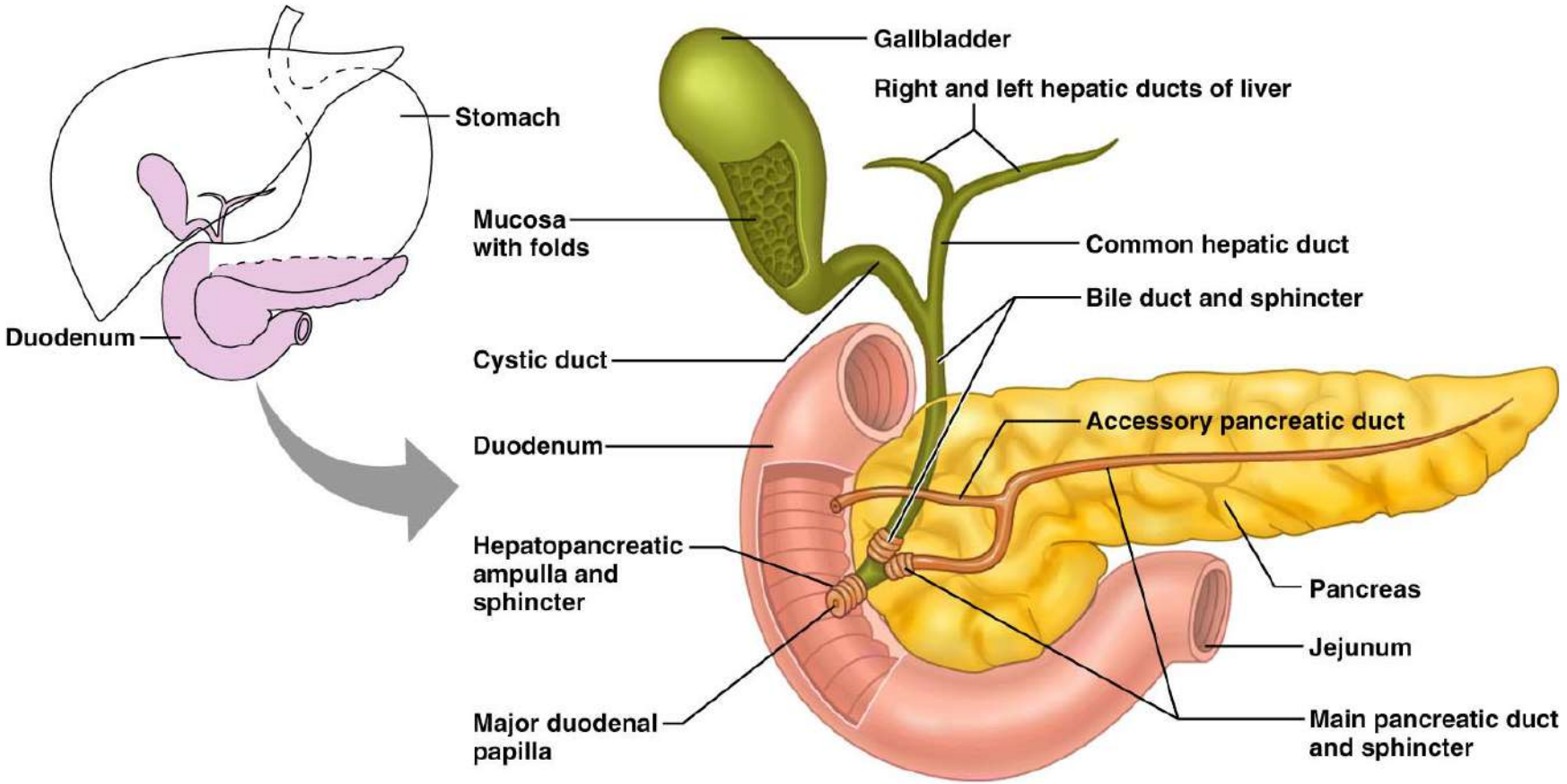


Figure 23.20

Small Intestine: Microscopic Anatomy

- Structural modifications of the small intestine wall increase surface area
  - Plicae circulares: deep circular folds of the mucosa and submucosa
  - Villi – fingerlike extensions of the mucosa
  - Microvilli – tiny projections of absorptive mucosal cells' plasma membranes

Small Intestine: Microscopic Anatomy

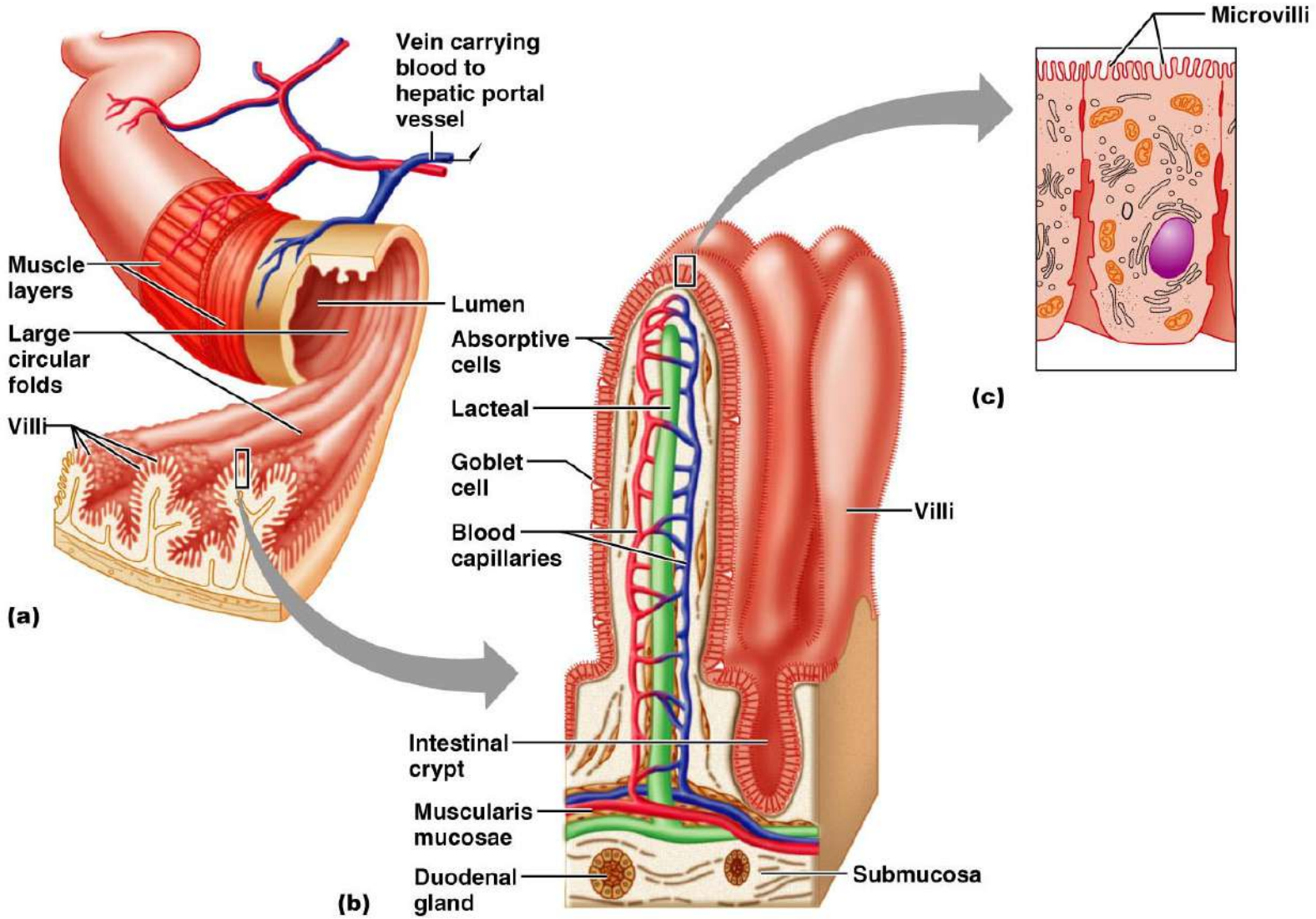


Figure 23.21

Liver

- The largest gland in the body
- Superficially has four lobes – right, left, caudate, and quadrate
- The falciform ligament:
  - Separates the right and left lobes anteriorly
  - Suspends the liver from the diaphragm and anterior abdominal wall

Liver: Associated Structures

- Bile leaves the liver via:
  - Bile ducts, which fuse into the common hepatic duct
  - The common hepatic duct, which fuses with the cystic duct
    - These two ducts form the bile duct

Gallbladder and Associated Ducts

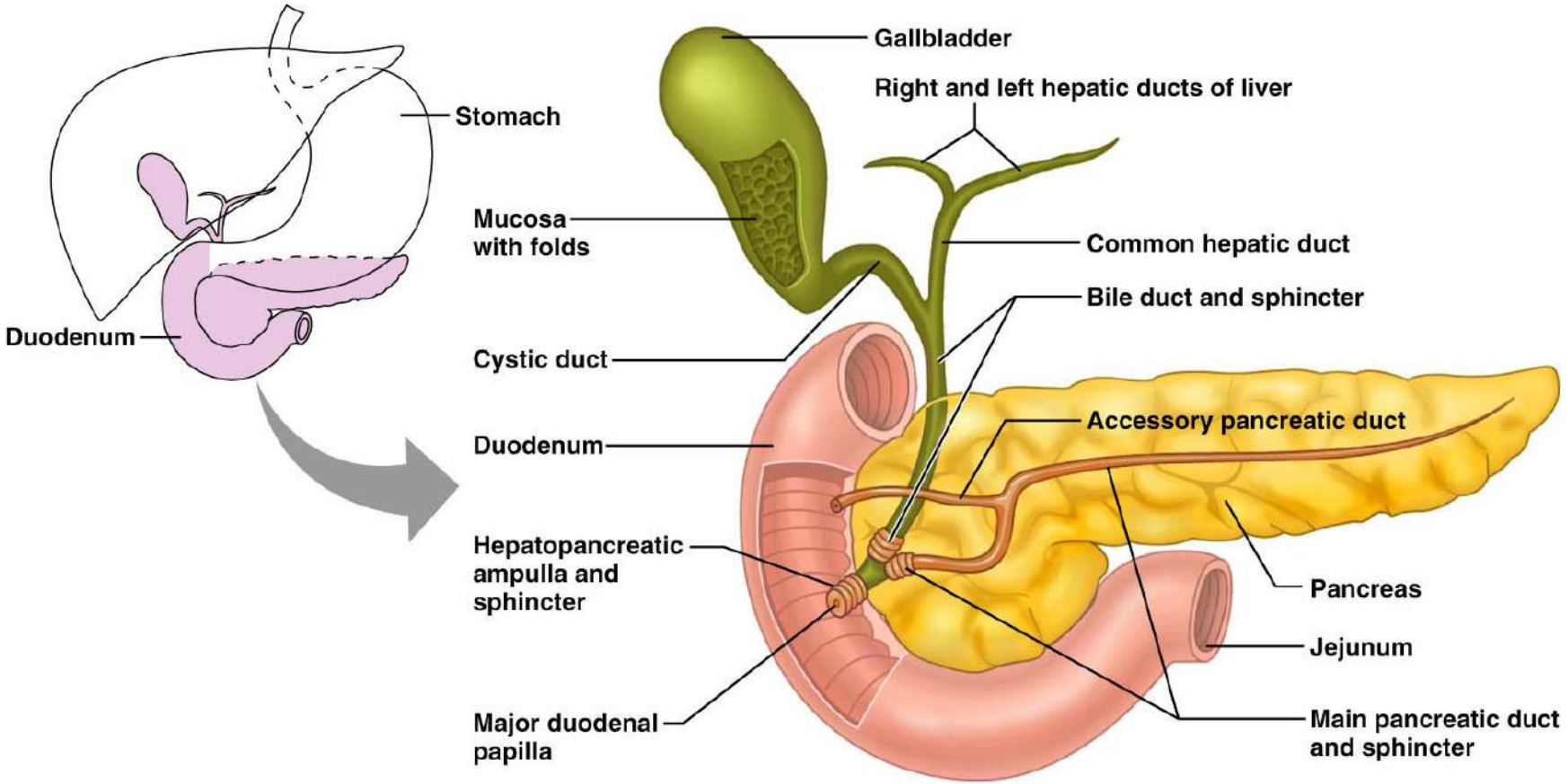


Figure 23.20

Liver: Microscopic Anatomy

- Hexagonal-shaped liver lobules are the structural and functional units of the liver
  - Composed of hepatocyte (liver cell) plates radiating outward from a central vein
  - Portal triads are found at each of the six corners of each liver lobule

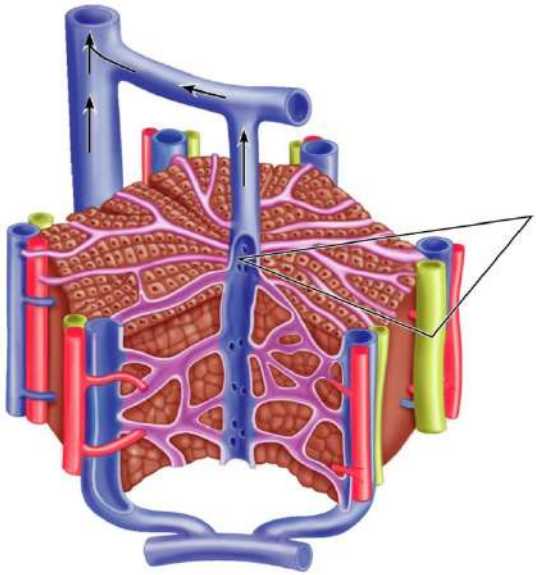


Figure 23.24c

Liver: Microscopic Anatomy

- Hepatocytes' functions include:
  - Production of bile
  - Processing blood borne nutrients
  - Storage of fat-soluble vitamins
  - Detoxification
- Secreted bile flows between hepatocytes toward the bile ducts in the portal triads

Microscopic Anatomy of the Liver

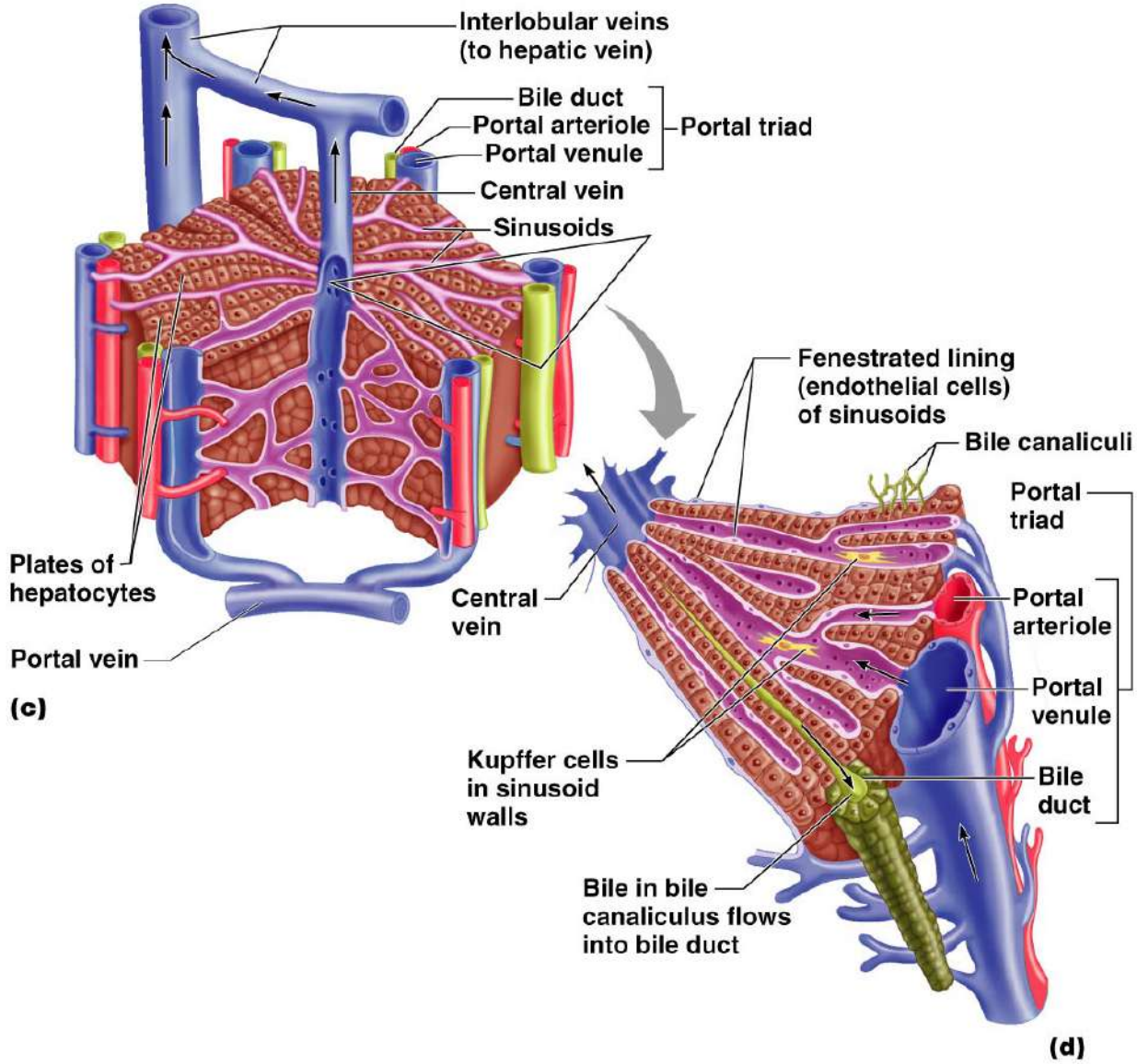


Figure 23.24c, d

Composition of Bile

- A yellow-green, alkaline solution containing bile salts, bile pigments, cholesterol, neutral fats, phospholipids, and electrolytes
- Bile salts are cholesterol derivatives that:
  - Emulsify fat
  - Facilitate fat and cholesterol absorption
  - Help solubilize cholesterol
- Enterohepatic circulation recycles bile salts
- The chief bile pigment is bilirubin, a waste product of heme

The Gallbladder

- Thin-walled, green muscular sac on the ventral surface of the liver
- Stores and concentrates bile by absorbing its water and ions
- Releases bile via the cystic duct, which flows into the bile duct

Regulation of Bile Release

- Acidic, fatty chyme causes the duodenum to release:
  - Cholecystokinin (CCK) and secretin into the bloodstream
- CCK and secretin transported in blood stimulate the liver to produce bile
- Vagal stimulation causes weak contractions of the gallbladder

Regulation of Bile Release

- Cholecystokinin (CCK) causes:
  - The gallbladder to contract
  - The hepatopancreatic (Oddi) sphincter to relax
- As a result, bile enters the duodenum

Regulation of Bile Release

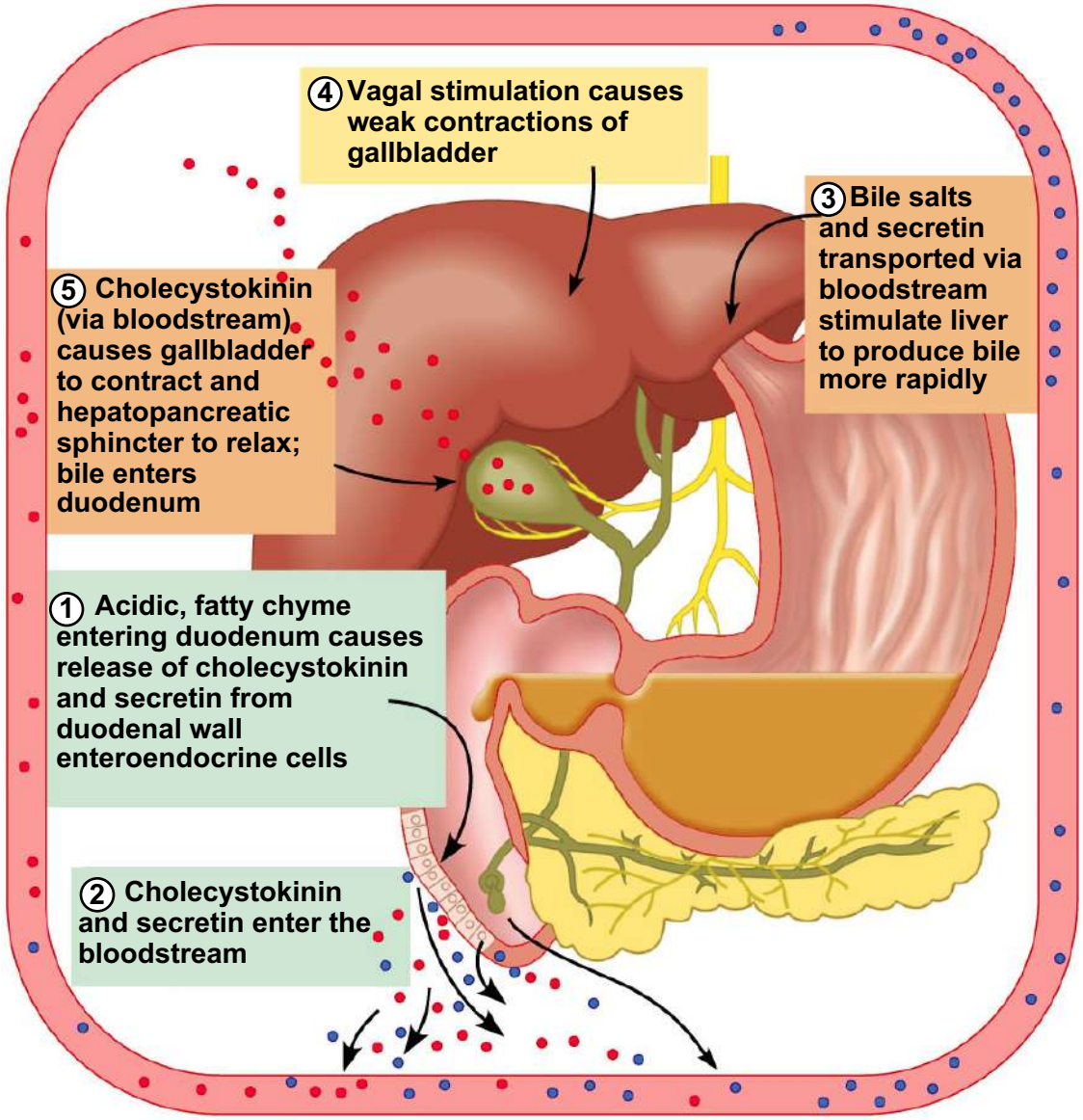


Figure 23.25

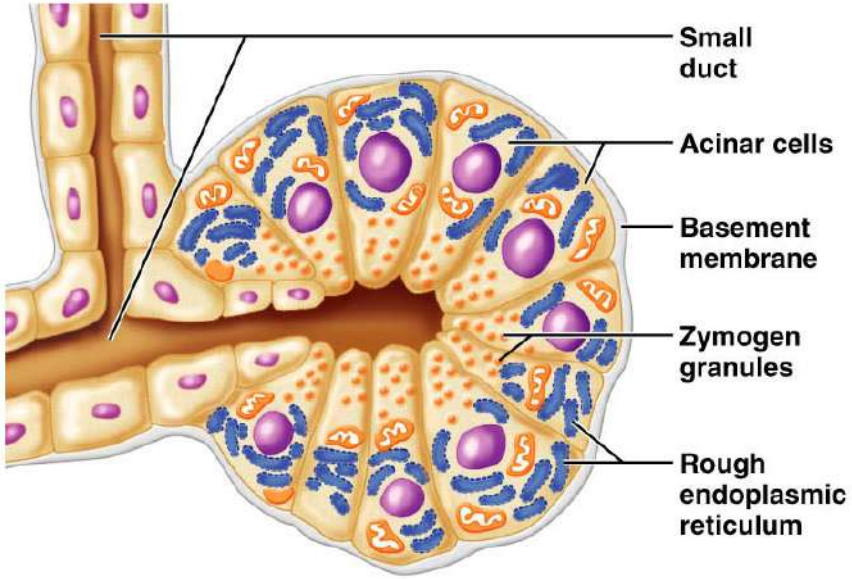
Pancreas

- Location
  - Lies deep to the greater curvature of the stomach
  - The head is encircled by the duodenum and the tail abuts the spleen

Pancreas

- Location
  - Lies deep to the greater curvature of the stomach
- Exocrine function
  - Secretes pancreatic juice which breaks down all categories of foodstuff
  - Acini (clusters of secretory cells) contain zymogen granules with digestive enzymes
- The pancreas also has an endocrine function – release of insulin and glucagon

Exocrine and endocrine cells in Pancreas



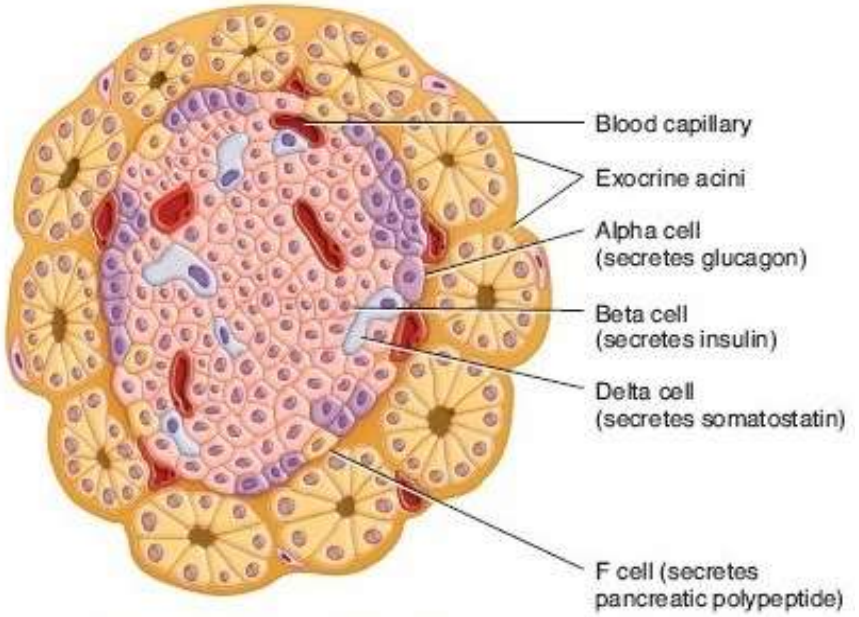
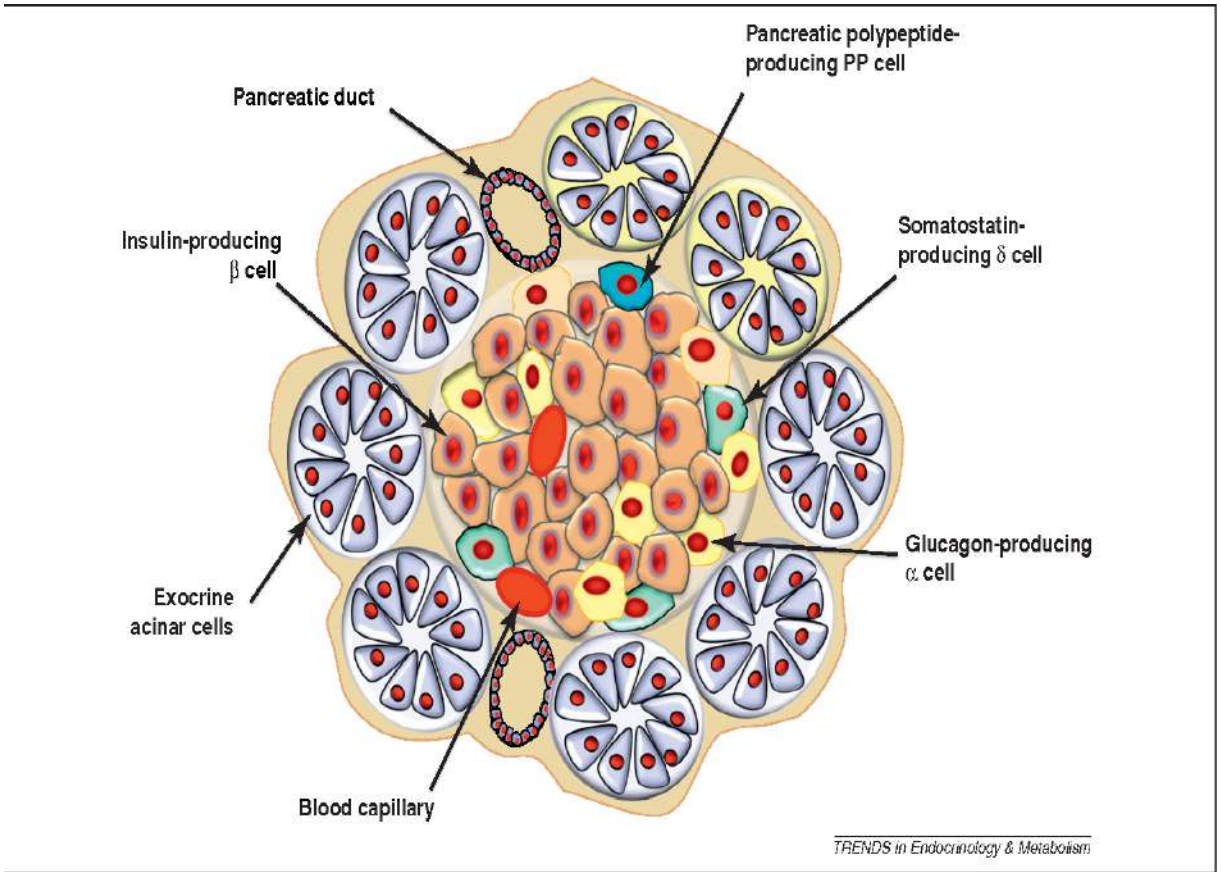


Figure 23.26a



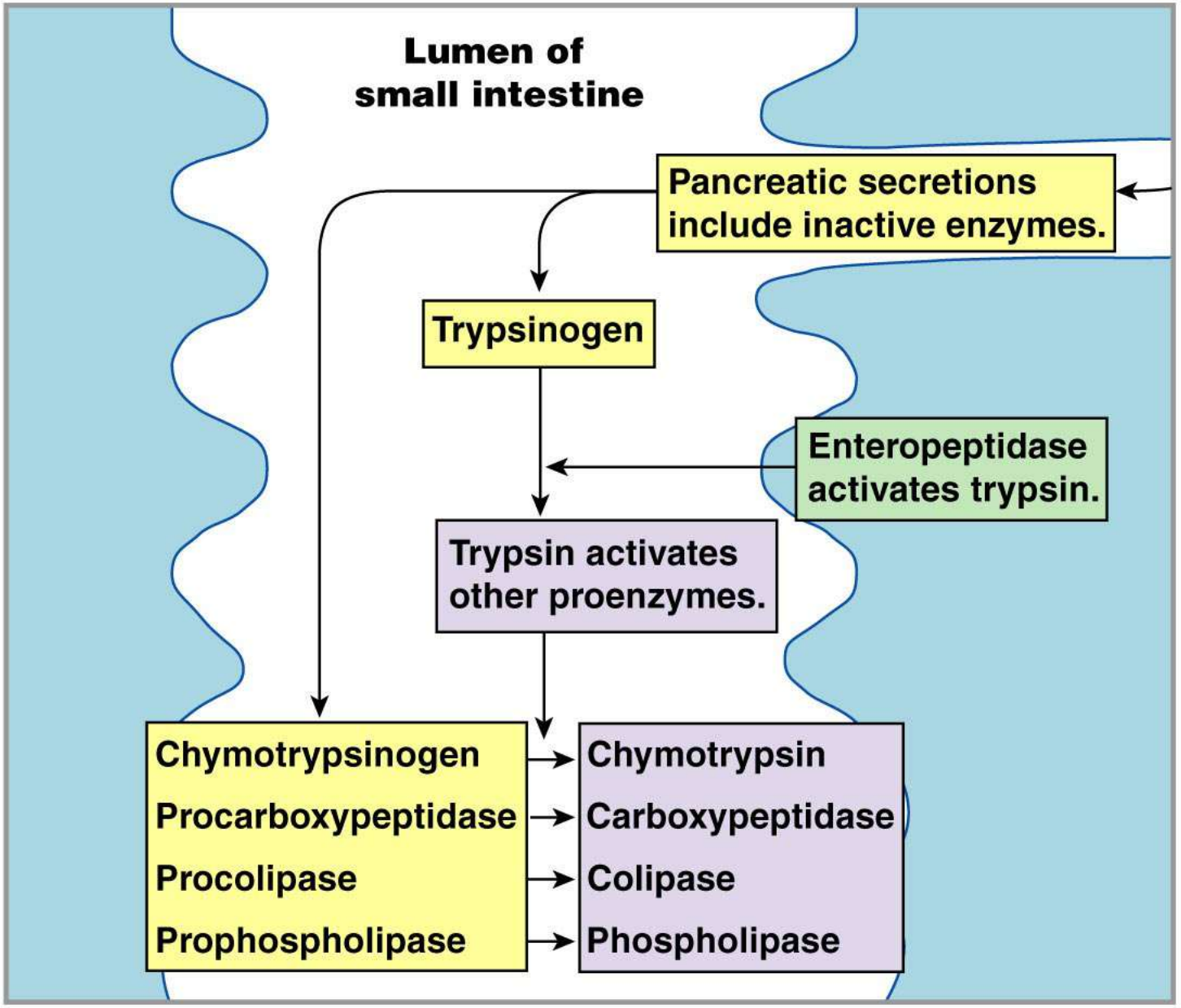


Figure 21-29

Pancreatic Activation

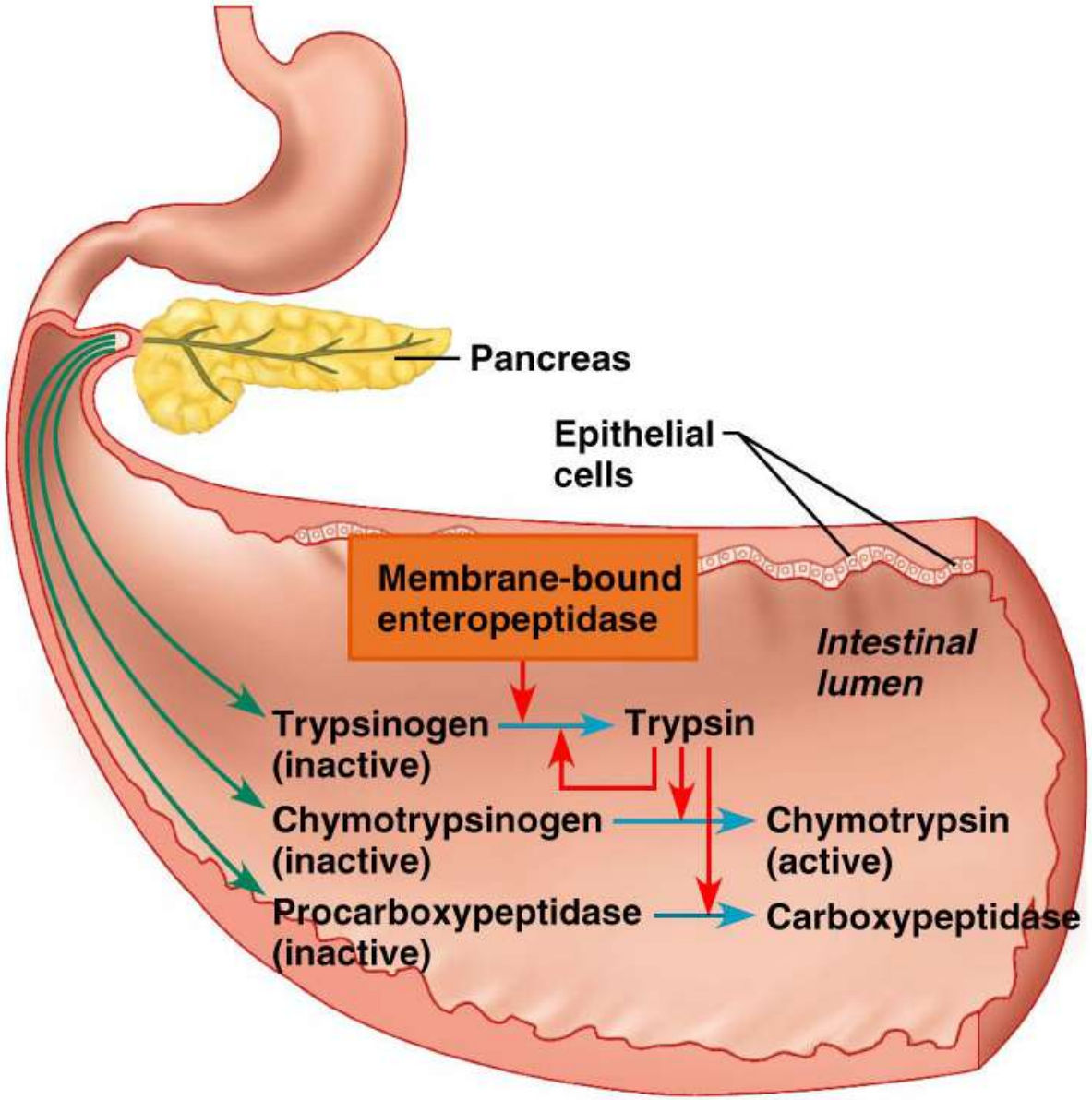


Figure 23.27

Composition and Function of Pancreatic Juice

- Water solution of enzymes and electrolytes (primarily HCO_3^-)
  - Neutralizes acid chyme
  - Provides optimal environment for pancreatic enzymes
- Enzymes are released in inactive form and activated in the duodenum

Composition and Function of Pancreatic Juice

- Examples include
  - Trypsinogen is activated to trypsin
  - Procarboxypeptidase is activated to carboxypeptidase
- Active enzymes secreted
  - Amylase, lipases, and nucleases
  - These enzymes require ions or bile for optimal activity

Regulation of Pancreatic Secretion

- Secretin and CCK are released when fatty or acidic chyme enters the duodenum
- CCK and secretin enter the bloodstream to get to Pancreas
  - CCK induces the secretion of enzyme-rich pancreatic juice
  - Secretin causes secretion of bicarbonate-rich pancreatic juice
- Vagal stimulation also causes release of pancreatic juice

Regulation of Pancreatic Secretion

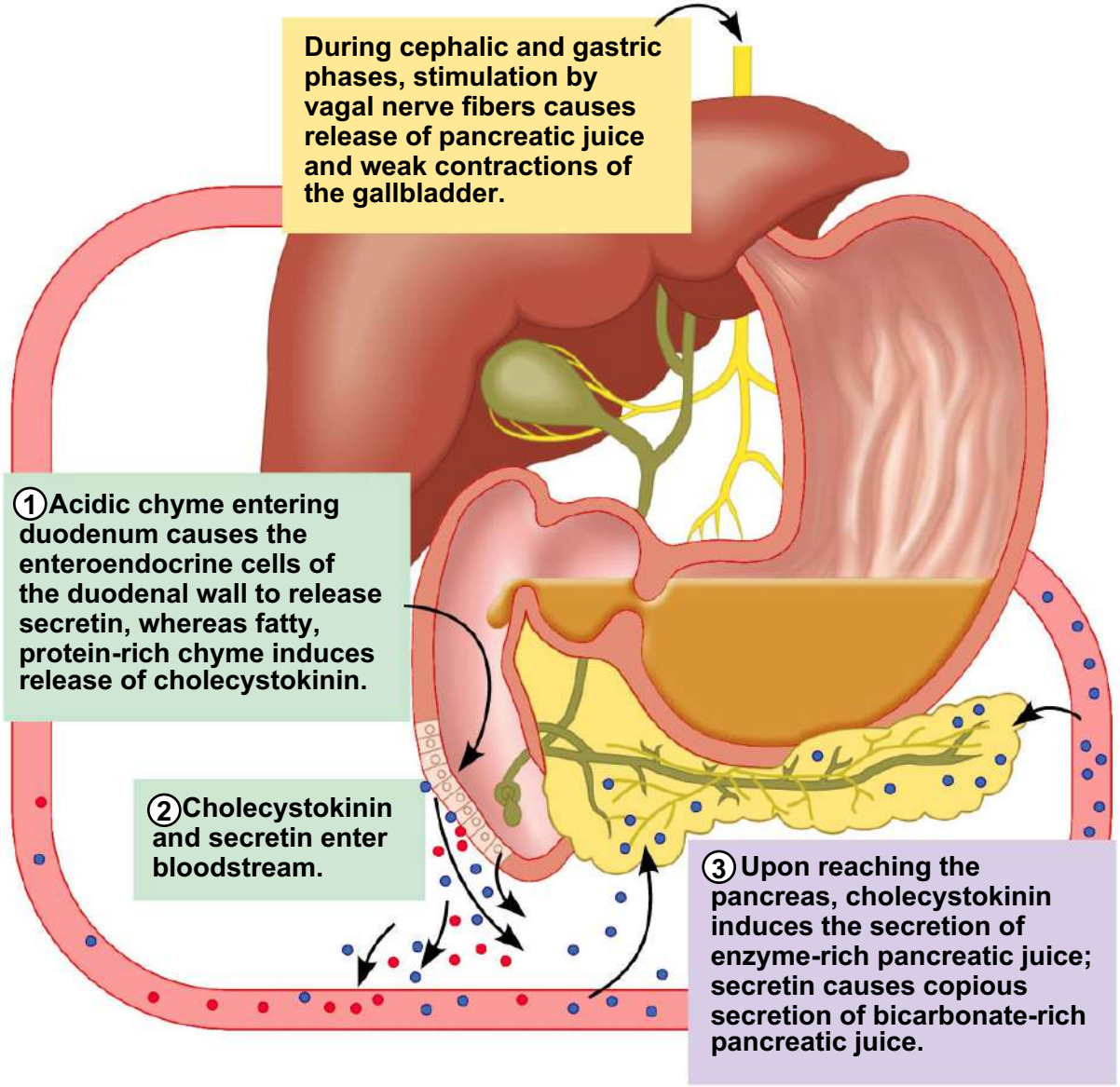


Figure 23.28

TABLE 21-1 The Digestive Hormones

	STIMULUS FOR RELEASE	PRIMARY TARGET(S)	PRIMARY EFFECT(S)	OTHER INFORMATION
STOMACH				
Gastrin	Peptides and amino acids; neural reflexes	ECL cells and parietal cells	Stimulates gastric acid secretion and mucosal growth.	Somatostatin inhibits release.
INTESTINE				
Cholecystokinin (CCK)	Fatty acids and some amino acids	Gallbladder, pancreas, stomach	Stimulates gallbladder contraction and pancreatic enzyme secretion. Inhibits gastric emptying and acid secretion.	Promotes satiety. Some effects may be due to CCK as a neurotransmitter.
Secretin	Acid in small intestine	Pancreas, stomach	Stimulates bicarbonate secretion. Inhibits gastric emptying and acid secretion.	
Motilin	Fasting: periodic release every 1.5–2 hours	Gastric and intestinal smooth muscle	Stimulates migrating motor complex.	Inhibited by eating a meal.
Gastric inhibitory peptide (GIP)	Glucose, fatty acids, and amino acids in small intestine	Beta cells of pancreas	Stimulates insulin release (feedforward mechanism). Inhibits gastric emptying and acid secretion.	
Glucagon-like peptide 1 (GLP-1)	Mixed meal that includes carbohydrates or fats in the lumen	Endocrine pancreas	Stimulates insulin release. Inhibits glucagon release and gastric function.	Promotes satiety.

Digestion in the Small Intestine

- Digestion continues in the small intestine
  - Chyme is released slowly into the duodenum
  - Because it is hypertonic and has low pH, mixing is required for proper digestion
  - Required substances needed are supplied by the liver
  - Virtually all nutrient absorption takes place in the small intestine

Motility in the Small Intestine

- The most common motion of the small intestine is segmentation
  - It is initiated by intrinsic pacemaker cells (Cajal cells)
  - Moves contents steadily toward the ileocecal valve
- After nutrients have been absorbed:
  - Peristalsis begins with each wave starting distal to the previous
  - Meal remnants, bacteria, mucosal cells, and debris are moved into the large intestine

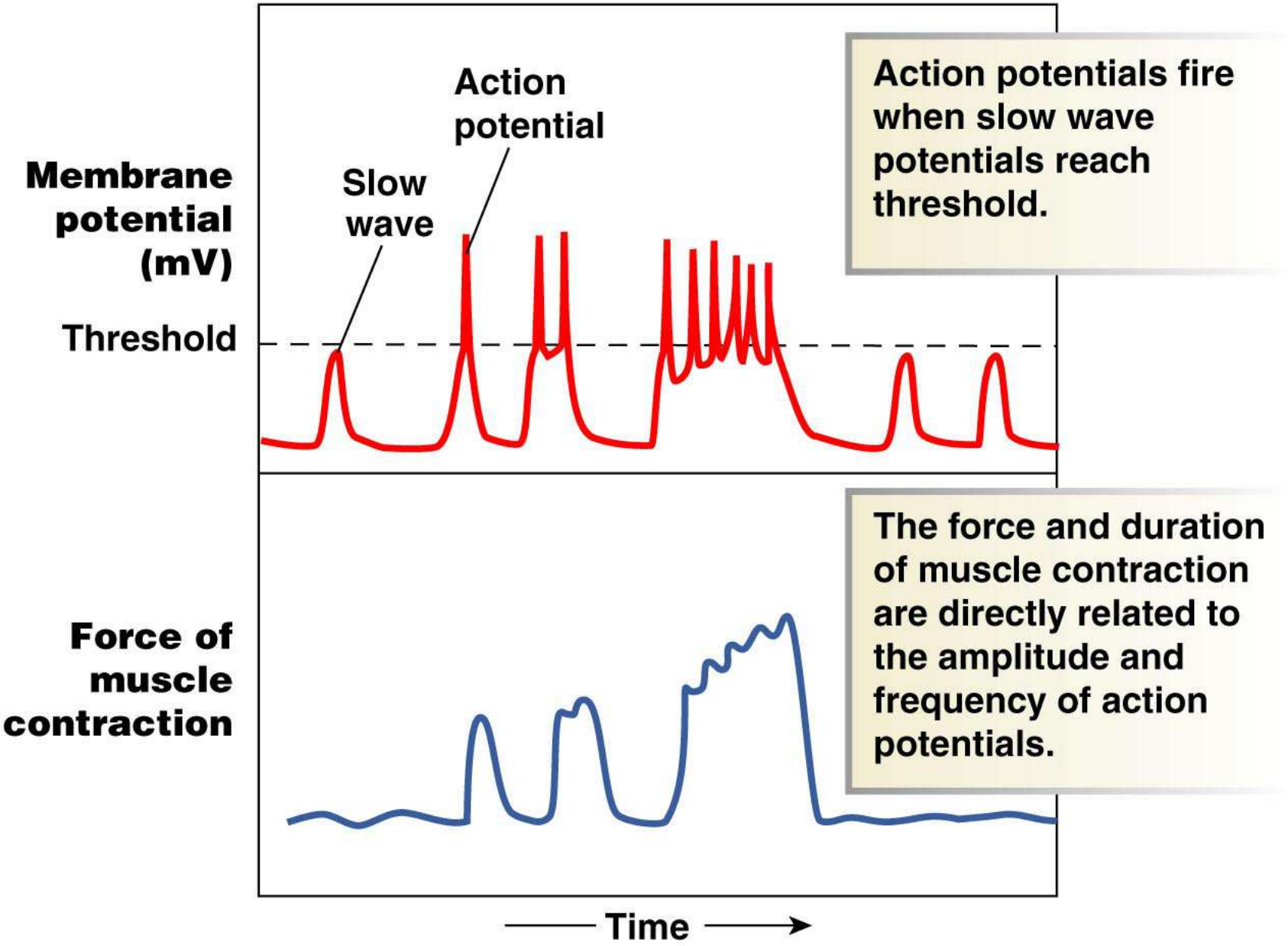


Figure 21-3

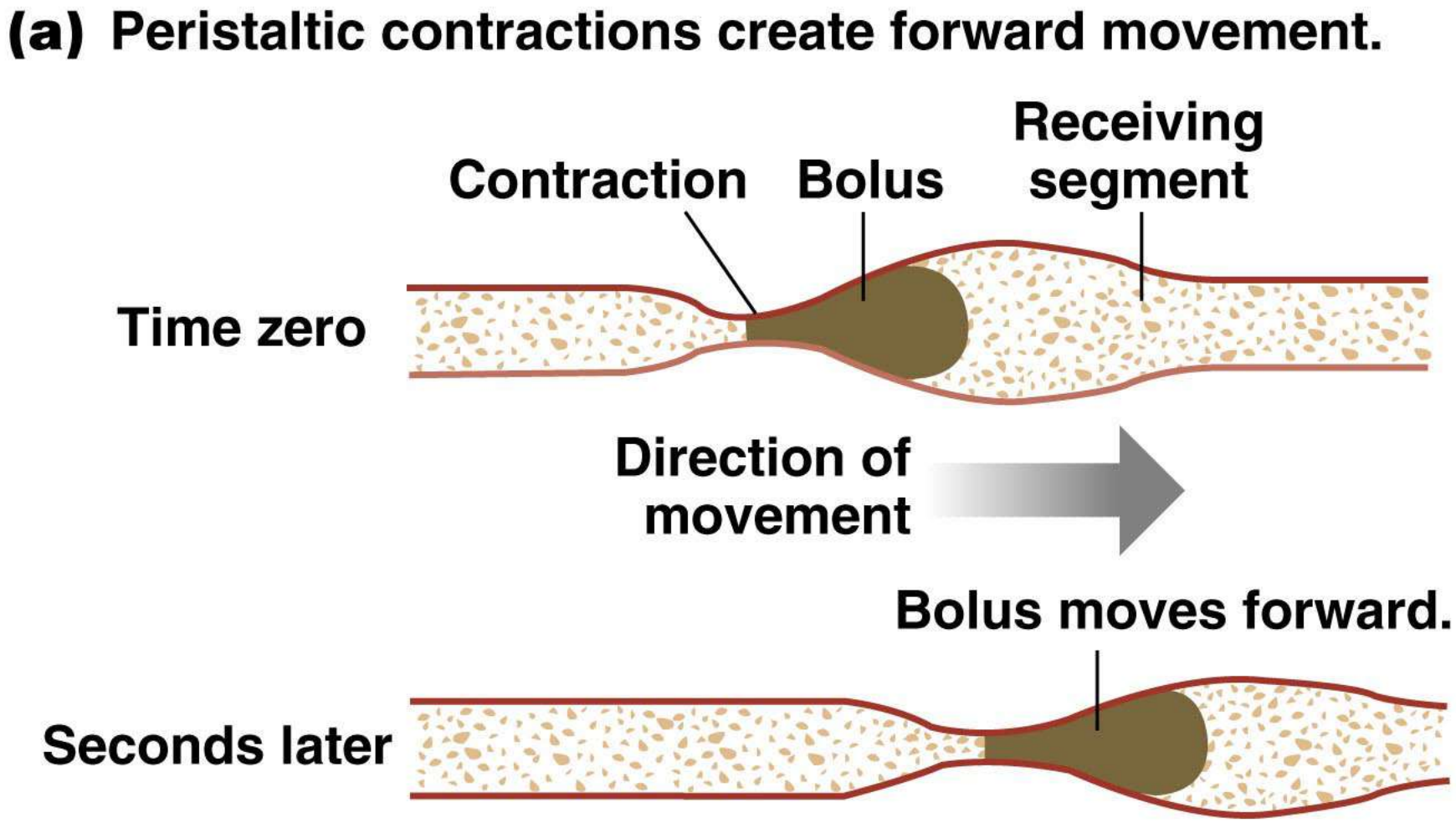
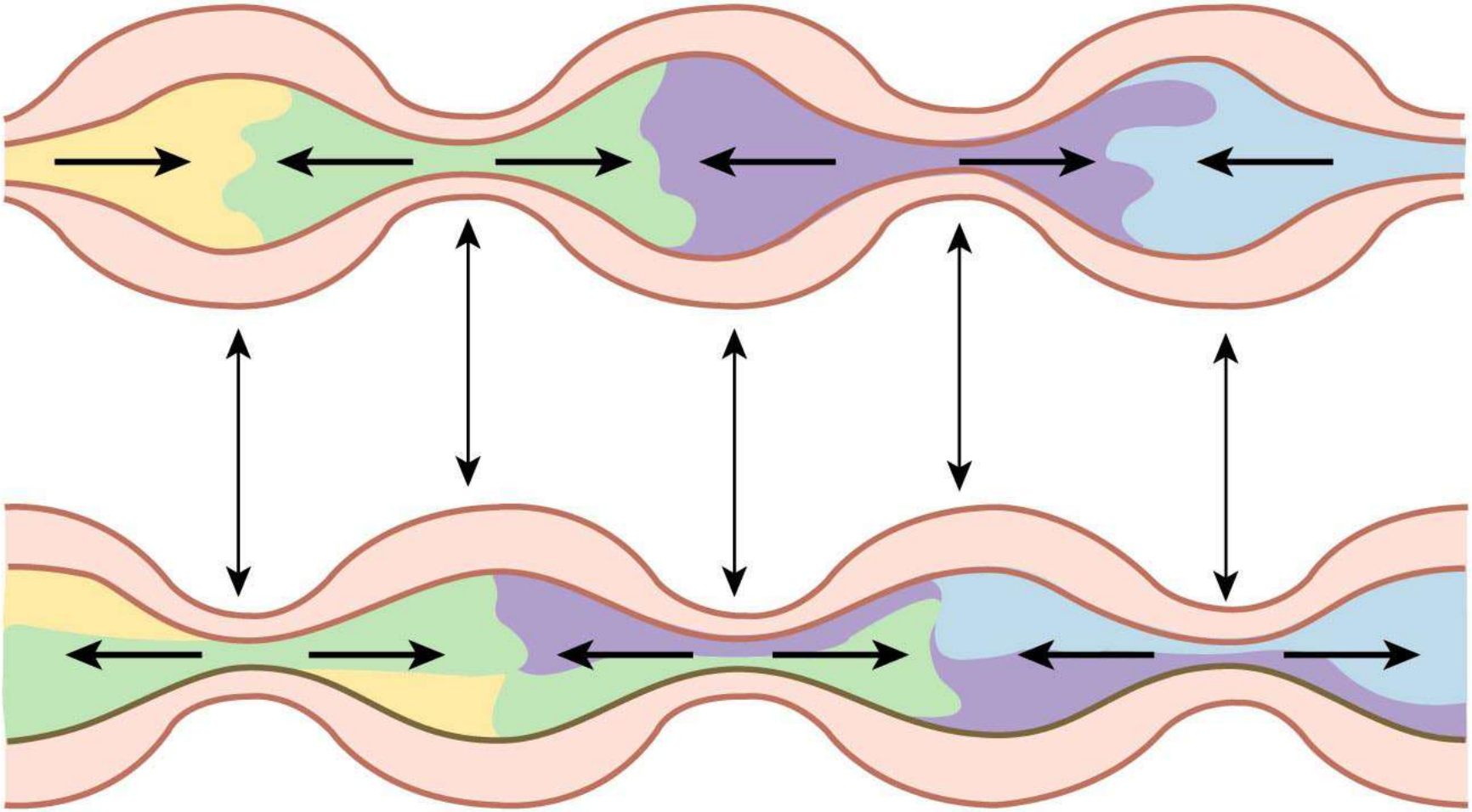


Figure 21-4a

(b) Segmental contractions are responsible for mixing.



No net forward movement

Figure 21-4b

Control of Motility

- ENS coordinate intestinal motility
- Cholinergic neurons (Parasympathetic)cause:
  - Contraction and shortening of the circular muscle and longitudinal muscle
  - Distension of the intestine
- The gastro-ileal reflex and gastrin:
  - Relax the ileocecal sphincter
  - Allow chyme to pass into the large intestine

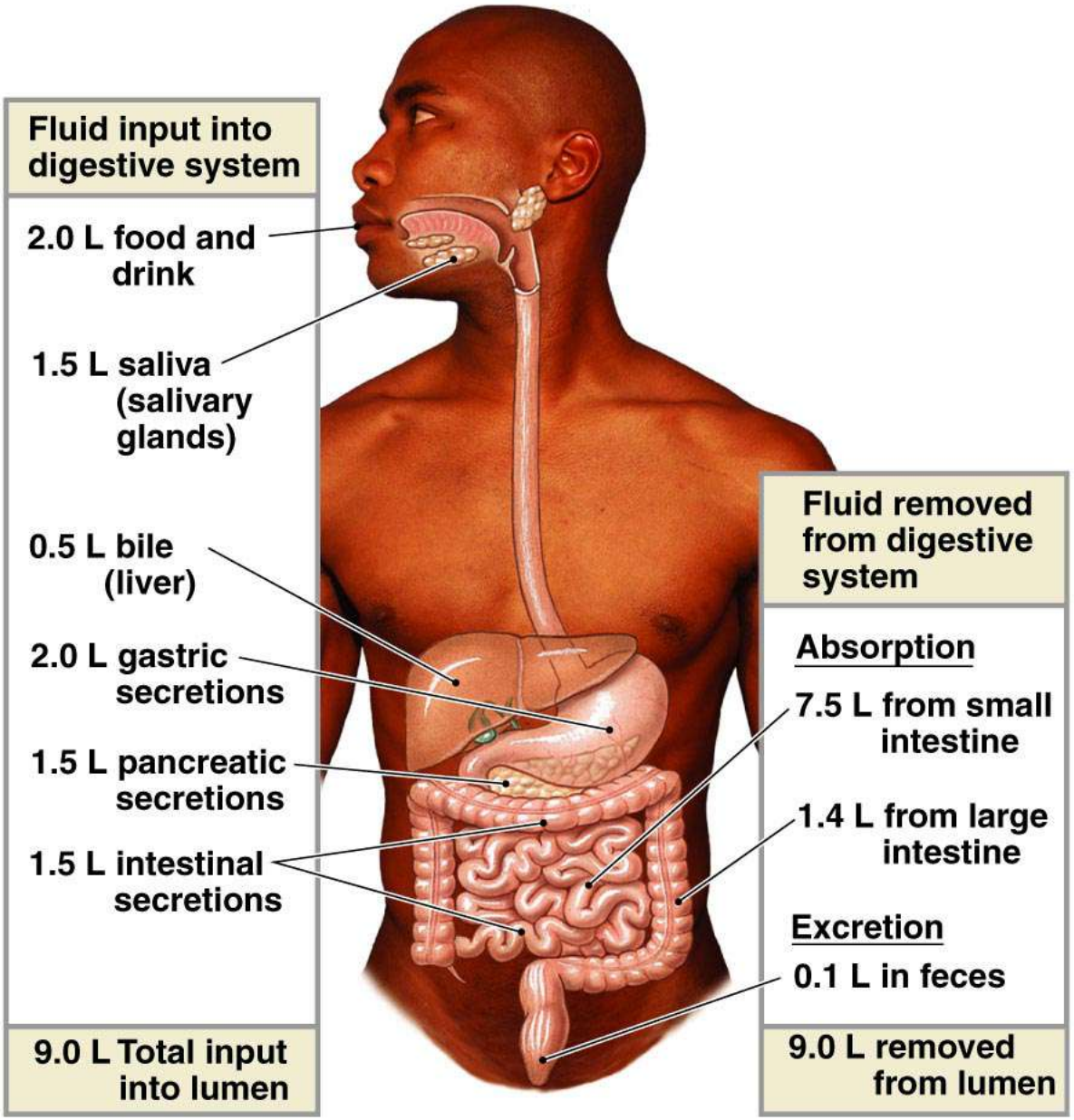


Figure 21-5

Chemical Digestion: Carbohydrates

- Enzymes used: salivary amylase, pancreatic amylase, and brush border enzymes

- Absorption: via cotransport with Na^+, and facilitated diffusion
  - Enter the capillary bed in the villi
  - Transported to the liver via the hepatic portal vein

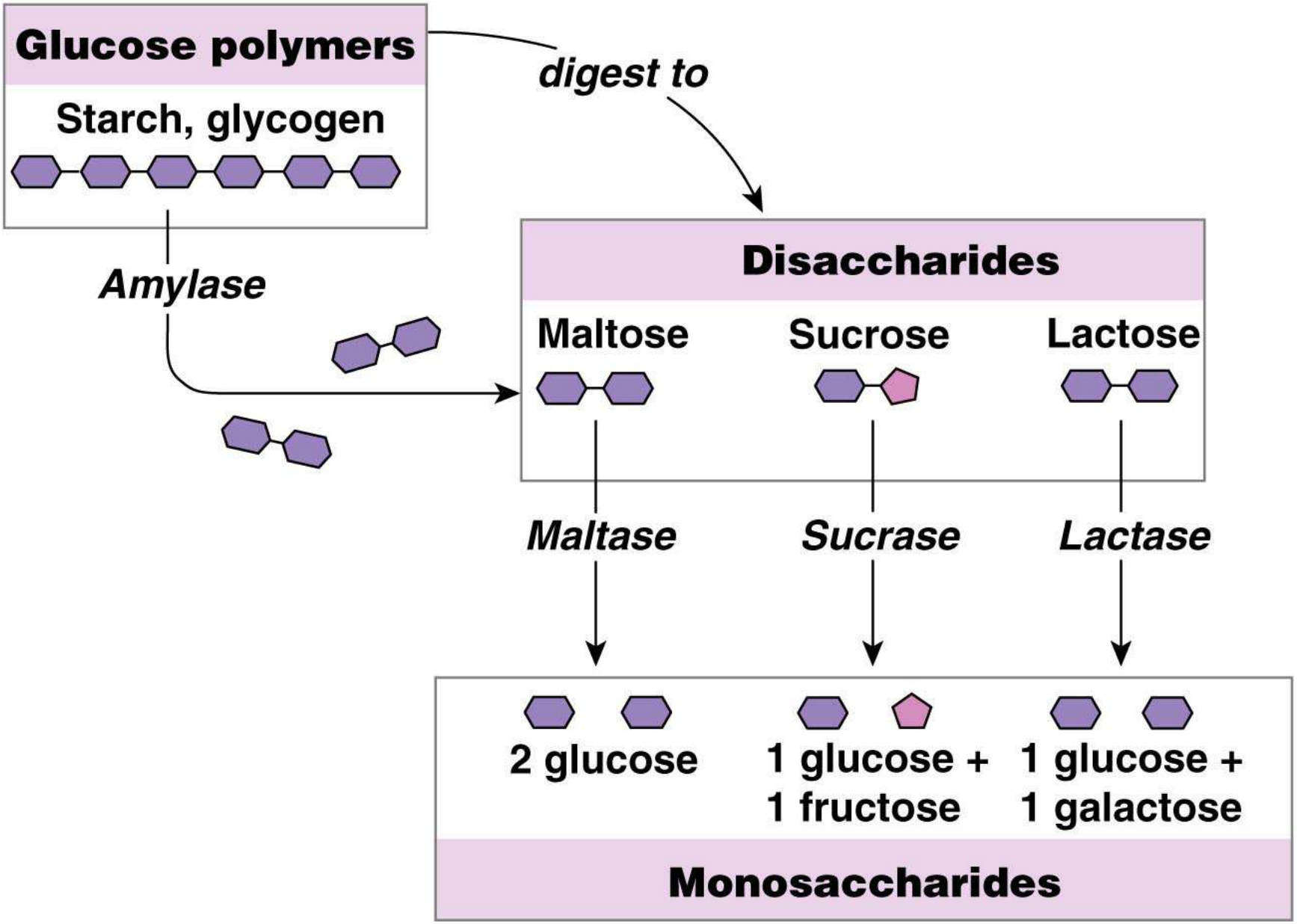


Figure 21-14

Chemical Digestion: Proteins

- Enzymes used: pepsin in the stomach
- Enzymes acting in the small intestine
  - Pancreatic enzymes – trypsin, chymotrypsin, and carboxypeptidase
  - Brush border enzymes – aminopeptidases, carboxypeptidases, and dipeptidases
- Absorption: similar to carbohydrates

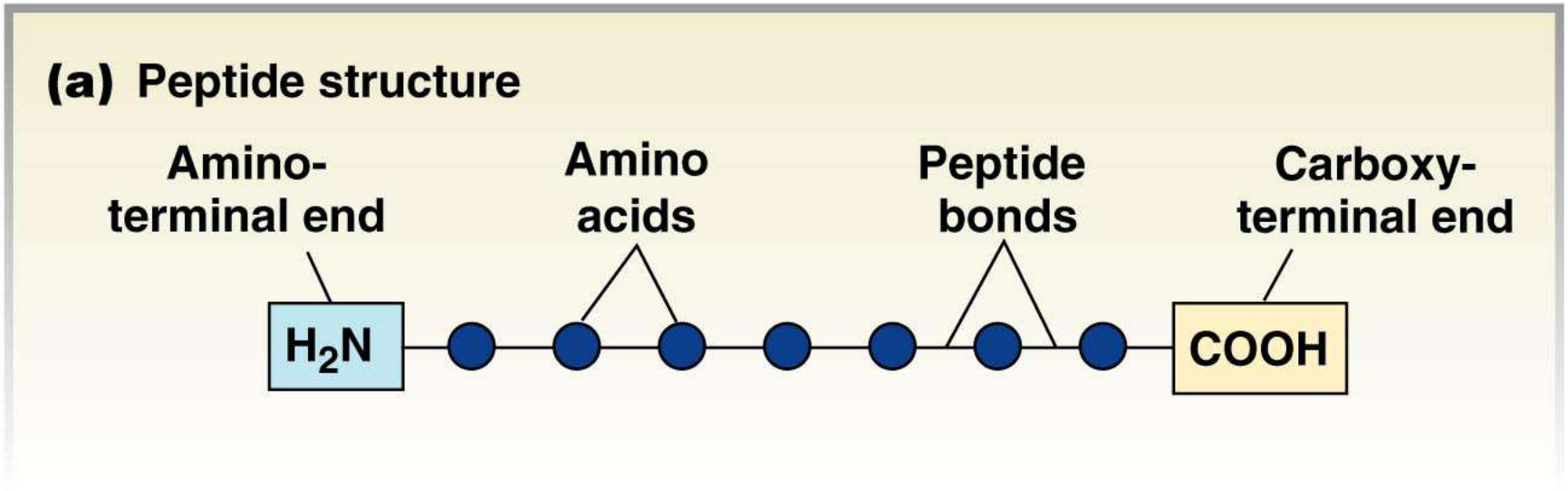


Figure 21-16a

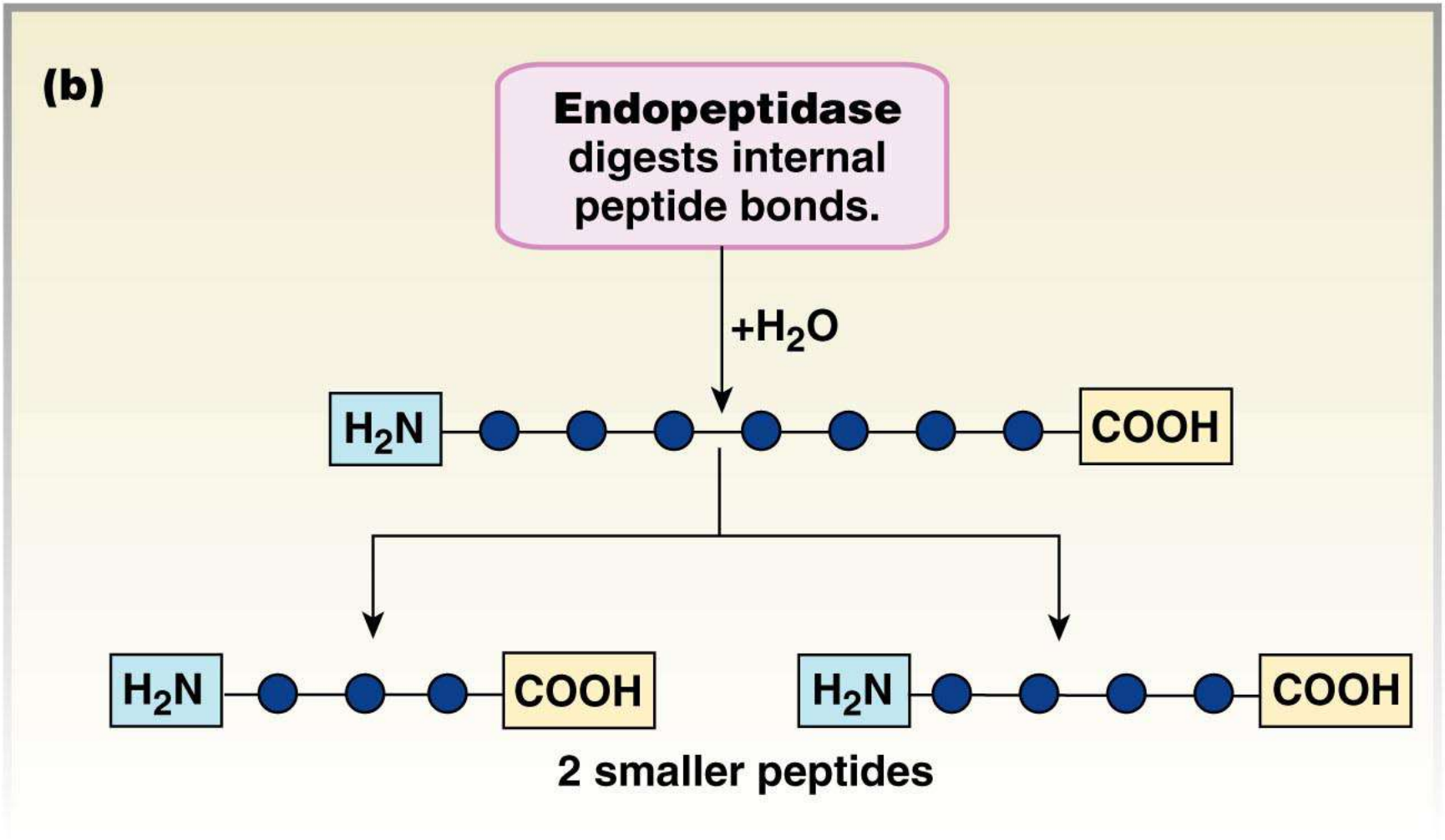


Figure 21-16b

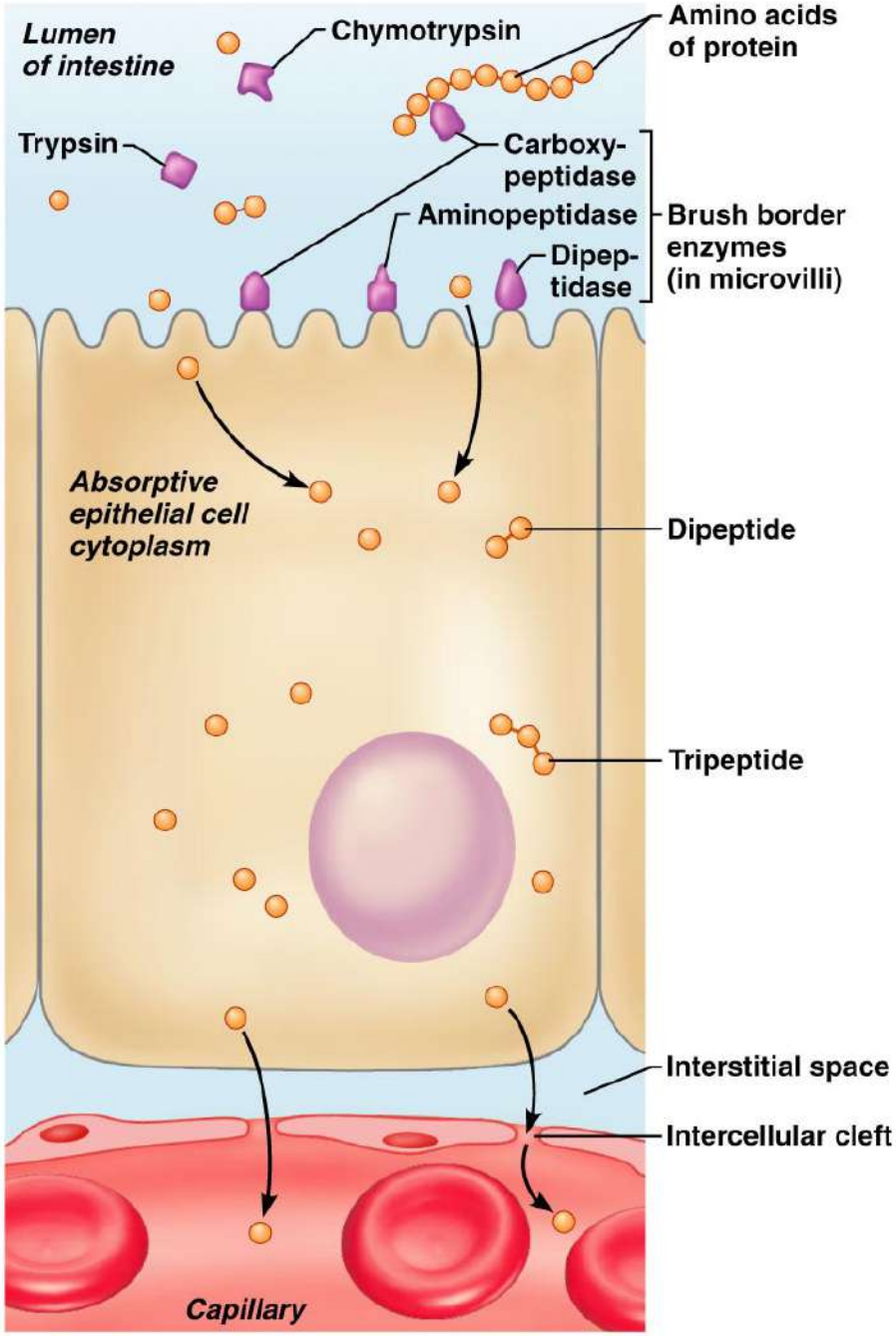


Figure 23.34

Chemical Digestion: Fats

- Enzymes/chemicals used: bile salts and pancreatic lipase
- Absorption: Diffusion into intestinal cells:
  - Combine with proteins and extrude chylomicrons
  - Enter lacteals and are transported via lymph
- Glycerol and short chain fatty acids are:
  - Absorbed into the capillary blood in villi
  - Transported via the hepatic portal vein

Chemical Digestion: Fats

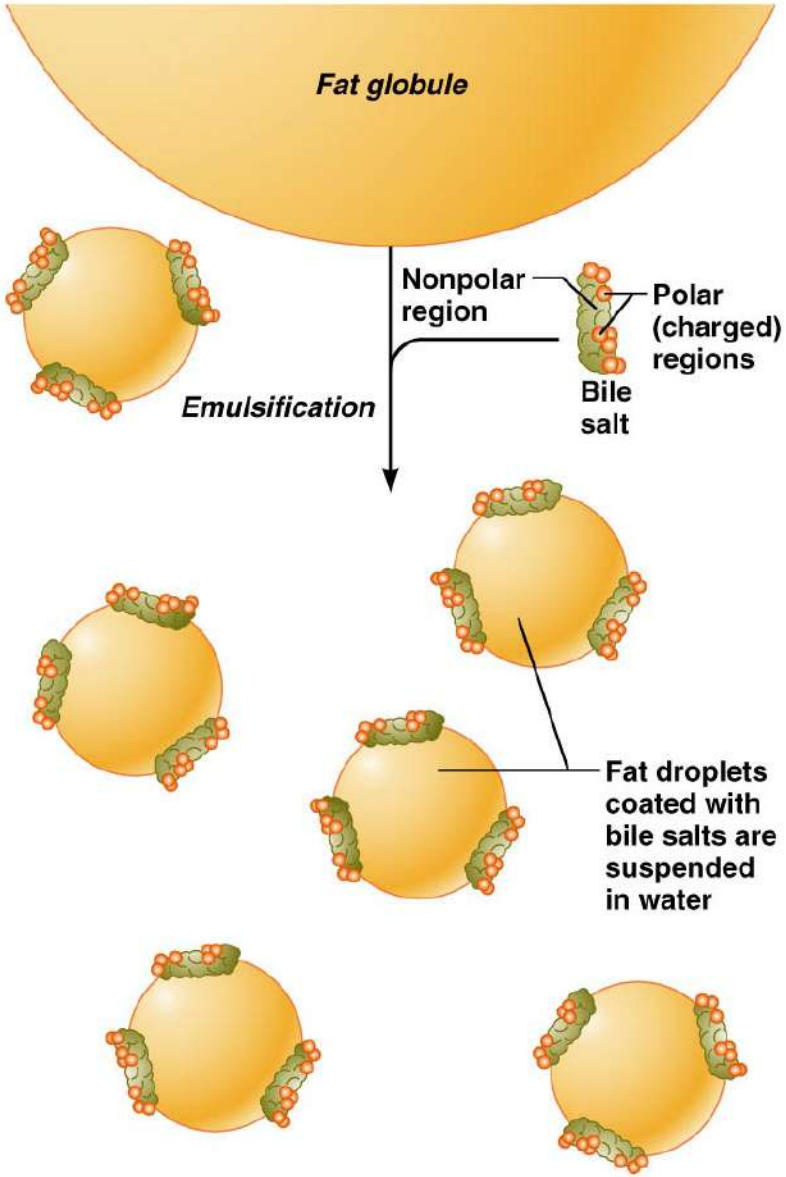
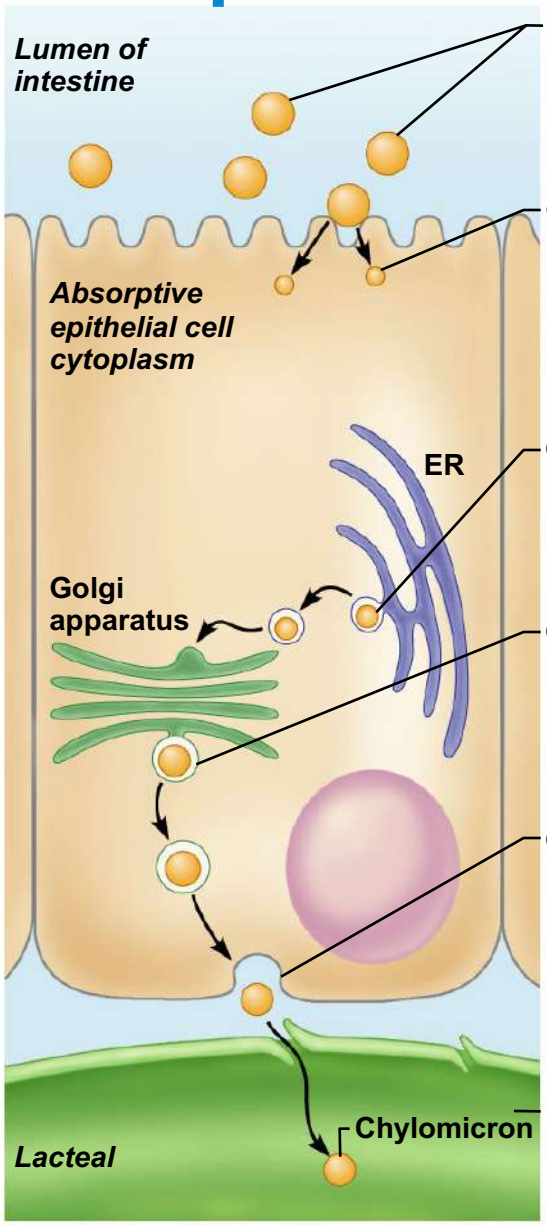


Figure 23.35

Fatty Acid Absorption



Fatty acids and monoglycerides associated with micelles in lumen of intestine

① Fatty acids and monoglycerides resulting from fat digestion leave micelles and enter epithelial cell by diffusion.

② Fatty acids are used to synthesize triglycerides in smooth endoplasmic reticulum.

③ Fatty globules are combined with proteins to form chylomicrons (within Golgi apparatus).

④ Vesicles containing chylomicrons migrate to the basal membrane, are extruded from the epithelial cell, and enter a lacteal (lymphatic capillary).

⑤ Lymph in the lacteal transports chylomicrons away from intestine.

Figure 23.36

Chemical Digestion: Nucleic Acids

- Enzymes used: pancreatic ribonucleases and deoxyribonuclease in the small intestines
- Absorption: active transport via membrane carriers
- Absorbed in villi and transported to liver via hepatic portal vein

Electrolyte Absorption

- Most ions are actively absorbed along the length of small intestine
  - Na^+ is coupled with absorption of glucose and amino acids
  - Ionic iron is transported into mucosal cells where it binds to ferritin
- Anions passively follow the electrical potential established by Na^+

Electrolyte Absorption

- K^+ diffuses across the intestinal mucosa in response to osmotic gradients
- Ca^{2+} absorption:
  - Is related to blood levels of ionic calcium
  - Is regulated by vitamin D and PTH

Water Absorption

- 95% of water is absorbed in the small intestines by osmosis
- Net osmosis occurs whenever a concentration gradient is established by active transport of solutes into the mucosal cells
- Water uptake is coupled with solute uptake, and as water moves into mucosal cells, substances follow along their concentration gradients

Malabsorption of Nutrients

- Results from anything that interferes with delivery of bile or pancreatic juice
- Factors that damage the intestinal mucosa (e.g., bacterial infection)
- Gluten enteropathy (adult celiac disease) – gluten damages the intestinal villi and reduces the length of microvilli
  - Treated by eliminating gluten from the diet (all grains but rice and corn)

Large Intestine

- Has three unique features:
  - Teniae coli – three bands of longitudinal smooth muscle in its muscularis
  - Haustra – pocketlike sacs caused by the tone of the teniae coli
  - Epiploic appendages – fat-filled pouches of visceral peritoneum

Large Intestine

- Is subdivided into the cecum, appendix, colon, rectum, and anal canal
- The saclike cecum:
  - Lies below the ileocecal valve in the right iliac fossa
  - Contains a wormlike vermiform appendix

Large Intestine

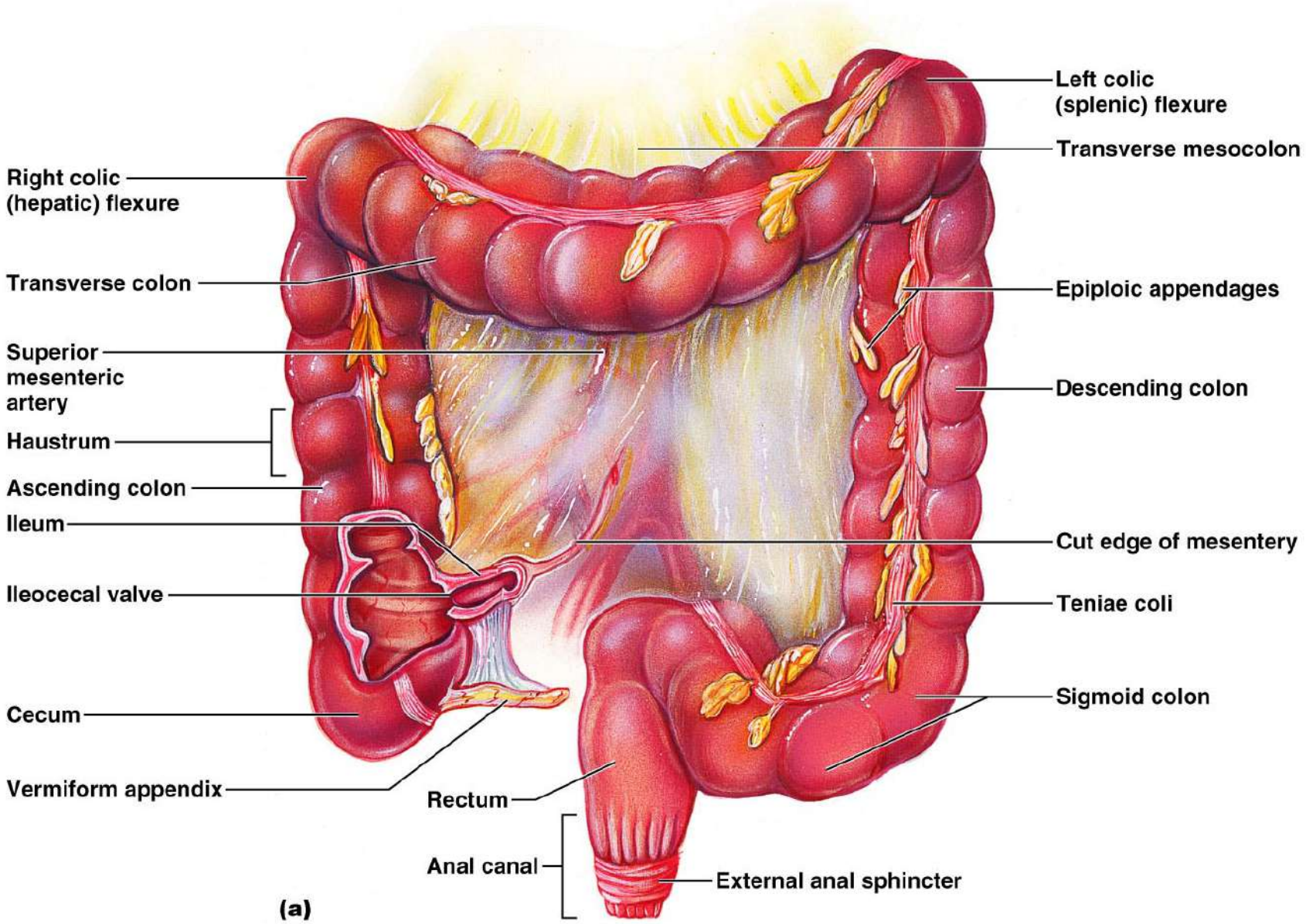


Figure 23.29a

Colon

- Has distinct regions: ascending colon, hepatic flexure, transverse colon, splenic flexure, descending colon, and sigmoid colon
- The sigmoid colon joins the rectum
- The anal canal, the last segment of the large intestine, opens to the exterior at the anus

Valves and Sphincters of the Rectum and Anus

- Three valves of the rectum stop feces from being passed with gas
- The anus has two sphincters:
  - Internal anal sphincter composed of smooth muscle
  - External anal sphincter composed of skeletal muscle
- These sphincters are closed except during defecation

Structure of the Anal Canal

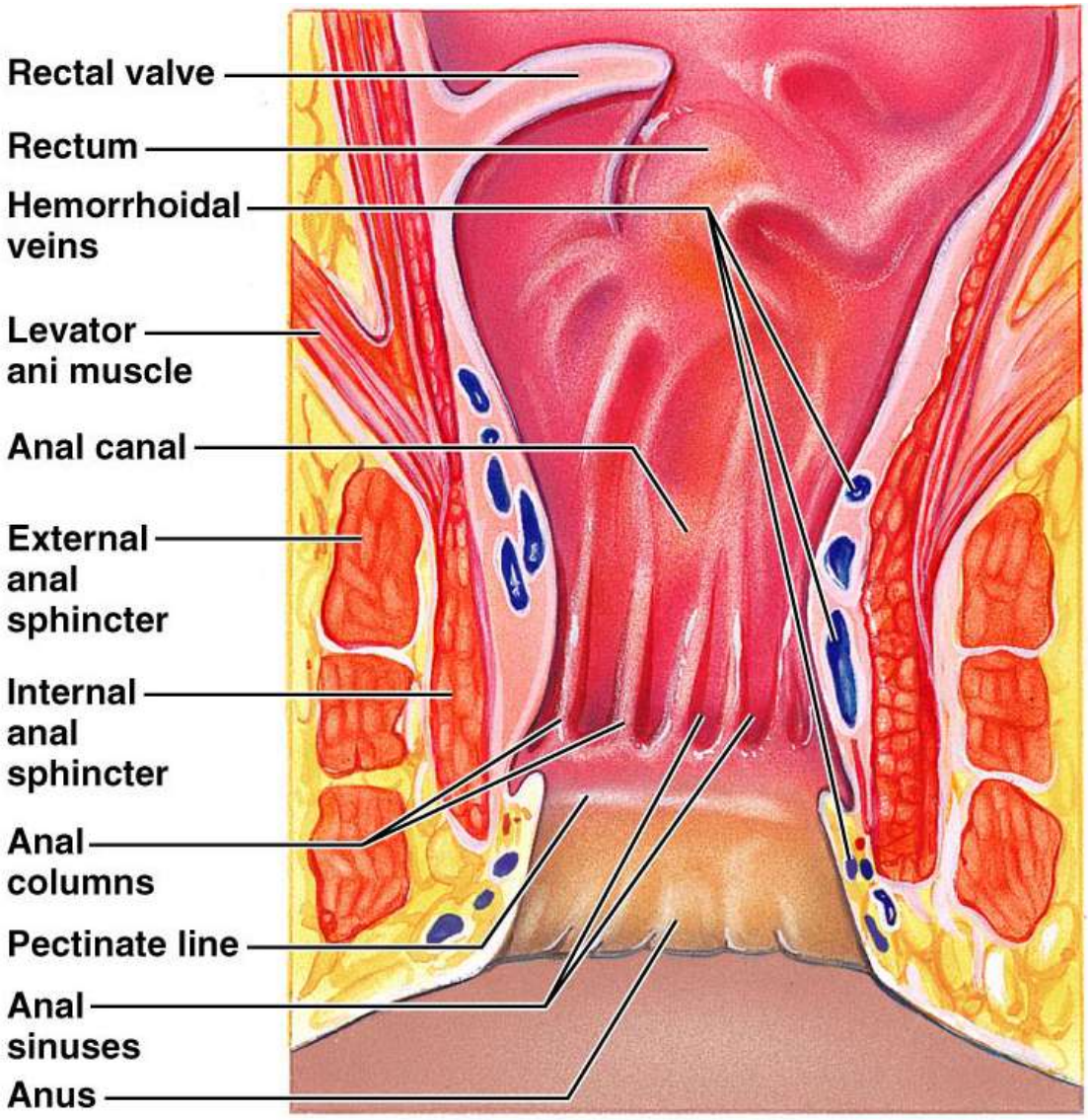


Figure 23.29b

Bacterial Flora

- The bacterial flora of the large intestine consist of:
  - Bacteria surviving the small intestine that enter the cecum and
  - Those entering via the anus
- These bacteria:
  - Colonize the colon
  - Ferment indigestible carbohydrates
  - Release irritating acids and gases (flatus)
  - Synthesize B complex vitamins and vitamin K

Functions of the Large Intestine

- Other than digestion of enteric bacteria, no further digestion takes place
- Vitamins, water, and electrolytes are reclaimed
- Its major function is propulsion of fecal material toward the anus
- Though essential for comfort, the colon is not essential for life

Motility of the Large Intestine

- Haustral contractions
  - Slow segmenting movements that move the contents of the colon
  - Haustra sequentially contract as they are stimulated by distension
- Presence of food in the stomach:
  - Activates the gastrocolic reflex
  - Initiates peristalsis that forces contents toward the rectum

Defecation

- Distension of rectal walls caused by feces:
  - Stimulates contraction of the rectal walls
  - Relaxes the internal anal sphincter
- Voluntary signals stimulate relaxation of the external anal sphincter and defecation occurs

Defecation

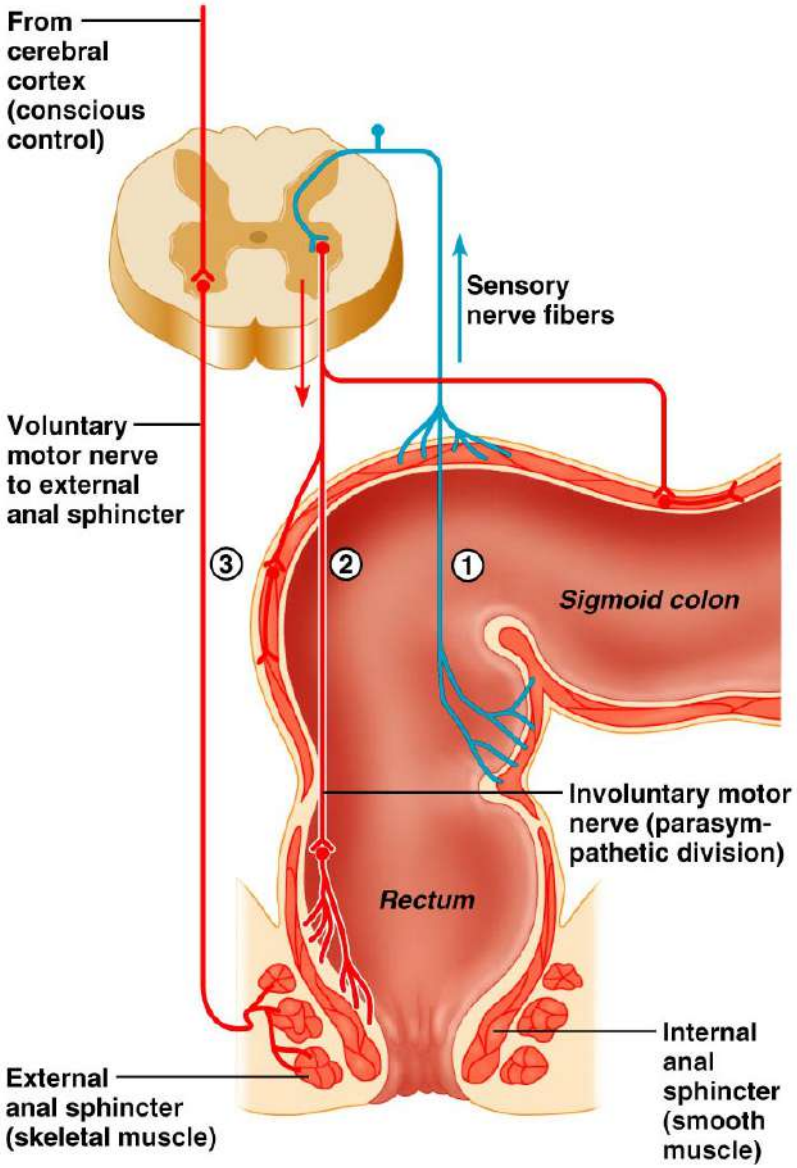


Figure 23.32

Cancer

- Stomach and colon cancers rarely have early signs or symptoms
- Metastasized colon cancers frequently cause secondary liver cancer
- Prevention is by regular dental and medical examinations

Cancer

- Colon cancer is the 2nd largest cause of cancer deaths in males (lung cancer is 1st)
- Forms from benign mucosal tumors called polyps whose formation increases with age
- Regular colon examination should be done for all those over 50