



NINTH EDITION

ESSENTIALS OF
HUMAN ANATOMY
& PHYSIOLOGY

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The Digestive System and Body Metabolism

14 PART A

The Digestive System Functions

- **Ingestion—taking in food**
- **Digestion—breaking food down both physically and chemically**
- **Absorption—movement of nutrients into the bloodstream**
- **Defecation—rids the body of indigestible waste**

Organs of the Digestive System

- **Two main groups**
 - **Alimentary canal (digestive tract, gastrointestinal tract or GI tract)—continuous coiled hollow tube**
 - **Accessory digestive organs**

Organs of the Digestive System

Mouth
Pharynx
Esophagus
Stomach
Small intestine
Large intestine
Anus

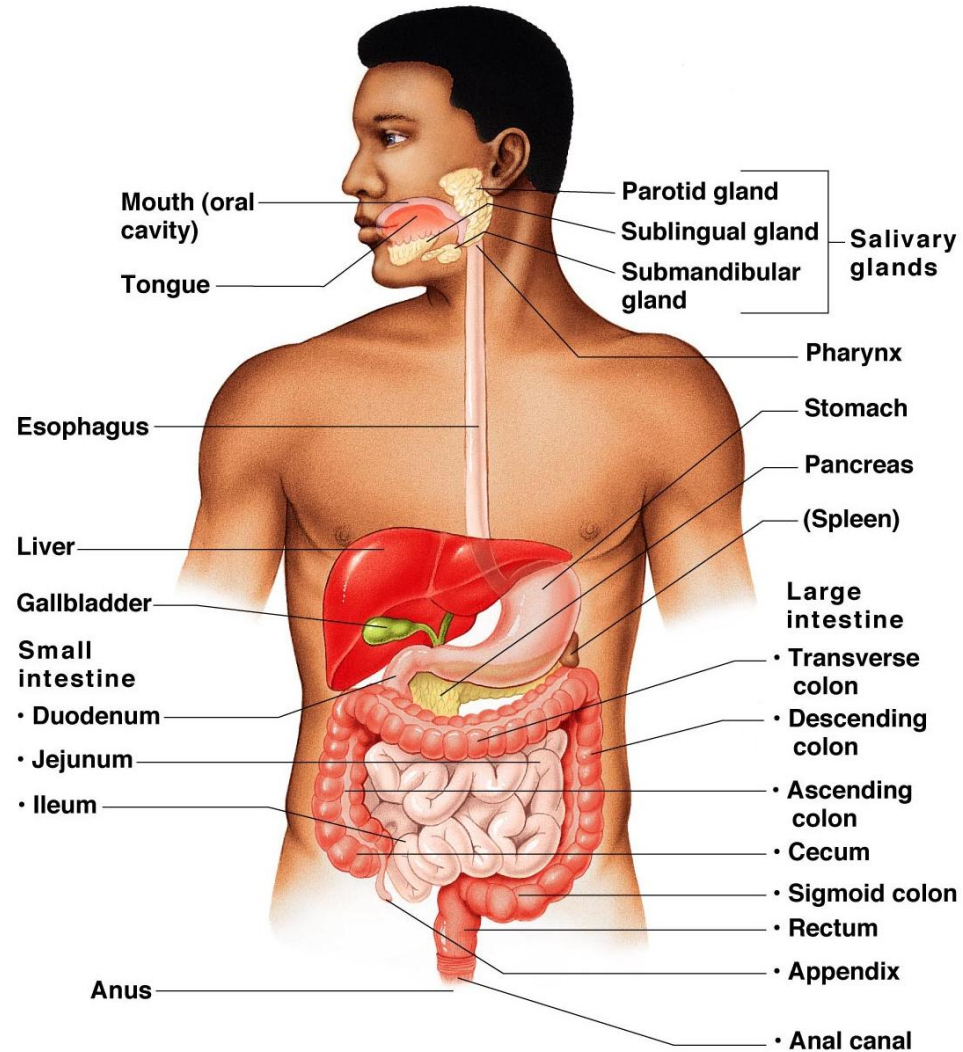
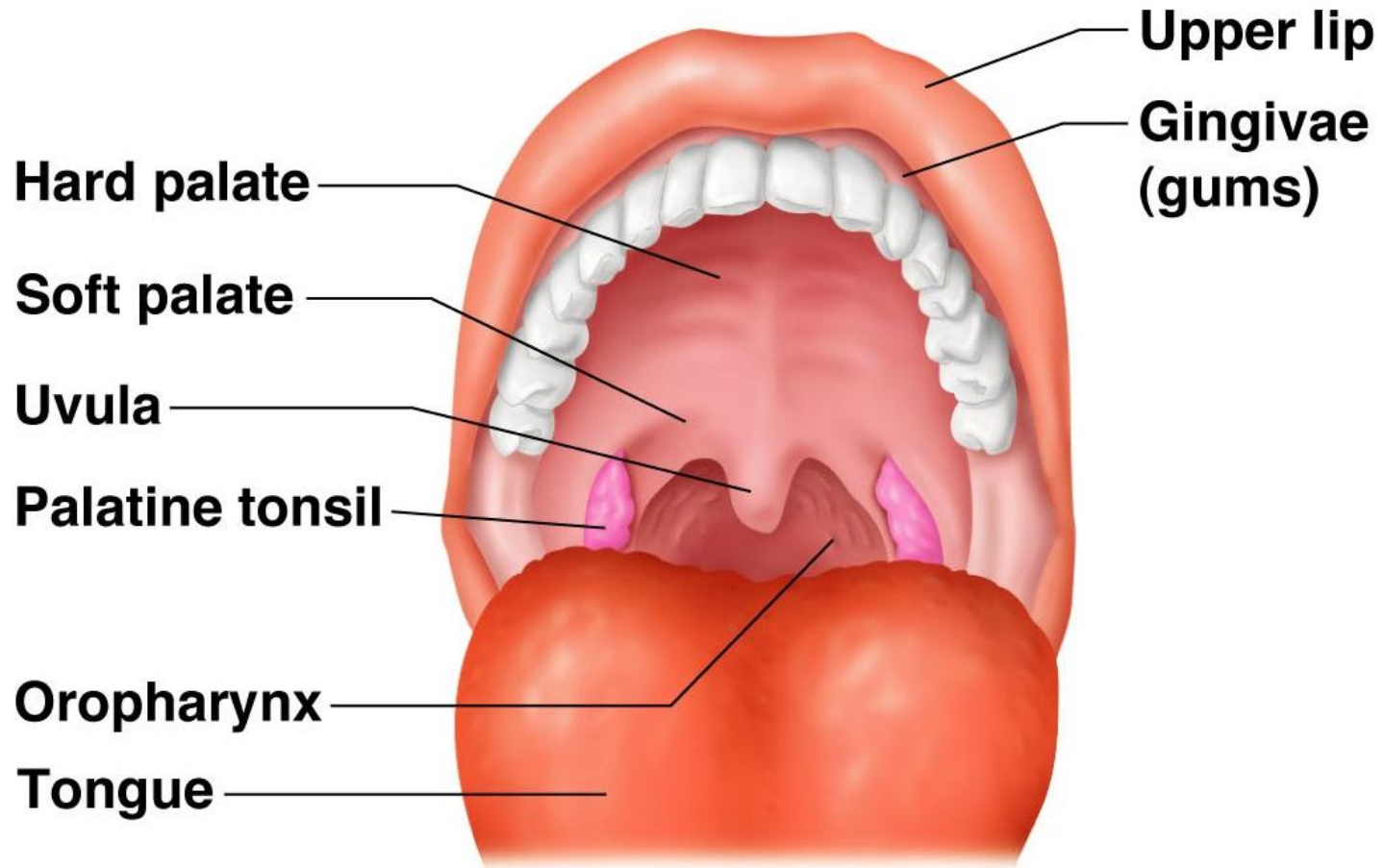


Figure 14.1

Mouth (Oral Cavity) Anatomy



(b)

Figure 14.2b

Mouth Physiology

- **Mastication (chewing) of food**
- **Mixing masticated food with saliva**
- **Initiation of swallowing by the tongue**
- **Allows for the sense of taste**

Pharynx Anatomy

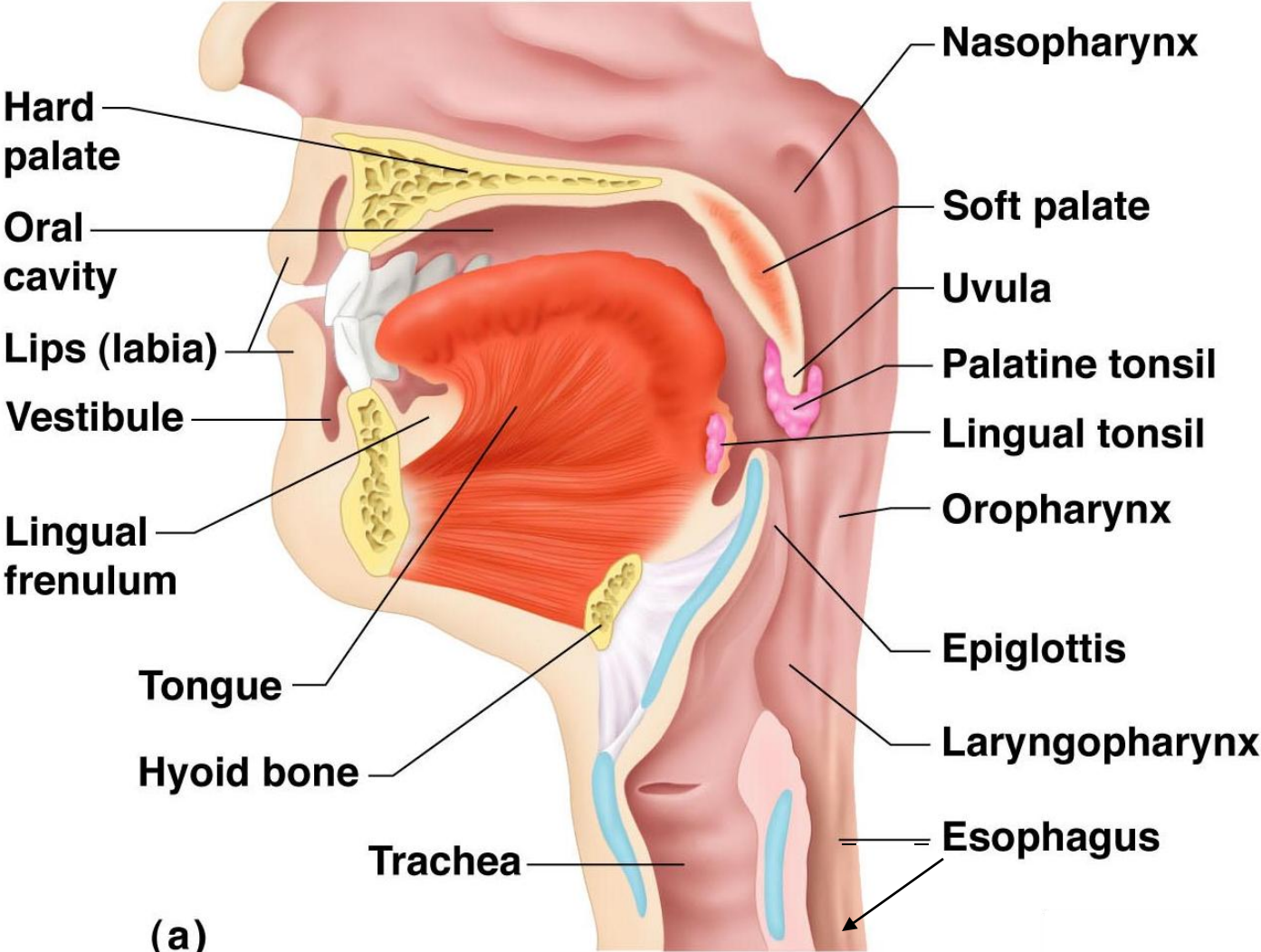


Figure 14.2a

Esophagus Anatomy and Physiology

- **Anatomy**

- **About 10 inches long**
- **Runs from pharynx to stomach through the diaphragm**

- **Physiology**

- **Conducts food by peristalsis (slow rhythmic squeezing)**
- **Passageway for food only (respiratory system branches off after the pharynx)**

Layers of Alimentary Canal Organs

- **Four layers**
 - **Mucosa**
 - **Submucosa**
 - **Muscularis externa**
 - **Serosa**

Layers of Alimentary Canal Organs

- **Mucosa**
 - **Innermost, moist membrane consisting of**
 - **Surface epithelium**
 - **Small amount of connective tissue (lamina propria)**
 - **Small smooth muscle layer**

Layers of Alimentary Canal Organs

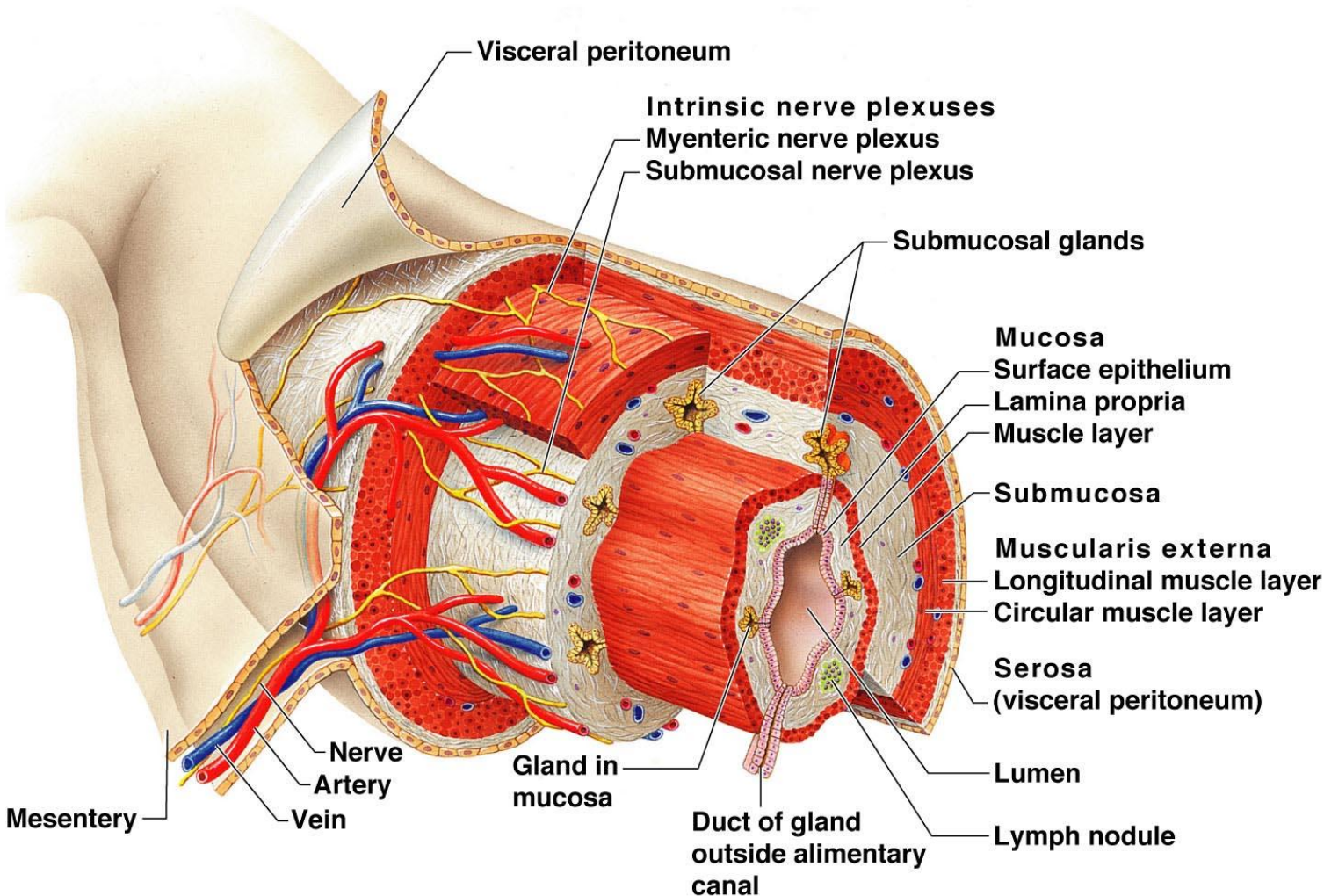


Figure 14.3

Layers of Alimentary Canal Organs

- **Submucosa**
 - **Just beneath the mucosa**
 - **Soft connective tissue with blood vessels, nerve endings, and lymphatics**

Layers of Alimentary Canal Organs

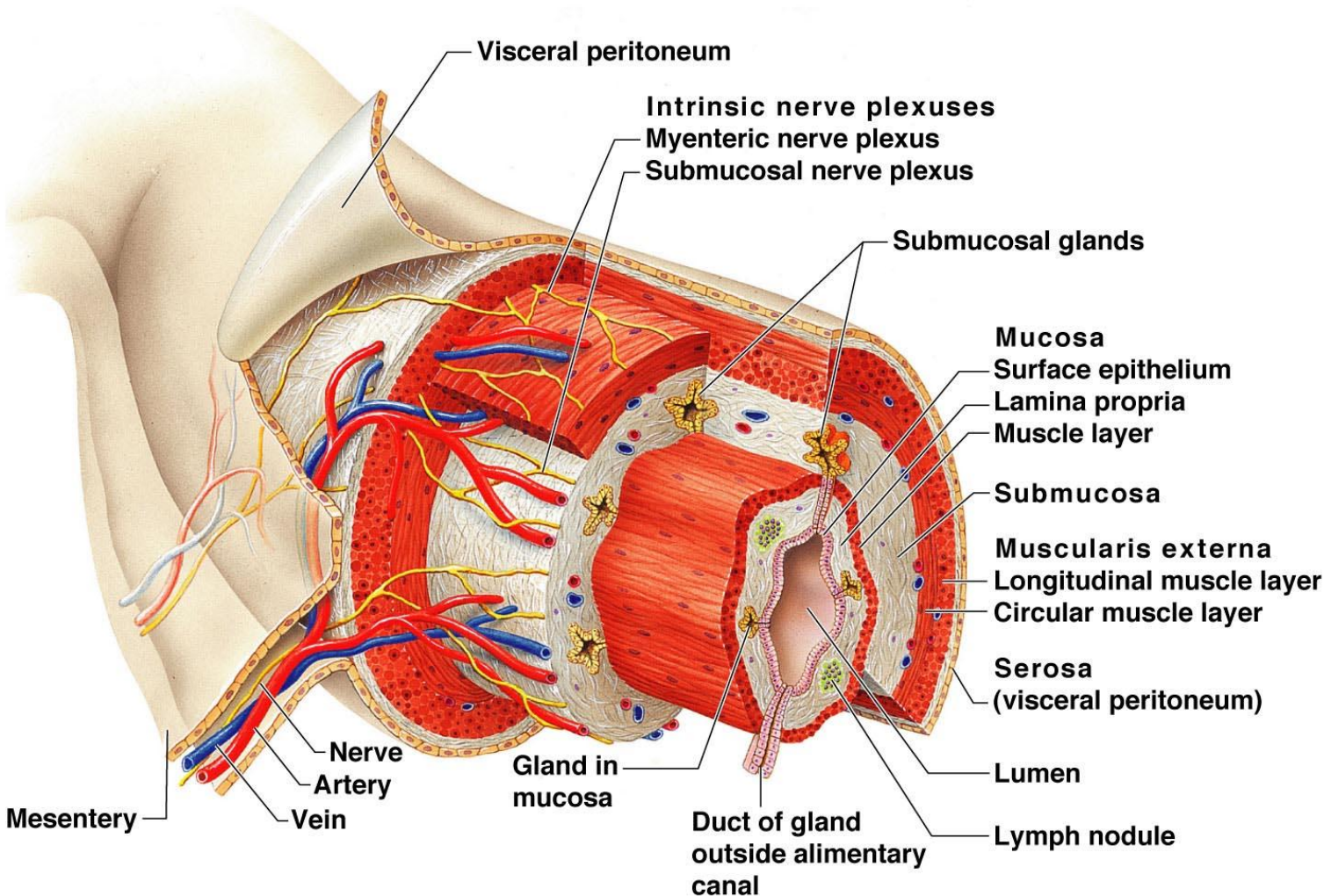


Figure 14.3

Layers of Alimentary Canal Organs

- **Muscularis externa—smooth muscle**
 - **Inner circular layer**
 - **Outer longitudinal layer**
- **Serosa—outermost layer of the canal wall contains fluid-producing cells**
 - **Visceral peritoneum—outermost layer of wall**
 - **Parietal peritoneum—lines the abdominopelvic cavity**

Layers of Alimentary Canal Organs

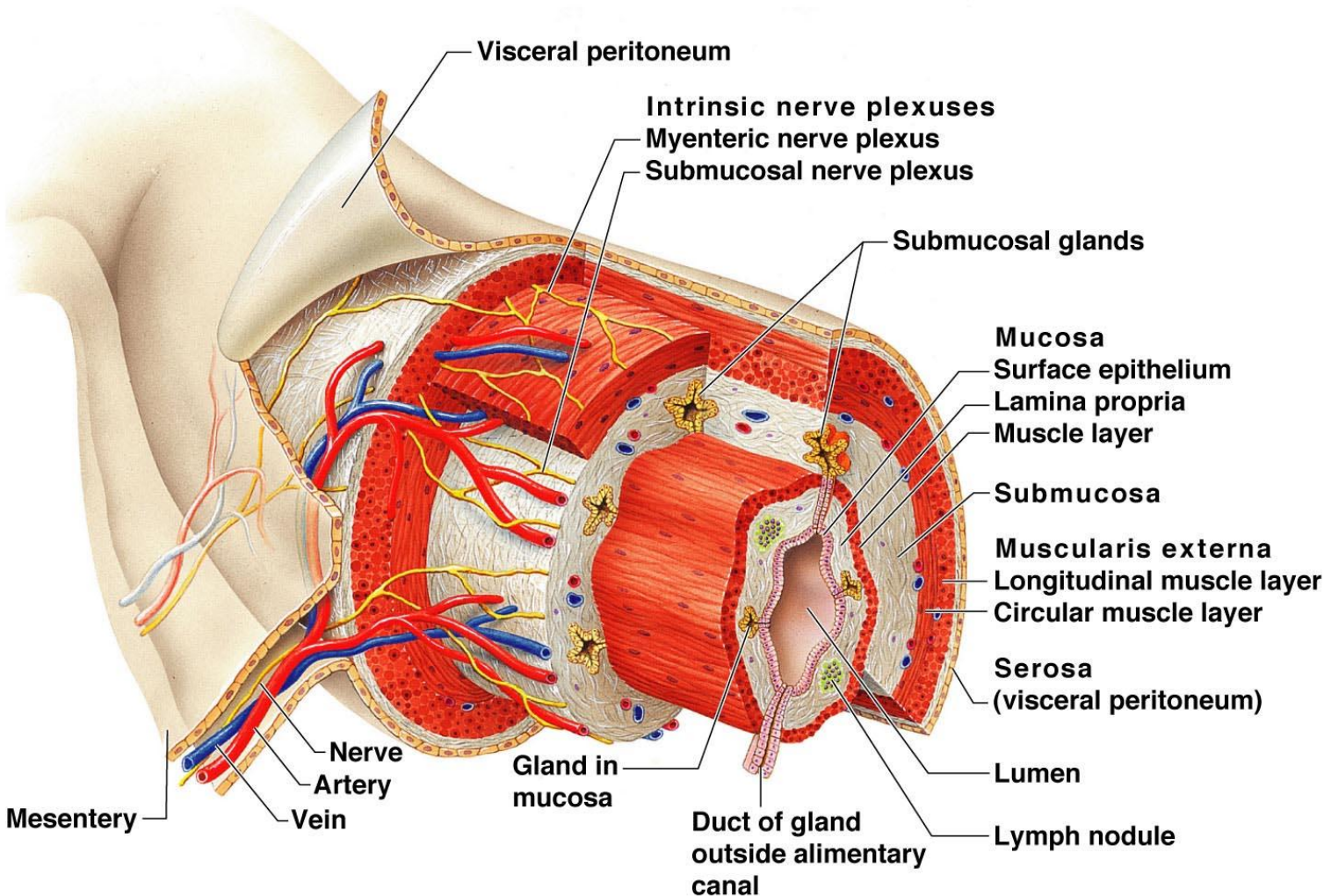


Figure 14.3

Alimentary Canal Nerve Plexuses

- **Two important nerve plexuses serve the alimentary canal**
- **Both are part of the autonomic nervous system**
 - **Submucosal nerve plexus**
 - **Myenteric nerve plexus**
- **Function is to regulate mobility and secretory activity of the GI tract organs**

Stomach Anatomy

- **Located on the left side of the abdominal cavity**
- **Food enters at the cardioesophageal sphincter**
- **Food empties into the small intestine at the pyloric sphincter (valve)**

Stomach Anatomy

- **Regions of the stomach**
 - **Cardiac region—near the heart**
 - **Fundus—expanded portion lateral to the cardiac region**
 - **Body—midportion**
 - **Pylorus—funnel-shaped terminal end**
- **Rugae—internal folds of the mucosa**
- **Lesser curvature—concave medial surface**
- **Greater curvature—convex lateral surface**

Stomach Anatomy

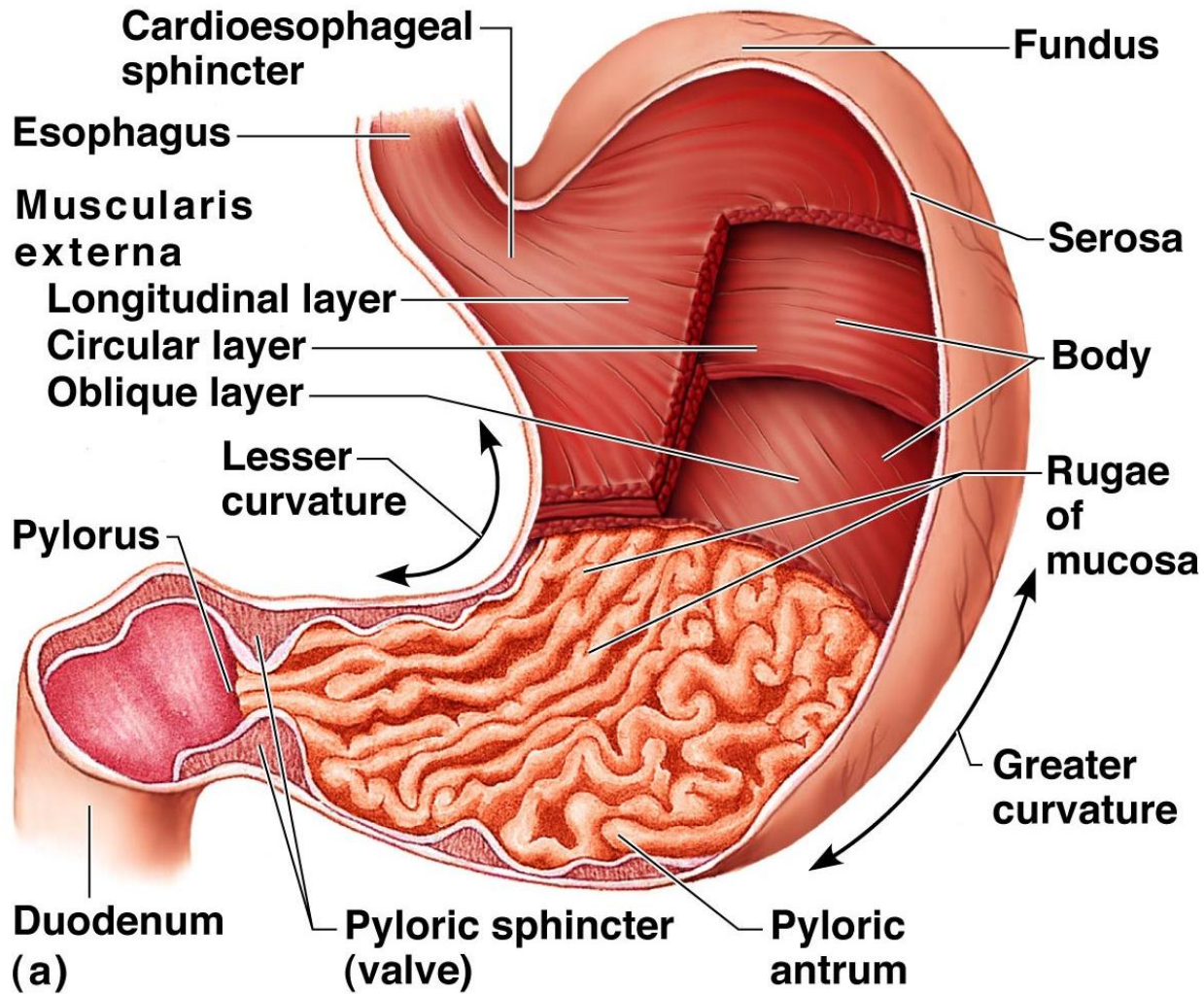


Figure 14.4a

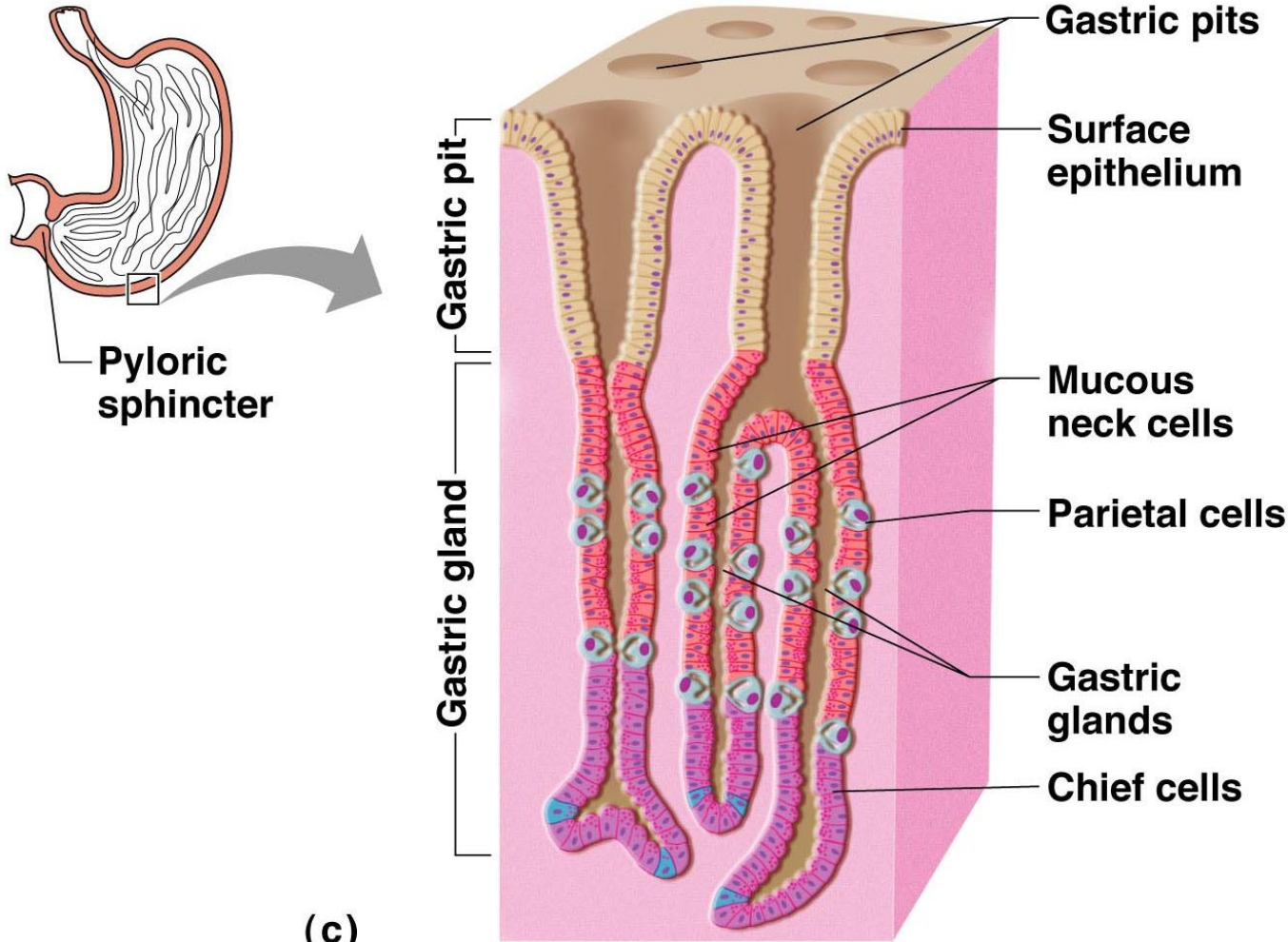
Stomach Physiology

- **Temporary storage for food**
- **Site of food breakdown**
- **Chemical breakdown of protein begins**
- **Delivers chyme (processed food) to the small intestine**

Structure of the Stomach Mucosa

- **Mucosa is simple columnar epithelium**
- **Gastric glands—situated in gastric pits and secrete gastric juice**
 - **Mucous neck cells—produce a sticky alkaline mucus**
 - **Parietal cells—produce hydrochloric acid**
 - **Chief cells—produce protein-digesting enzymes (pepsinogen, converted to pepsin)**
 - **Enteroendocrine cells—produce gastrin**

Structure of the Stomach Mucosa



(c)

Figure 14.4c

Structure of the Stomach Mucosa

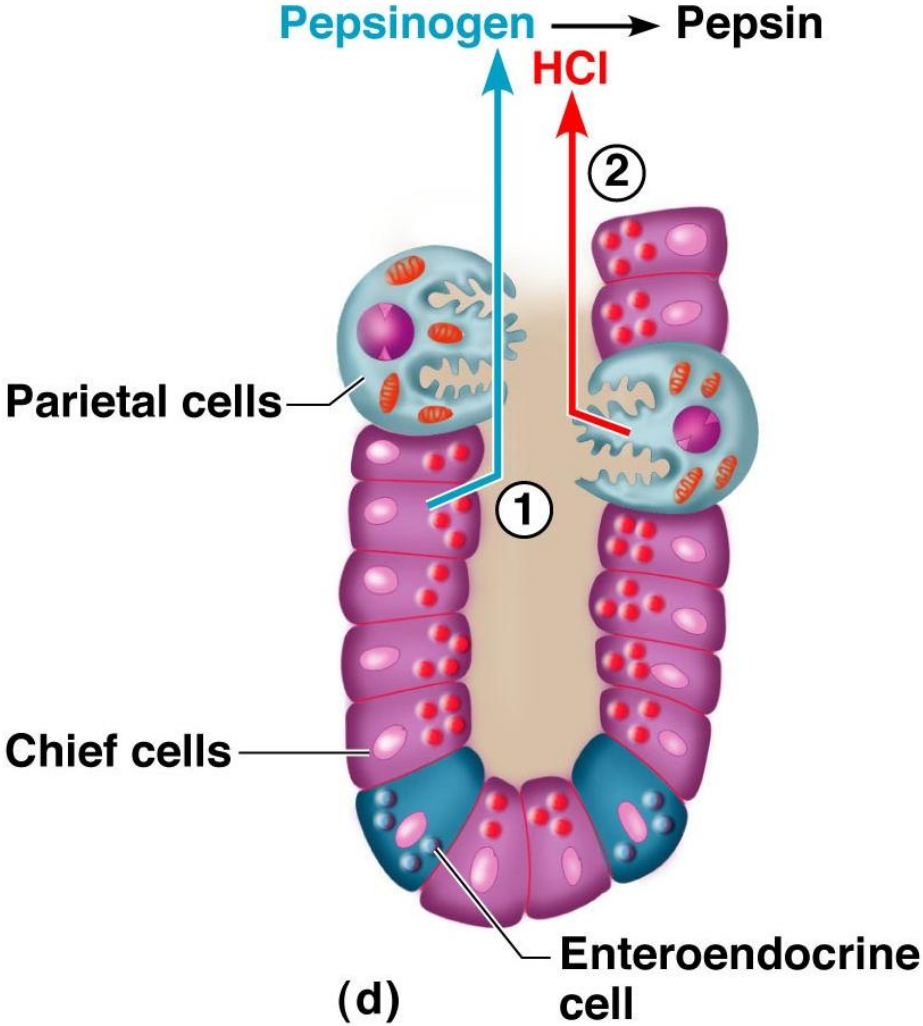


Figure 14.4d

Small Intestine

- **The body's major digestive organ**
- **Site of nutrient absorption into the blood**
- **Muscular tube extending from the pyloric sphincter to the ileocecal valve**
- **Suspended from the posterior abdominal wall by the mesentery**

Subdivisions of the Small Intestine

- **Duodenum**
 - Attached to the stomach
 - Curves around the head of the pancreas
- **Jejunum**
 - Attaches anteriorly to the duodenum
- **Ileum**
 - Extends from jejunum to large intestine

Anatomy of the Small Intestine

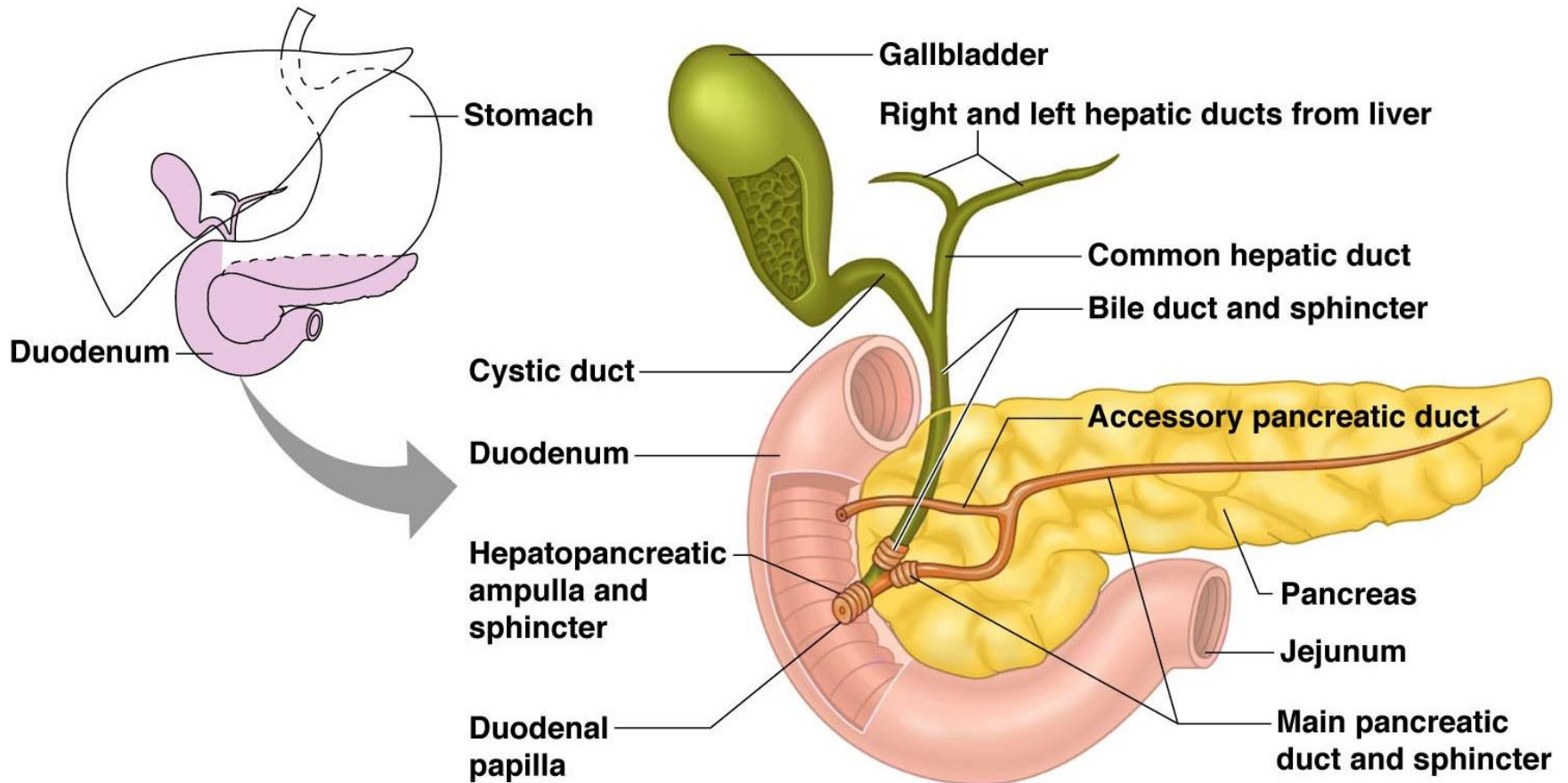
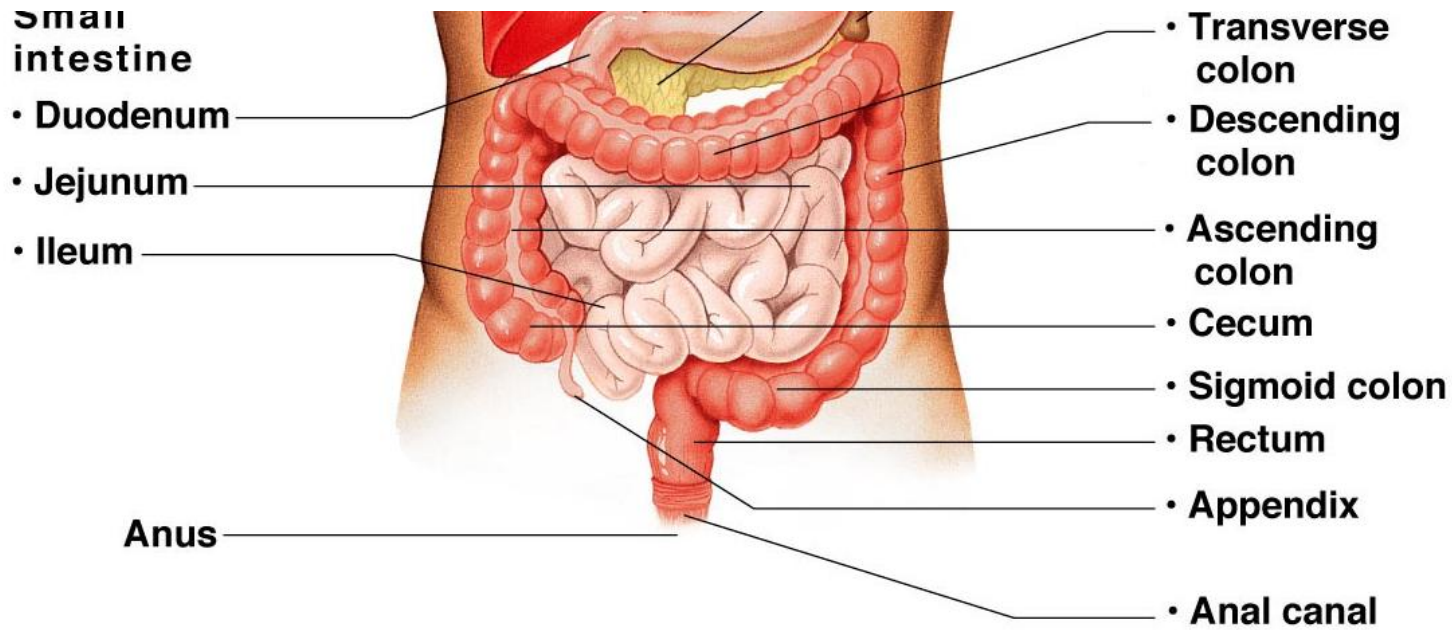


Figure 14.6

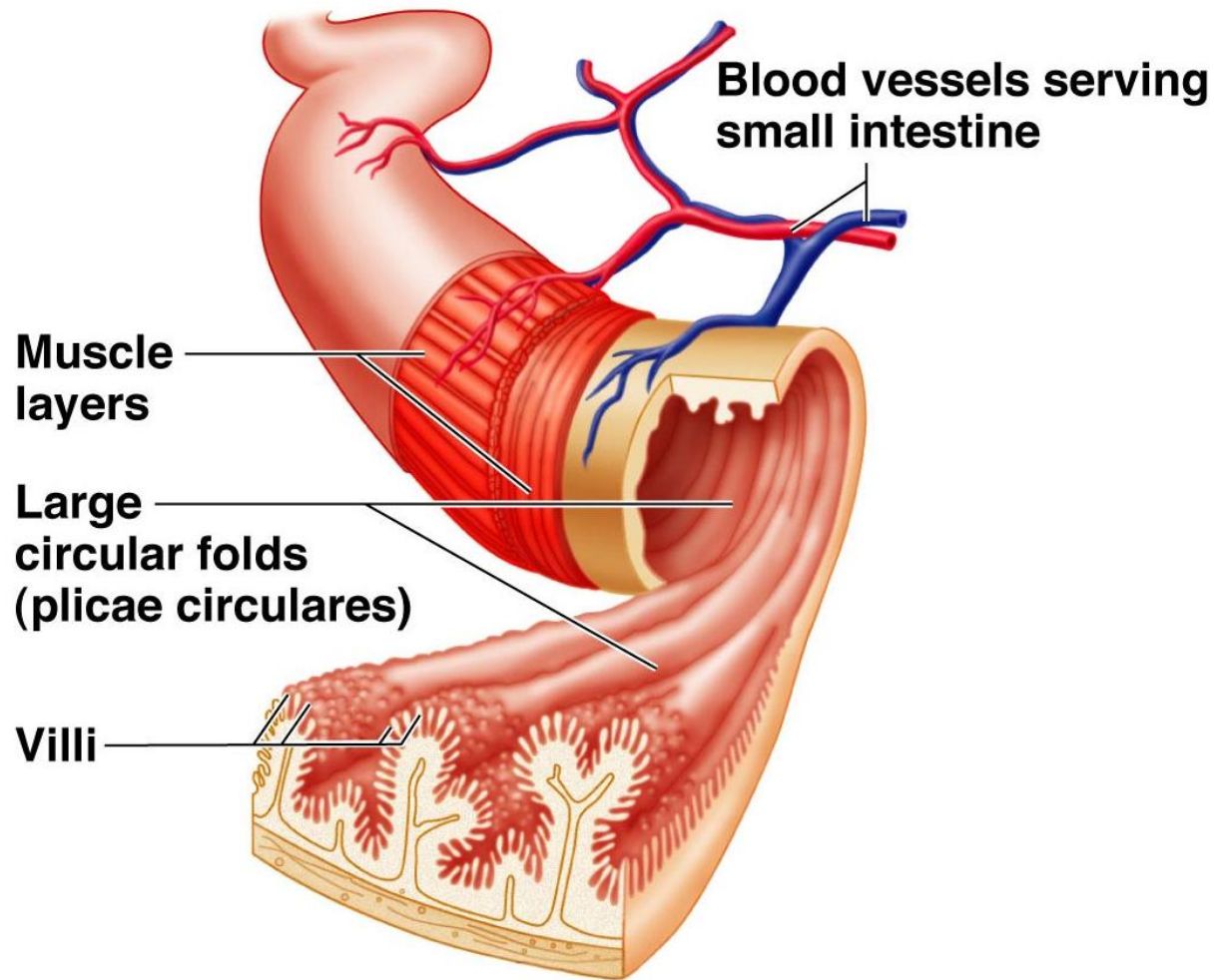
Anatomy of the Small Intestine



Small Intestine Anatomy

- **Three structural modifications that increase surface area**
 - **Microvilli—tiny projections of the plasma membrane (create a brush border appearance)**
 - **Villi—fingerlike structures formed with a mucosa core**
 - **Circular folds (plicae circulares)—visible folds with a submucosa core**

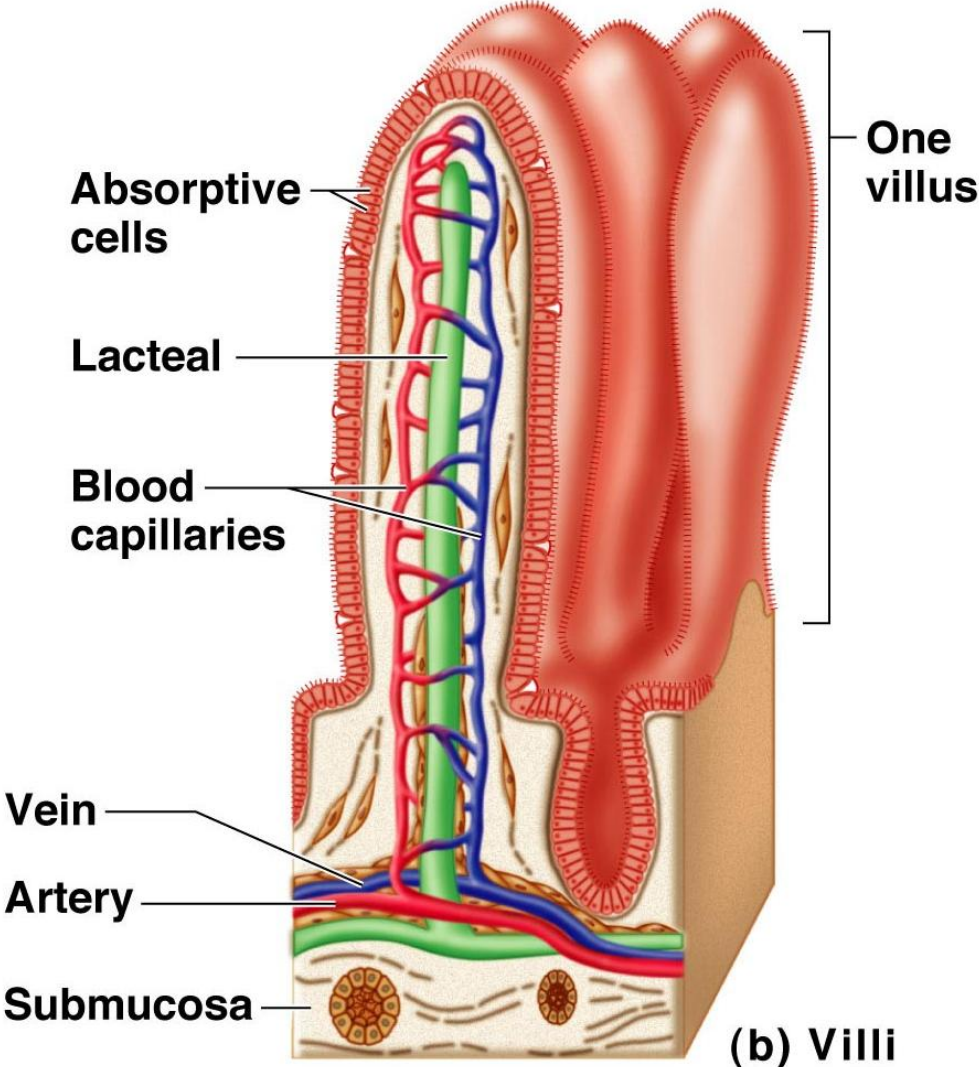
Small Intestine Anatomy



(a) Small intestine

Figure 14.7a

Small Intestine Anatomy



(b) Villi

Figure 14.7b

Small Intestine Anatomy

Microvilli



(c) Absorptive cells

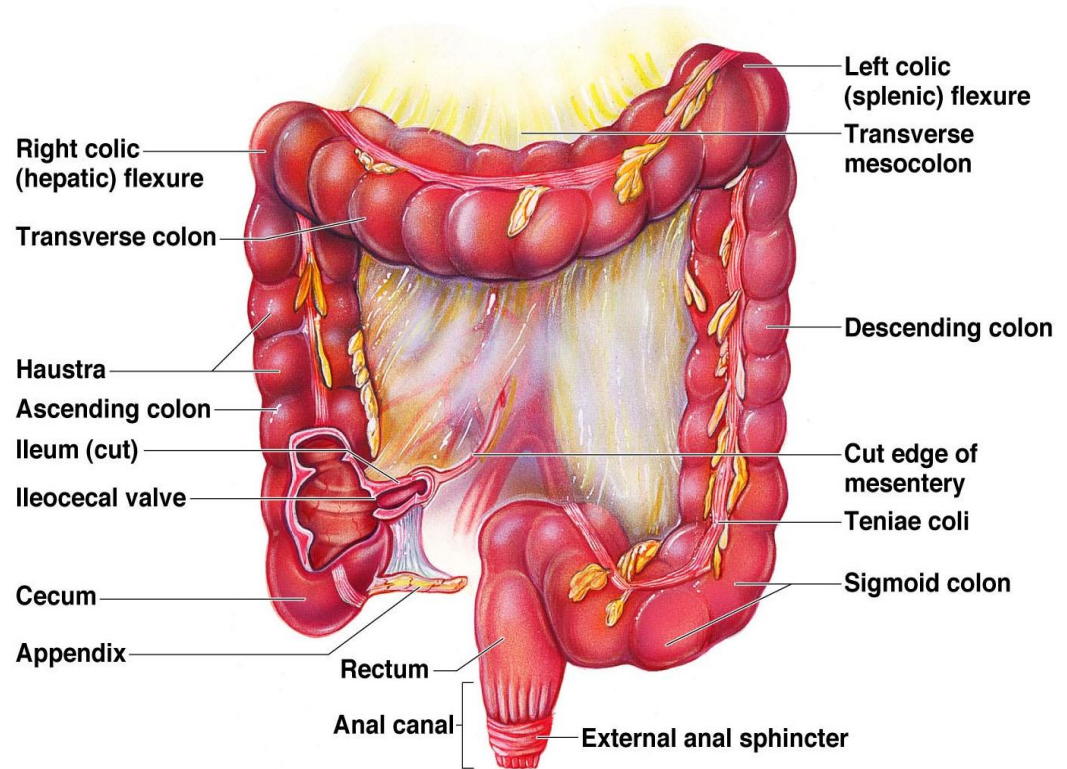
Figure 14.7c

Large Intestine

- Larger in diameter, but shorter in length, than the small intestine
- Frames the internal abdomen

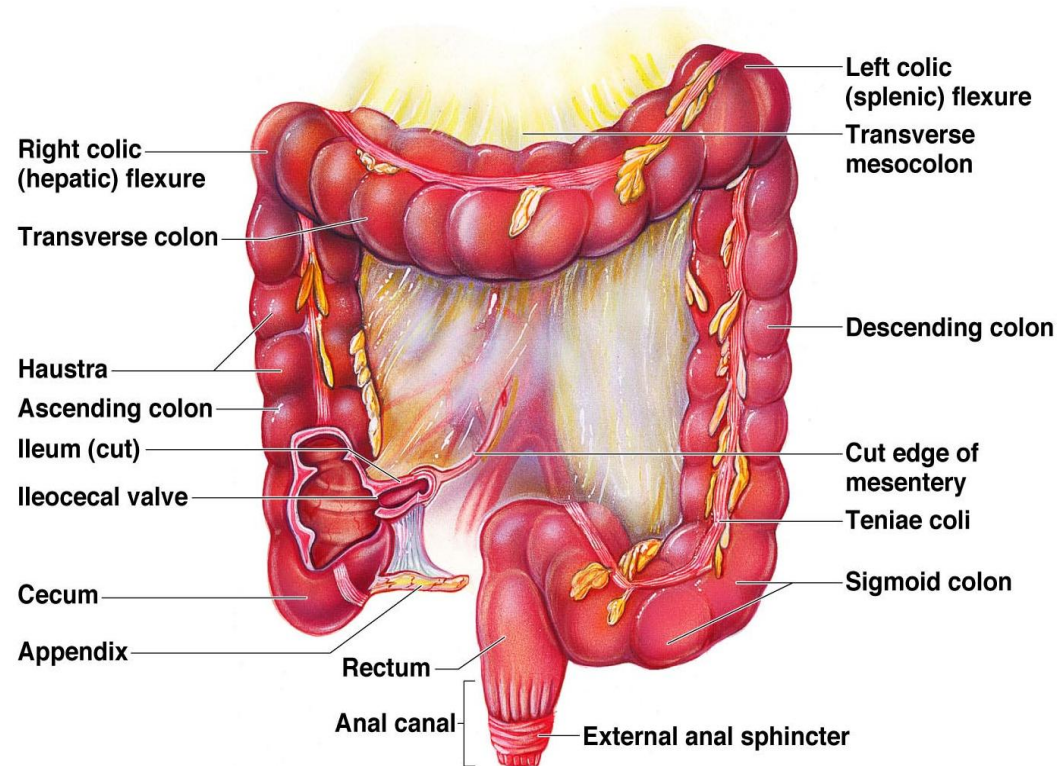
Large Intestine Anatomy

- Cecum—saclike first part of the large intestine
- Appendix
 - Accumulation of lymphatic tissue that sometimes becomes inflamed (appendicitis)
 - Hangs from the cecum



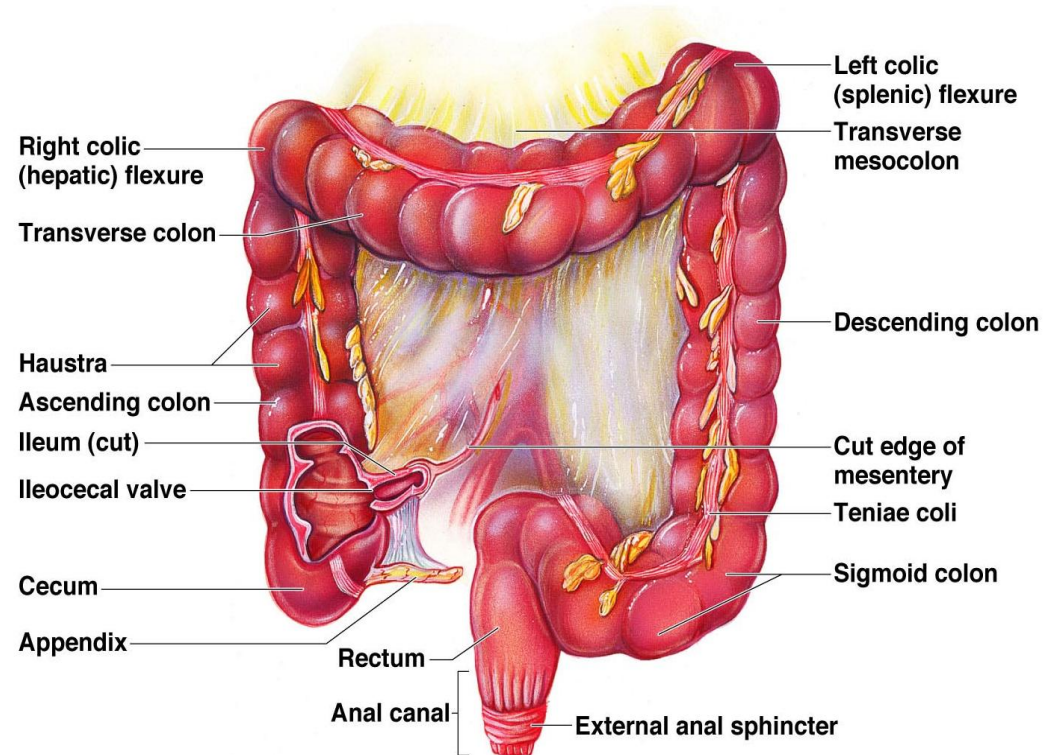
Large Intestine Anatomy

- **Colon**
 - **Ascending**—travels up right side of abdomen
 - **Transverse**—travels across the abdominal cavity
 - **Descending**—travels down the left side
 - **Sigmoid**—enters the pelvis
- **Rectum and anal canal**—also in pelvis



Large Intestine Anatomy

- **Anus—opening of the large intestine**
 - **External anal sphincter—formed by skeletal muscle and under voluntary control**
 - **Internal involuntary sphincter—formed by smooth muscle**
 - **These sphincters are normally closed except during defecation**



Large Intestine Anatomy

- **No villi present**
- **Goblet cells produce alkaline mucus which lubricates the passage of feces**
- **Muscularis externa layer is reduced to three bands of muscle called teniae coli**
- **These bands cause the wall to pucker into haustra (pocketlike sacs)**
- **Epiploic appendages: little tabs of fat hanging off wall**

Accessory Digestive Organs

- **Teeth**
- **Salivary glands**
- **Pancreas**
- **Liver**
- **Gallbladder**

Teeth

- **Function is to masticate (chew) food**
- **Humans have two sets of teeth**
 - **Deciduous (baby or “milk”) teeth**
 - **20 teeth are fully formed by age two**
- **Permanent teeth**
 - **Replace deciduous teeth between the ages of 6 and 12**
 - **A full set is 32 teeth, but some people do not have wisdom teeth (third molars)**
 - **If they do emerge, the wisdom teeth appear between ages of 17 and 25**

Human Deciduous and Permanent Teeth

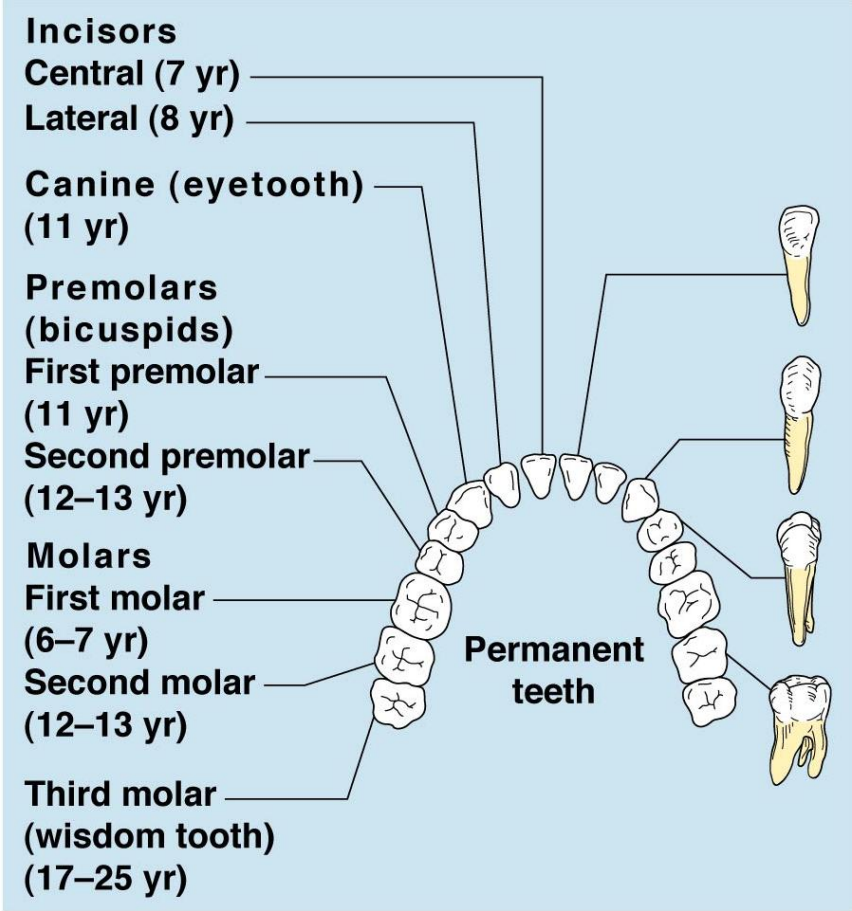
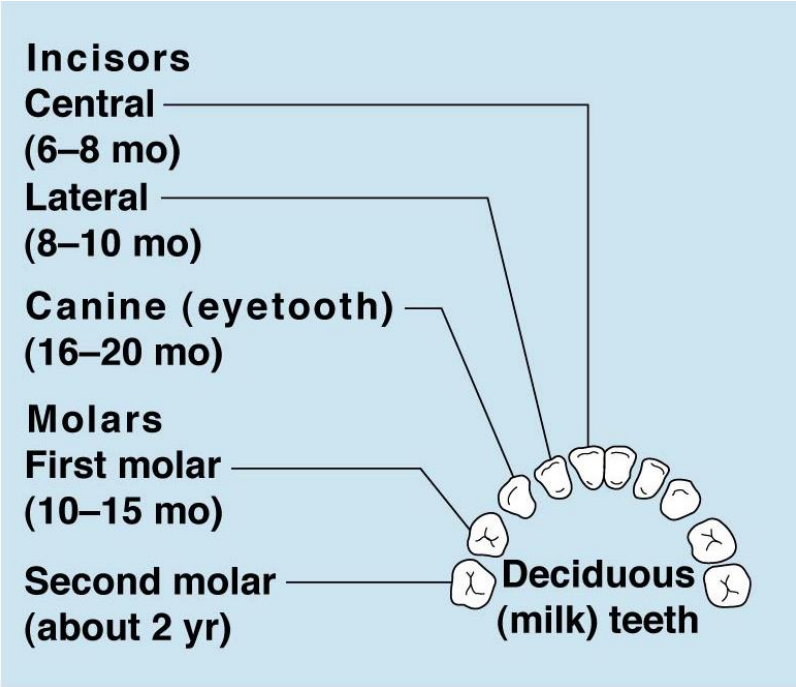
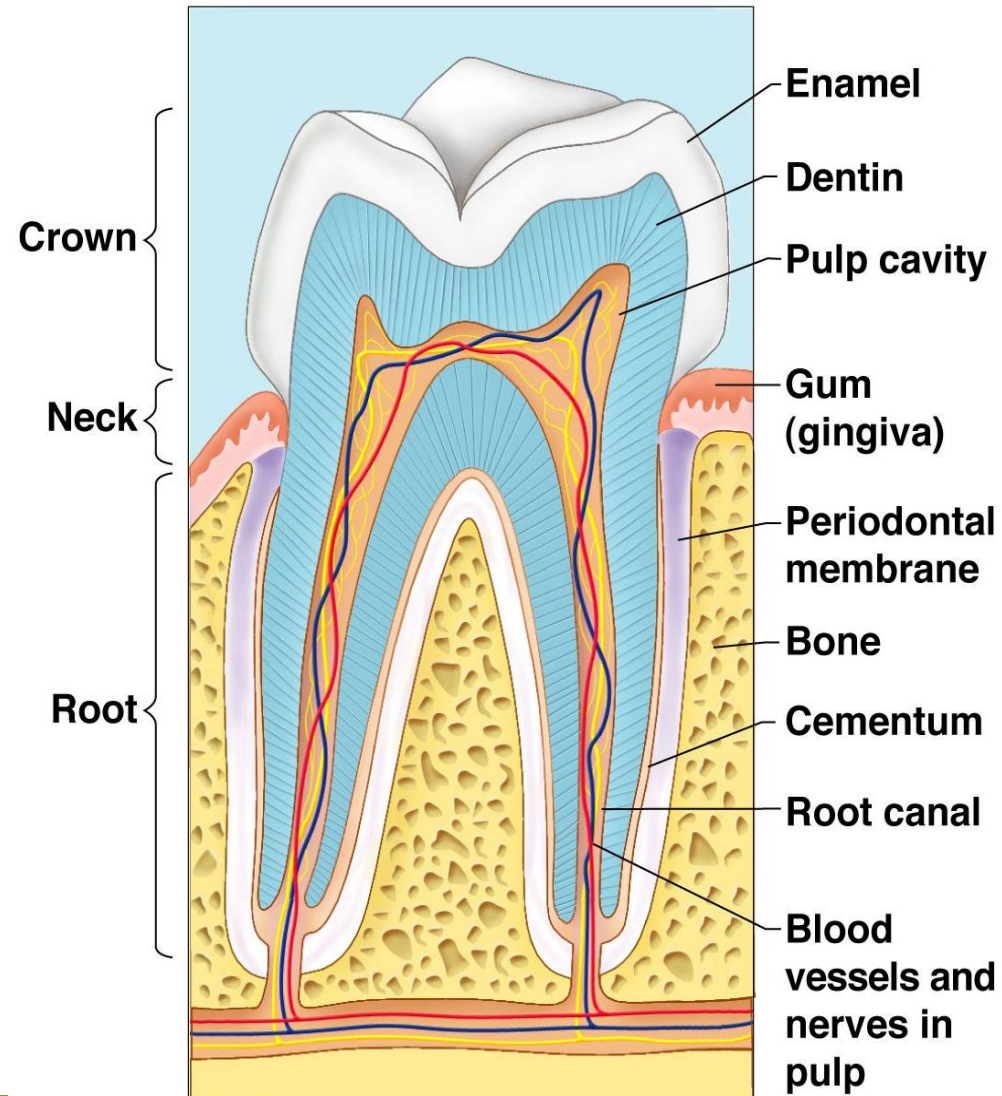


Figure 14.9

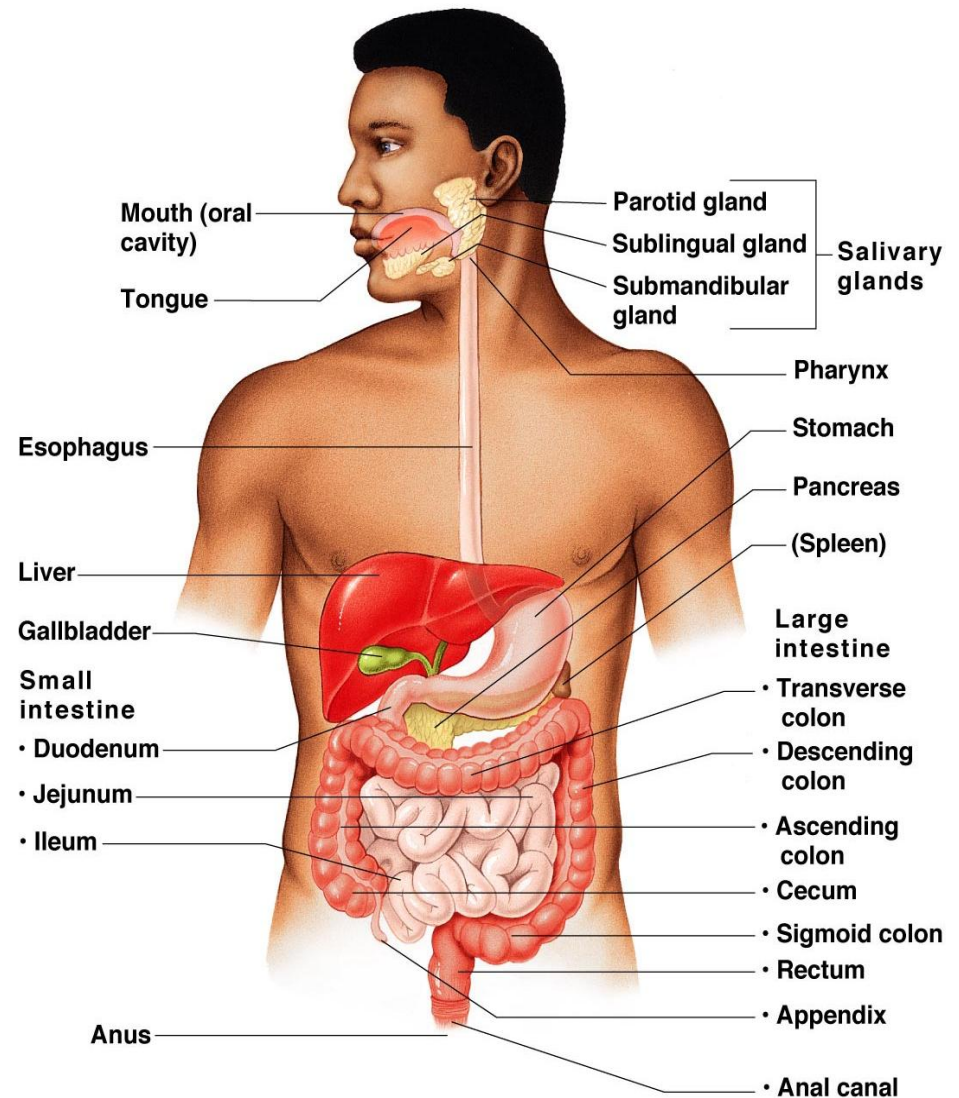
Regions of a Tooth

- **Crown**—exposed part
 - **Enamel**—hardest substance in the body
 - **Dentin**—found deep to the enamel and forms the bulk of the tooth
 - **Pulp cavity**—contains connective tissue, blood vessels, and nerve fibers
 - **Root canal**—where the pulp cavity extends into the root
- **Neck**
 - **Region in contact with the gum**
 - **Connects crown to root**
- **Root**
 - **Cementum**—covers outer surface and attaches the tooth to the periodontal membrane



Salivary Glands

- Three pairs of salivary glands empty secretions into the mouth
 - Parotid glands
 - Submandibular glands
 - Sublingual glands

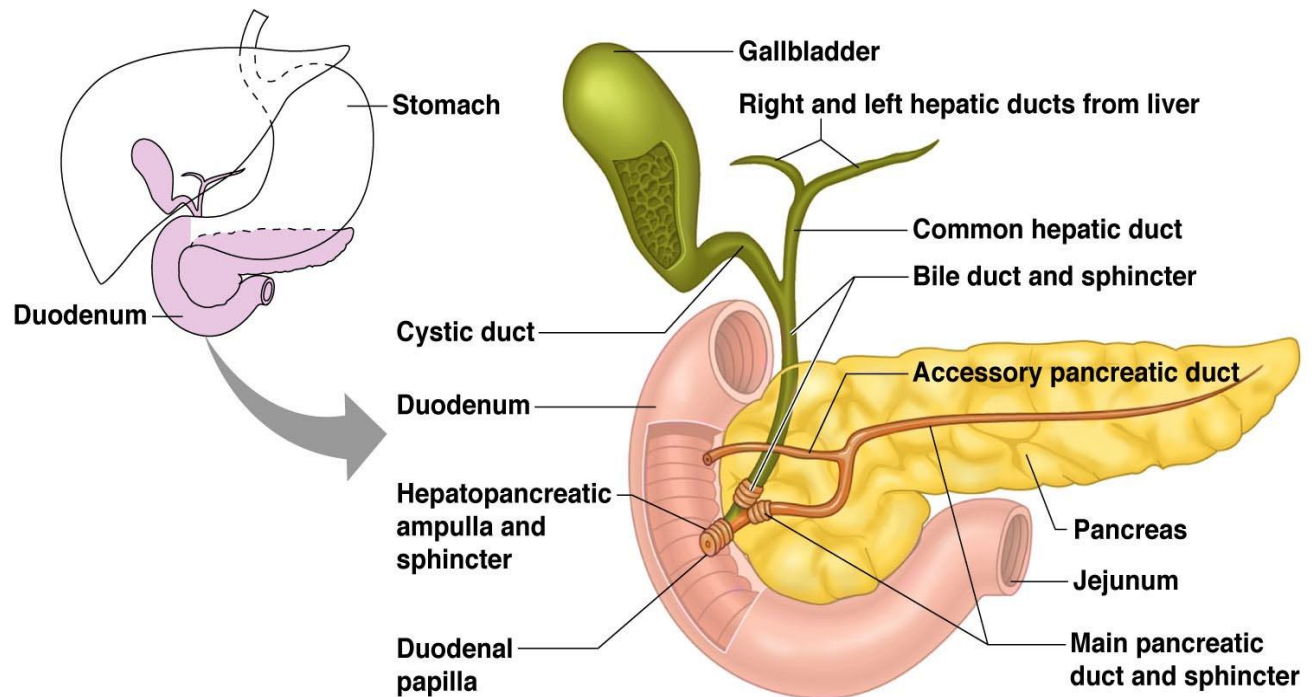


Saliva

- **Mixture of mucus and serous fluids**
- **Helps to form a food bolus**
- **Contains salivary amylase to begin starch digestion**
- **Dissolves chemicals so they can be tasted**

Pancreas

- Located against back, posterior to the parietal peritoneum
- Extends across the abdomen from spleen to duodenum

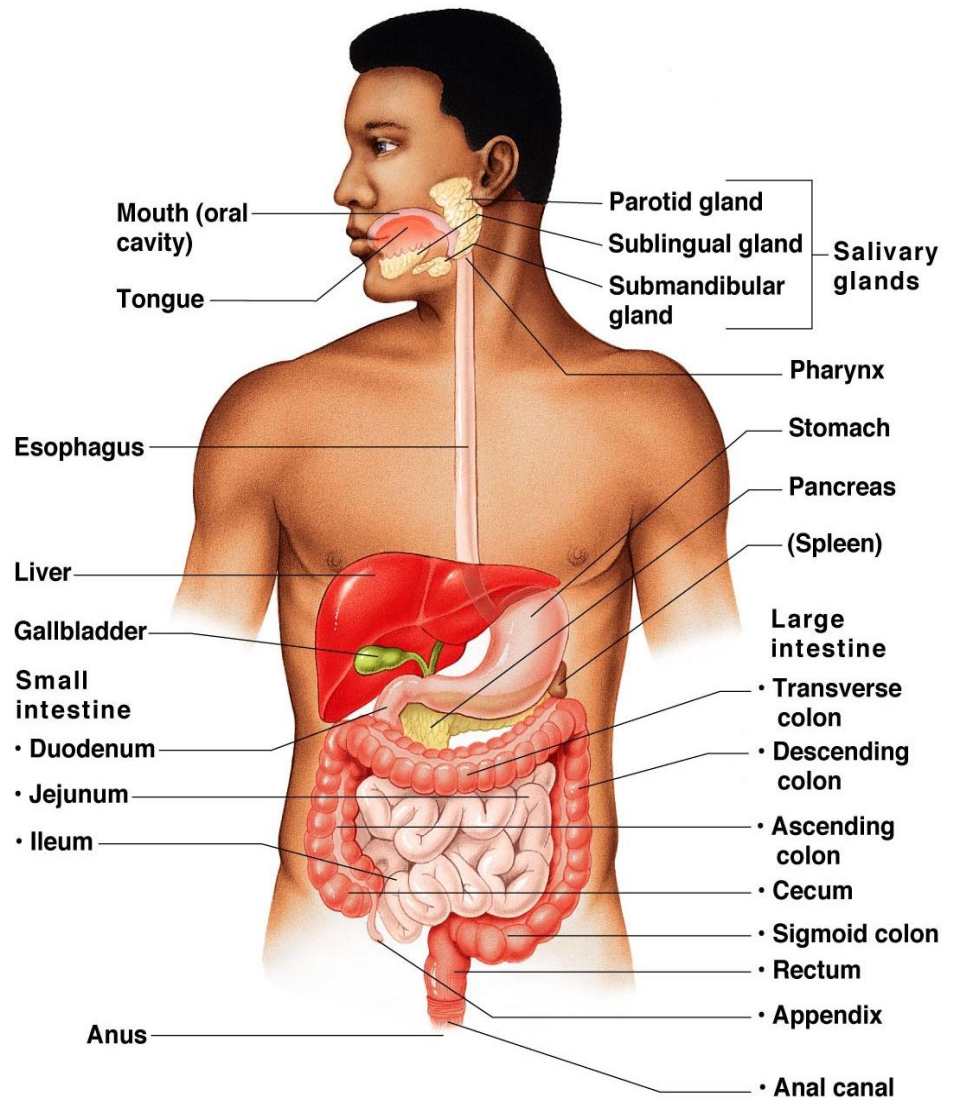


Pancreas

- **Produces a wide spectrum of digestive enzymes that break down all categories of food**
- **Enzymes are secreted into the duodenum**
- **Alkaline fluid introduced with enzymes neutralizes acidic chyme coming from stomach**
- **Hormones produced by the pancreas**
 - **Insulin**
 - **Glucagon**

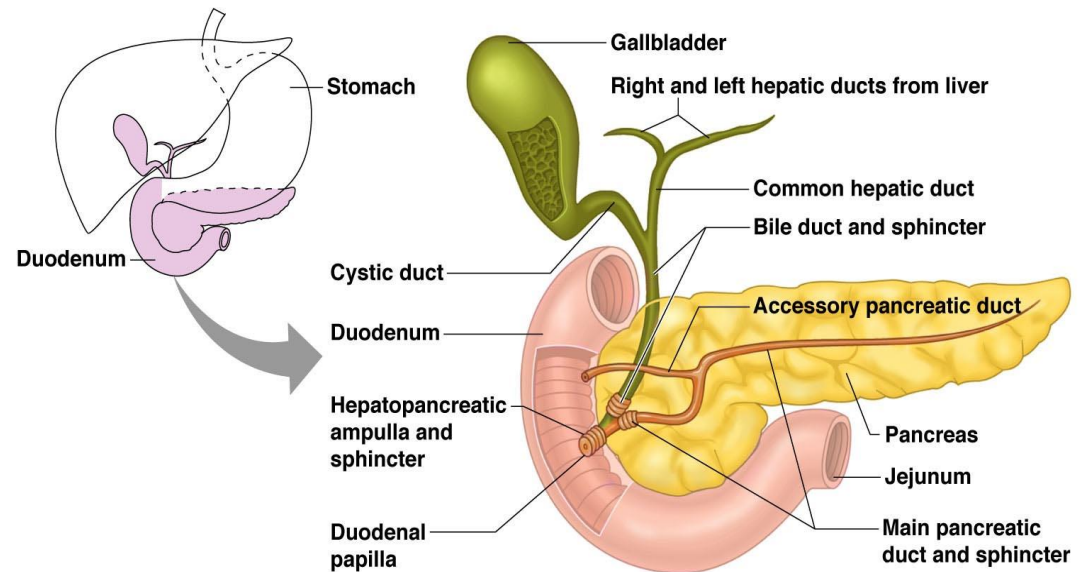
Liver & Gall Bladder

- Largest gland in the body
- Located on the right side of the body under the diaphragm
- Consists of four lobes suspended from the diaphragm and abdominal wall by the falciform ligament
- Connected to the gallbladder via the common hepatic duct



Gallbladder

- Stores and concentrates bile
- When digestion of fatty food is occurring, bile is introduced into the duodenum from the gallbladder
- Gallstones are crystallized cholesterol which can cause blockages

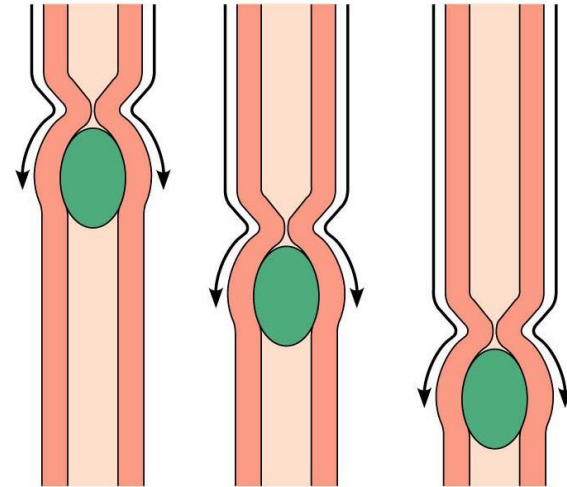


Bile

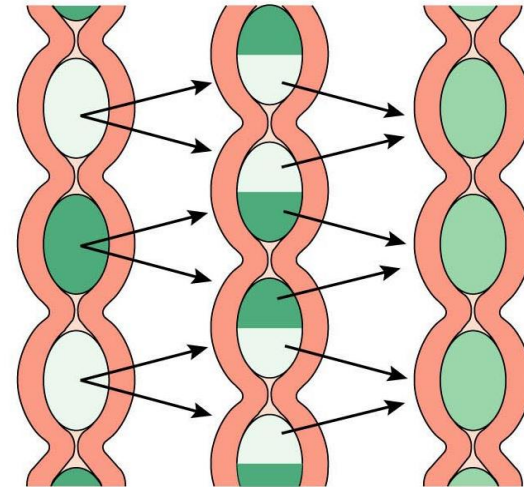
- **Produced by cells in the liver**
- **Composition is**
 - **Bile salts**
 - **Bile pigments (mostly bilirubin from the breakdown of hemoglobin)**
 - **Cholesterol**
 - **Phospholipids**
 - **Electrolytes**
- **Function—emulsify fats by physically breaking large fat globules into smaller ones**

Functions of the Digestive System

- **Ingestion**—getting food into the mouth
- **Propulsion**—moving foods from one region of the digestive system to another
 - **Peristalsis**—alternating waves of contraction and relaxation that squeezes food along the GI tract
 - **Segmentation**—moving materials back and forth to aid with mixing in the small intestine



(a)



(b)

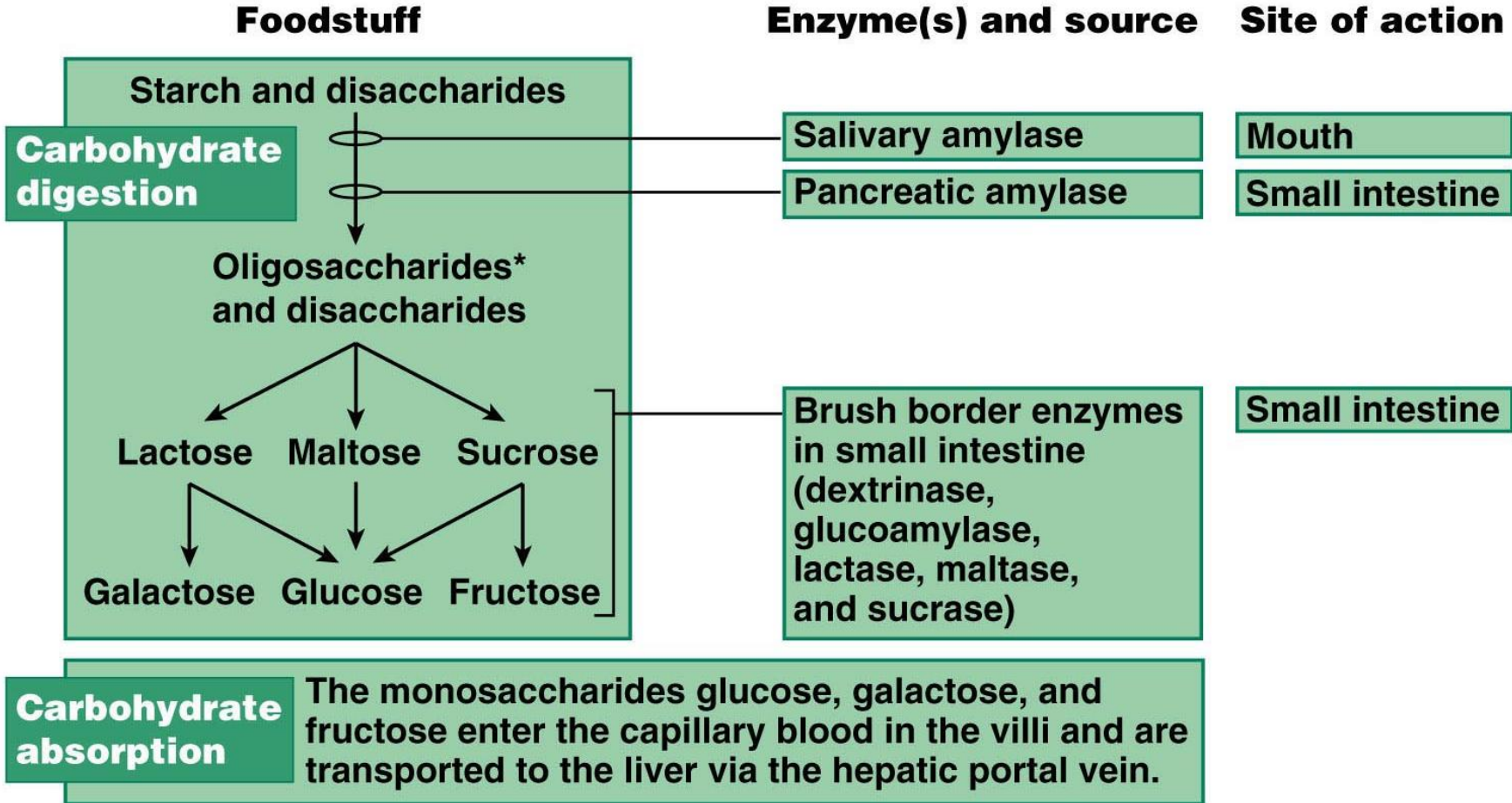
Functions of the Digestive System

- Food breakdown as *mechanical* digestion
 - ***Examples:***
 - Mixing food in the mouth by the tongue
 - Churning food in the stomach
 - Segmentation in the small intestine
 - Mechanical digestion prepares food for further degradation by enzymes

Functions of the Digestive System

- Food breakdown as *chemical* digestion
 - Enzymes break down food molecules into their building blocks
 - Each major food group uses different enzymes
 - Carbohydrates are broken to simple sugars
 - Proteins are broken to amino acids
 - Fats are broken to fatty acids and alcohols

Functions of the Digestive System



*Oligosaccharides consist of a few linked monosaccharides.

Figure 14.13 (1 of 3)

Functions of the Digestive System

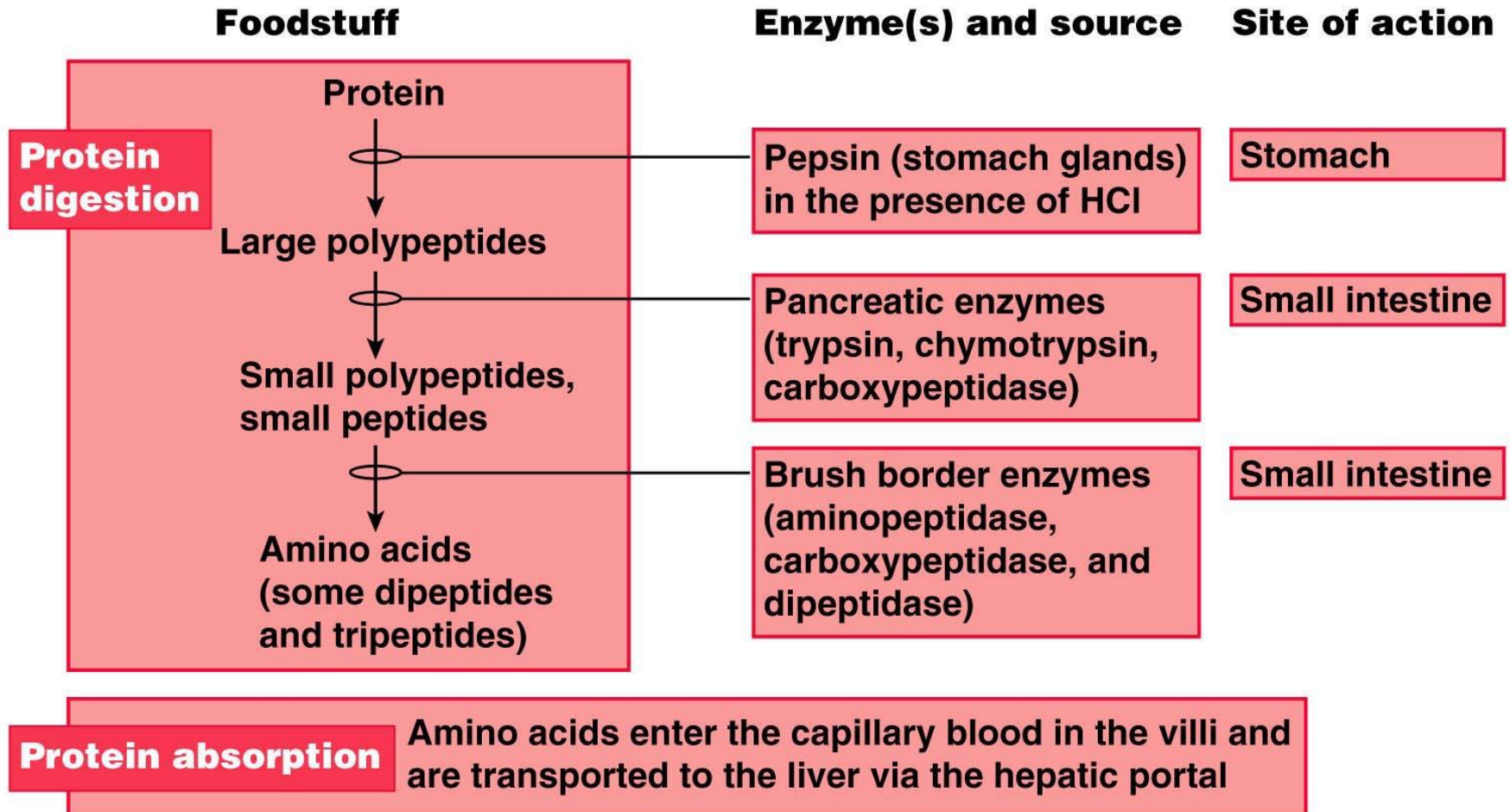


Figure 14.13 (2 of 3)

Functions of the Digestive System

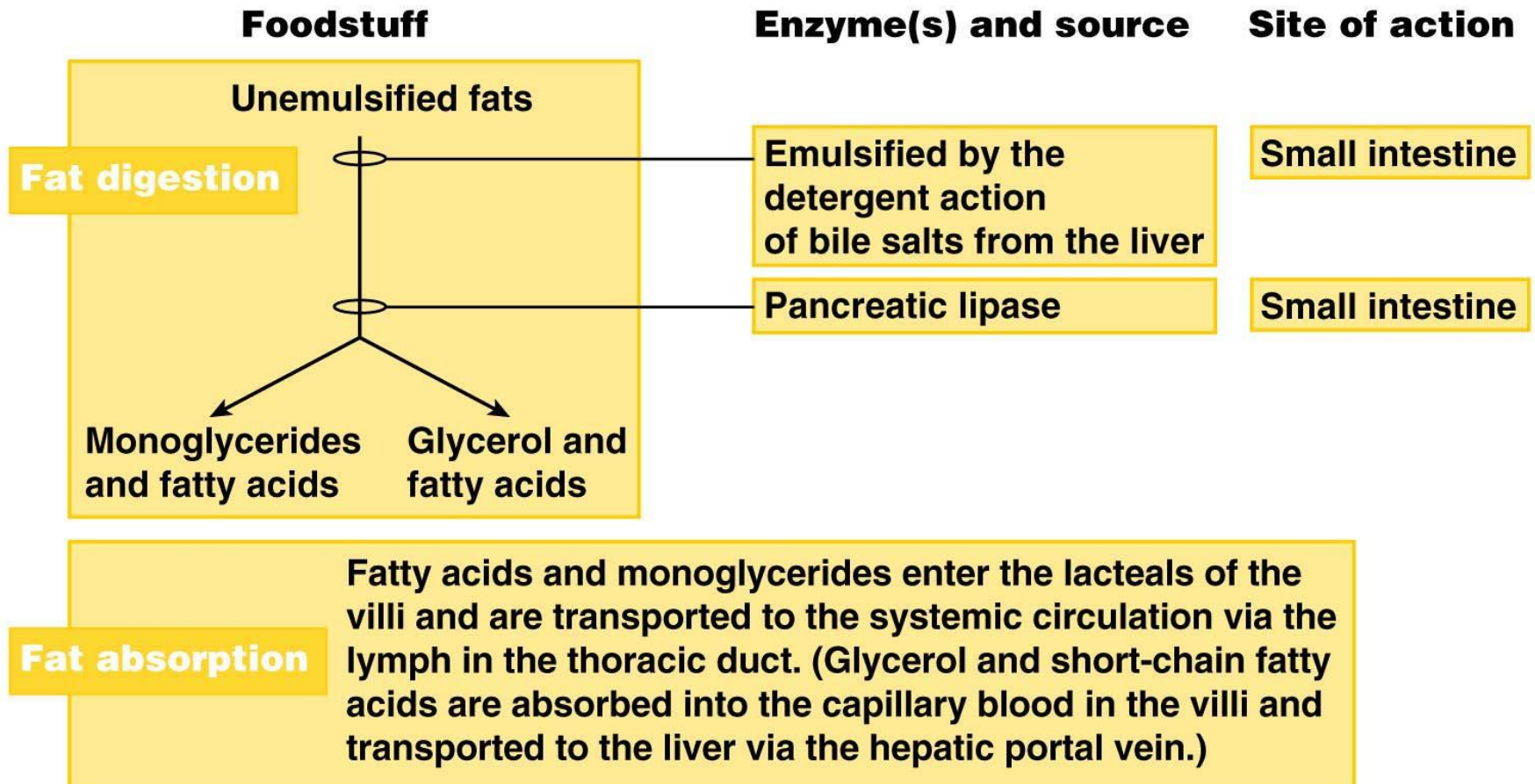


Figure 14.13 (3 of 3)

Small Intestine Anatomy

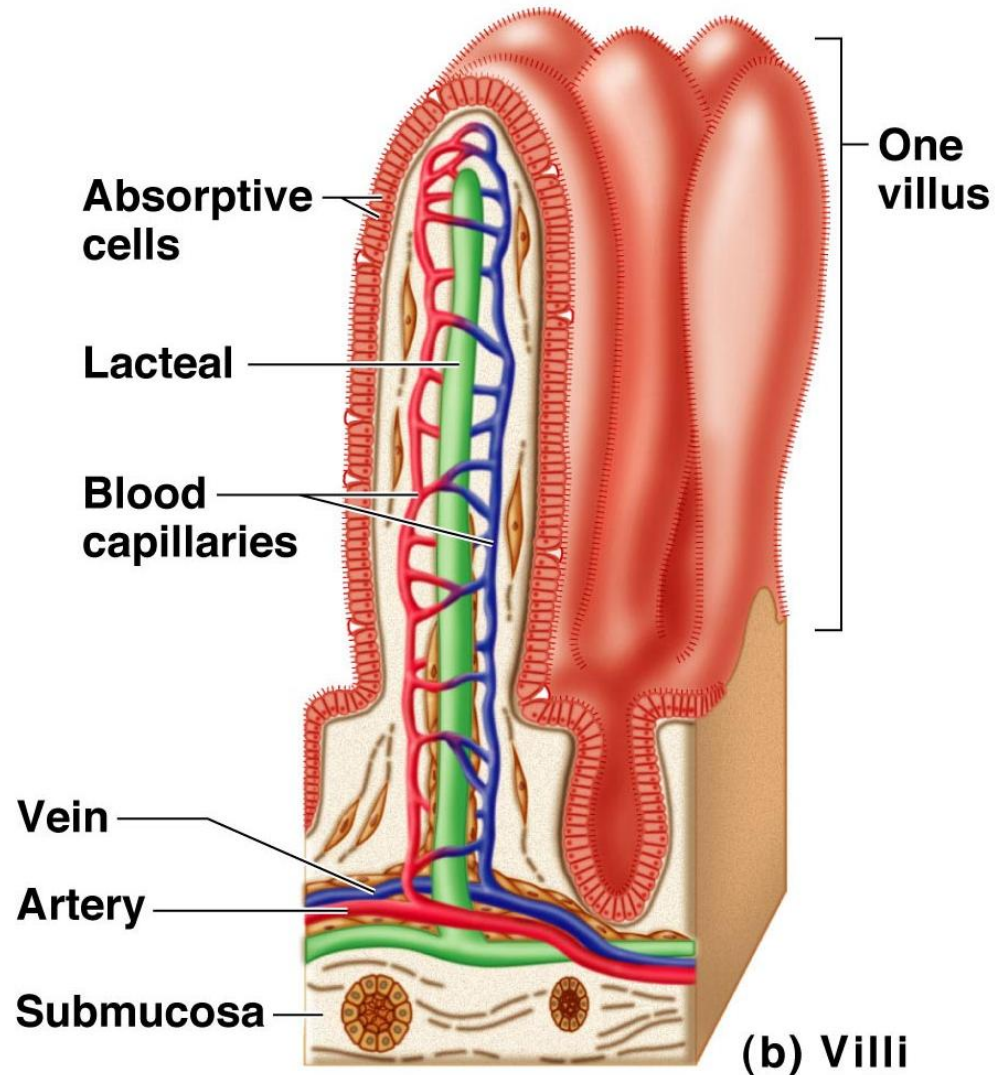


Figure 14.7b

Functions of the Digestive System

- **Absorption**
 - **End products of digestion are absorbed in the blood or lymph**
 - **Food must enter mucosal cells and then into blood or lymph capillaries**
- **Defecation**
 - **Elimination of indigestible substances from the GI tract in the form of feces**

Control of Digestive Activity

- **Mostly controlled by reflexes via the parasympathetic division**
- **Chemical and mechanical receptors are located in organ walls that trigger reflexes**

Control of Digestive Activity

- **Stimuli include**
 - **Stretch of the organ**
 - **pH of the contents**
 - **Presence of breakdown products**
- **Reflexes include**
 - **Activation or inhibition of glandular secretions**
 - **Smooth muscle activity**

Digestive Activities of the Mouth

- **Mechanical breakdown**
 - **Food is physically broken down by chewing**
- **Chemical digestion**
 - **Food is mixed with saliva**
 - **Starch is broken down into maltose by salivary amylase**

Activities of the Pharynx and Esophagus

- **These organs have no digestive function**
- **Serve as passageways to the stomach**

Food Breakdown in the Stomach

- **Gastric juice is regulated by neural and hormonal factors**
- **Presence of food or rising pH causes the release of the hormone gastrin**
- **Gastrin causes stomach glands to produce**
 - **Protein-digesting enzymes**
 - **Mucus**
 - **Hydrochloric acid**

Food Breakdown in the Stomach

- **Hydrochloric acid makes the stomach contents very acidic**
- **Acidic pH**
 - **Activates pepsinogen to pepsin for protein digestion**
 - **Provides a hostile environment for microorganisms**

Digestion and Absorption in the Stomach

- **Protein digestion enzymes**
 - **Pepsin—an active protein-digesting enzyme**
- **Alcohol and aspirin are the only items absorbed in the stomach**

Propulsion in the Stomach

- **Food must first be well mixed, churning activity**
- **Rippling peristalsis occurs in the lower stomach**
- **The pylorus meters out chyme into the small intestine (30 mL at a time; about 2 tablespoons)**
- **The stomach empties in 4–6 hours, depending on diet**

Propulsion in the Stomach

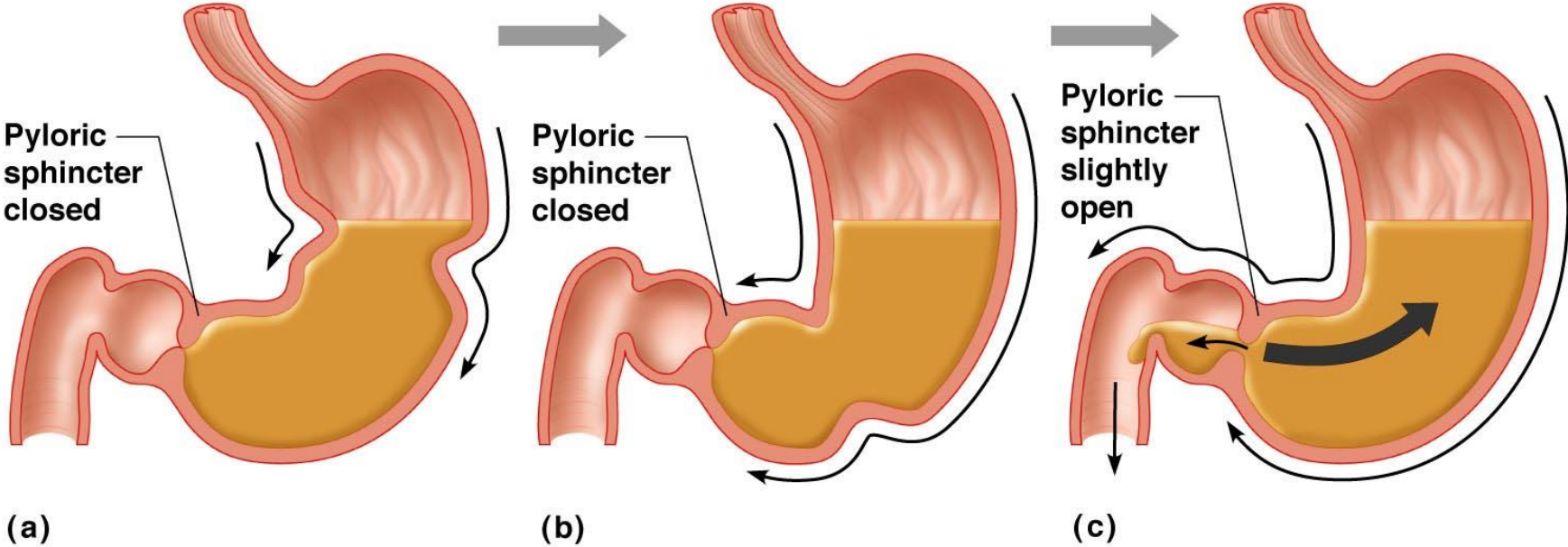


Figure 14.15a–c

Digestion in the Small Intestine

- **Enzymes from the intestinal brush border function to**
 - **Break double sugars into simple sugars**
 - **Complete some protein digestion**
- **Pancreatic enzymes (via pancreatic ducts) play the major digestive function**
 - **Help complete digestion of starch (pancreatic amylase)**
 - **Carry out about half of all protein digestion**
 - **Digest fats using lipases from the pancreas**
 - **Digest nucleic acids using nucleases**
- **Alkaline content neutralizes acidic chyme**
- **Bile, formed by the liver, enters via the bile duct**

Digestion in the Small Intestine

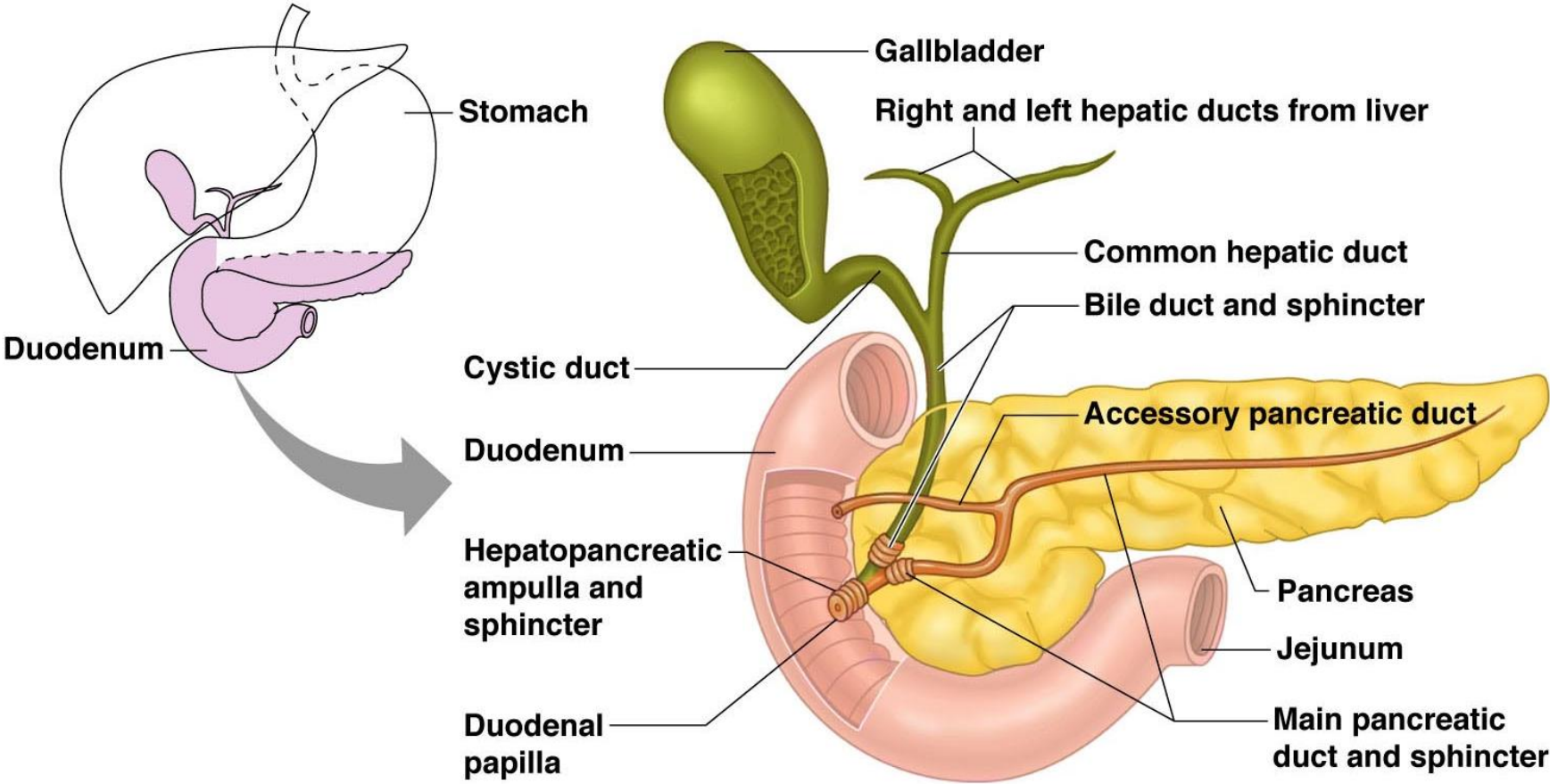


Figure 14.6

Absorption in the Small Intestine

- **Water is absorbed along the length of the small intestine**
- **End products of digestion**
 - **Most substances are absorbed by active transport through cell membranes**
 - **Lipids are absorbed by diffusion**
- **Substances are transported to the liver by the hepatic portal vein or lymph**

Food Breakdown and Absorption in the Large Intestine

- No digestive enzymes are produced
- Resident bacteria digest remaining nutrients
 - Produce some vitamin K and B
 - Release gases
- Water and vitamins K and B are absorbed
- Remaining materials are eliminated via feces
- Feces contains
 - Undigested food residues
 - Mucus
 - Bacteria
 - Water