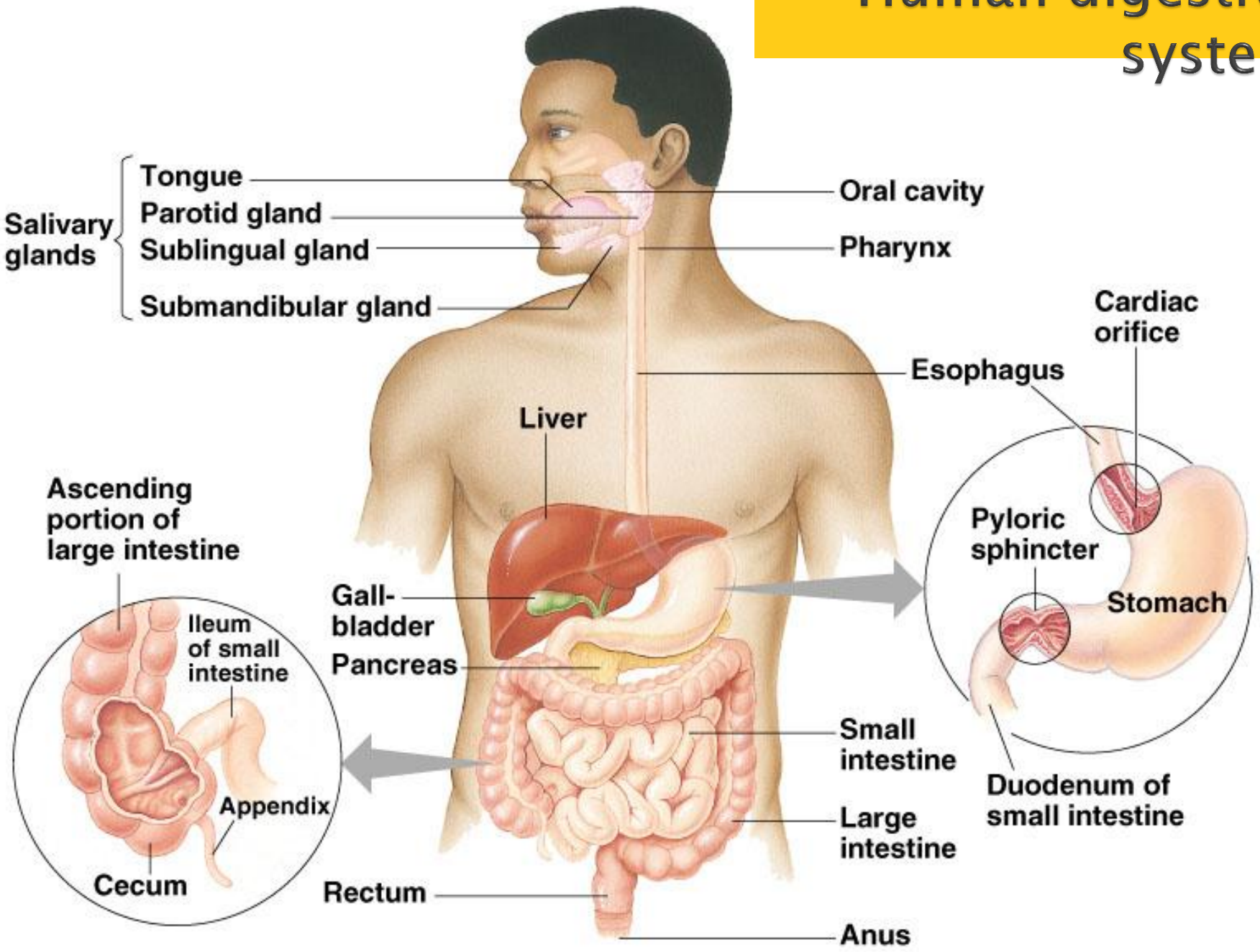
The Digestive System

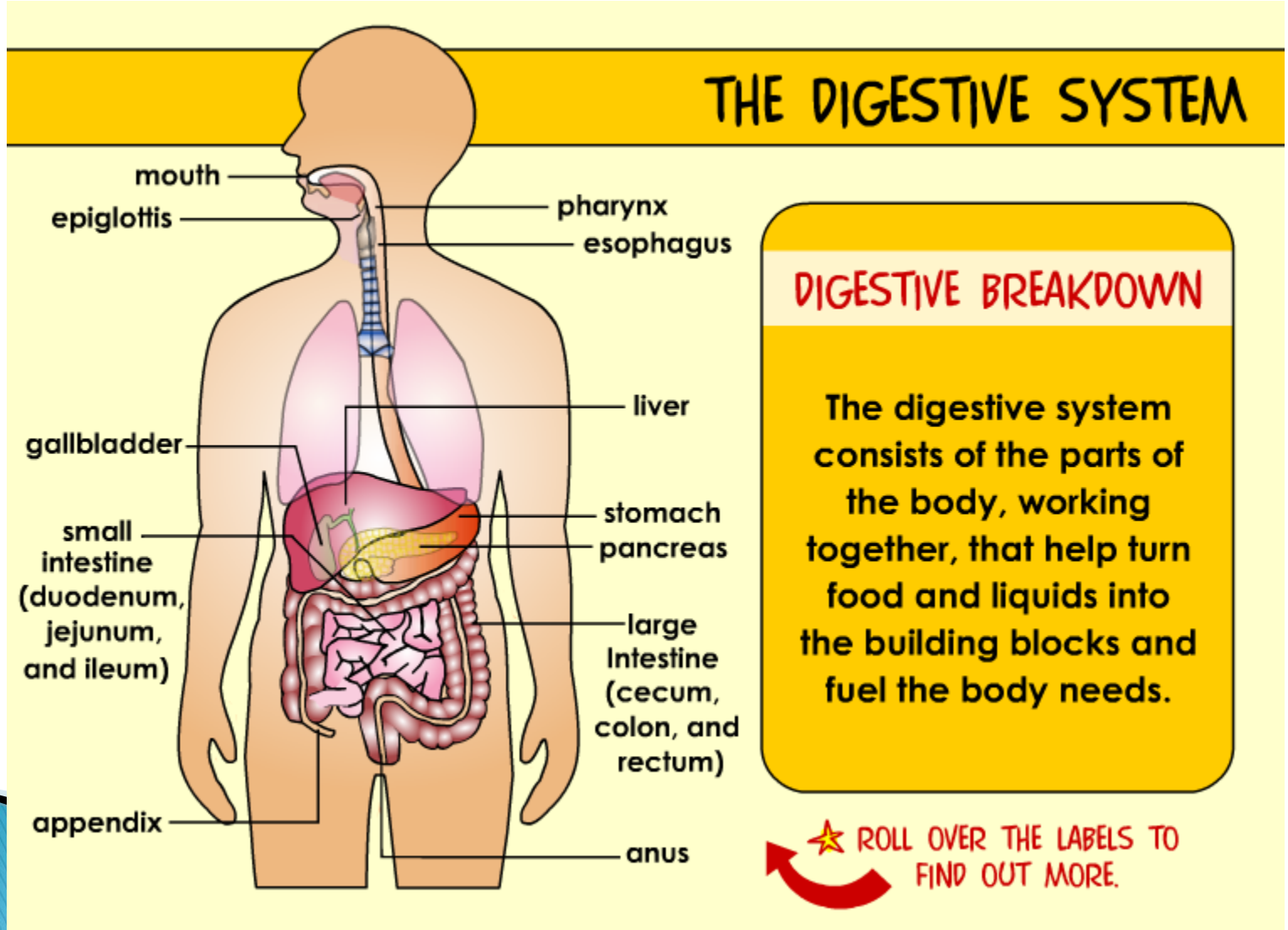
- Chapter 16
- Adapted from: Copyright 2009, John Wiley & Sons, Inc
- http://anatronica.com/anatronica-flash-abdominal-cavity.html

Introduction

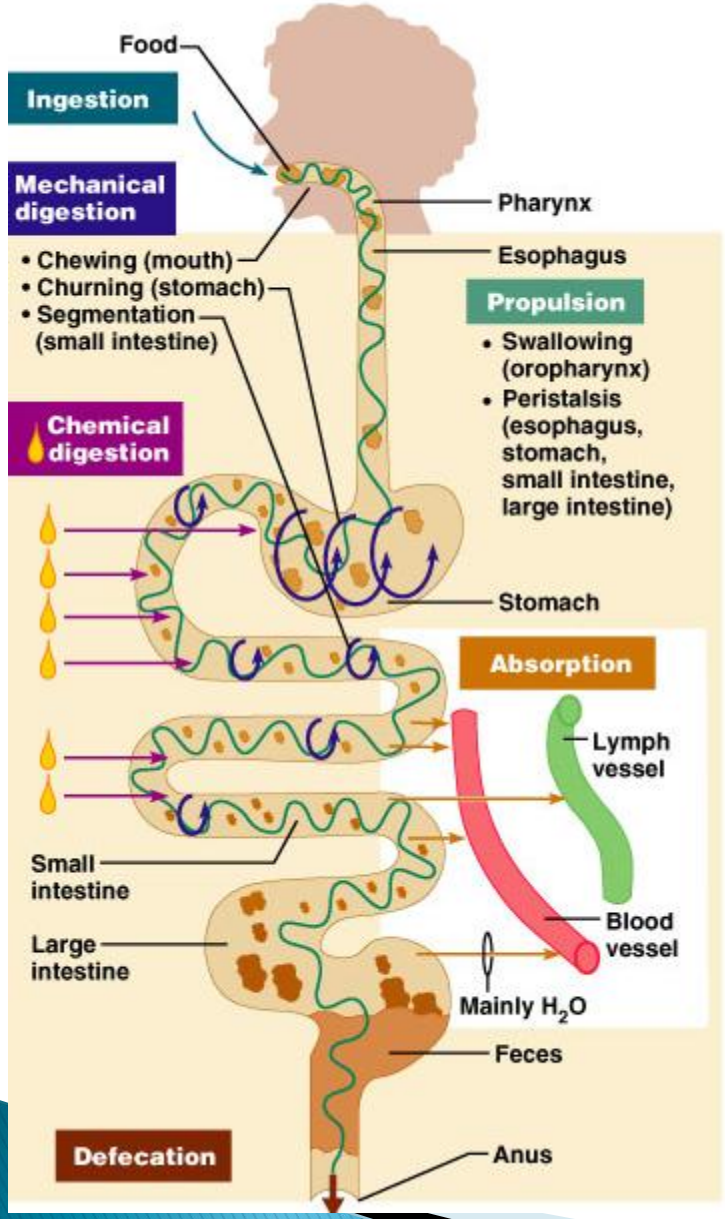
Human digestive system



GI (gastrointestinal) tract = alimentary canal



The Digestive Process

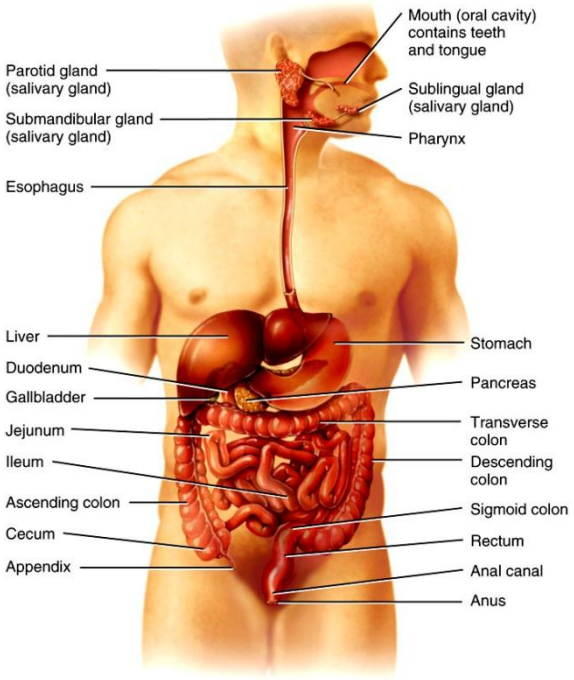


- Ingestion
  - Taking in food through the mouth
- Propulsion (movement of food)
  - Swallowing
  - Peristalsis – propulsion by alternate contraction &relaxation
- Mechanical digestion
  - Chewing
  - Churning in stomach
  - Mixing by segmentation
- Chemical digestion
  - By secreted enzymes: see later
- Absorption
  - Transport of digested end products into blood and lymph in wall of canal
- Defecation
  - Elimination of indigestible substances from body as feces

2 groups of organs compose the digestive system

1. **Gastrointestinal (GI) tract or alimentary canal** – mouth (oral cavity), most of pharynx, esophagus, stomach, small intestine, & large intestine
    1. 30 feet
    2. Long continuous tube
    3. Ventral body Cavity
2. **Accessory digestive organs** – teeth, tongue, salivary glands, liver, gallbladder, & pancreas

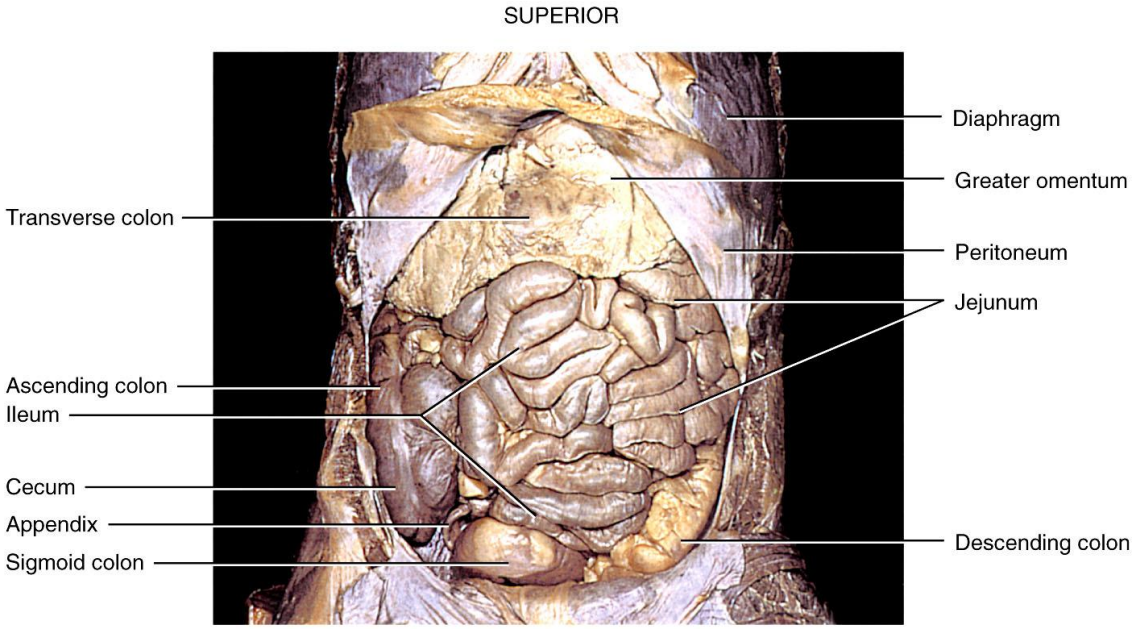
Organs of the digestive system



(a) Right lateral view of head and neck and anterior view of trunk

Figure 24.01a Tortora - PAP 12/e

Copyright © John Wiley and Sons, Inc. All rights reserved.



(b) Anterior view

Figure 24.01b Tortora - PAP 12/e

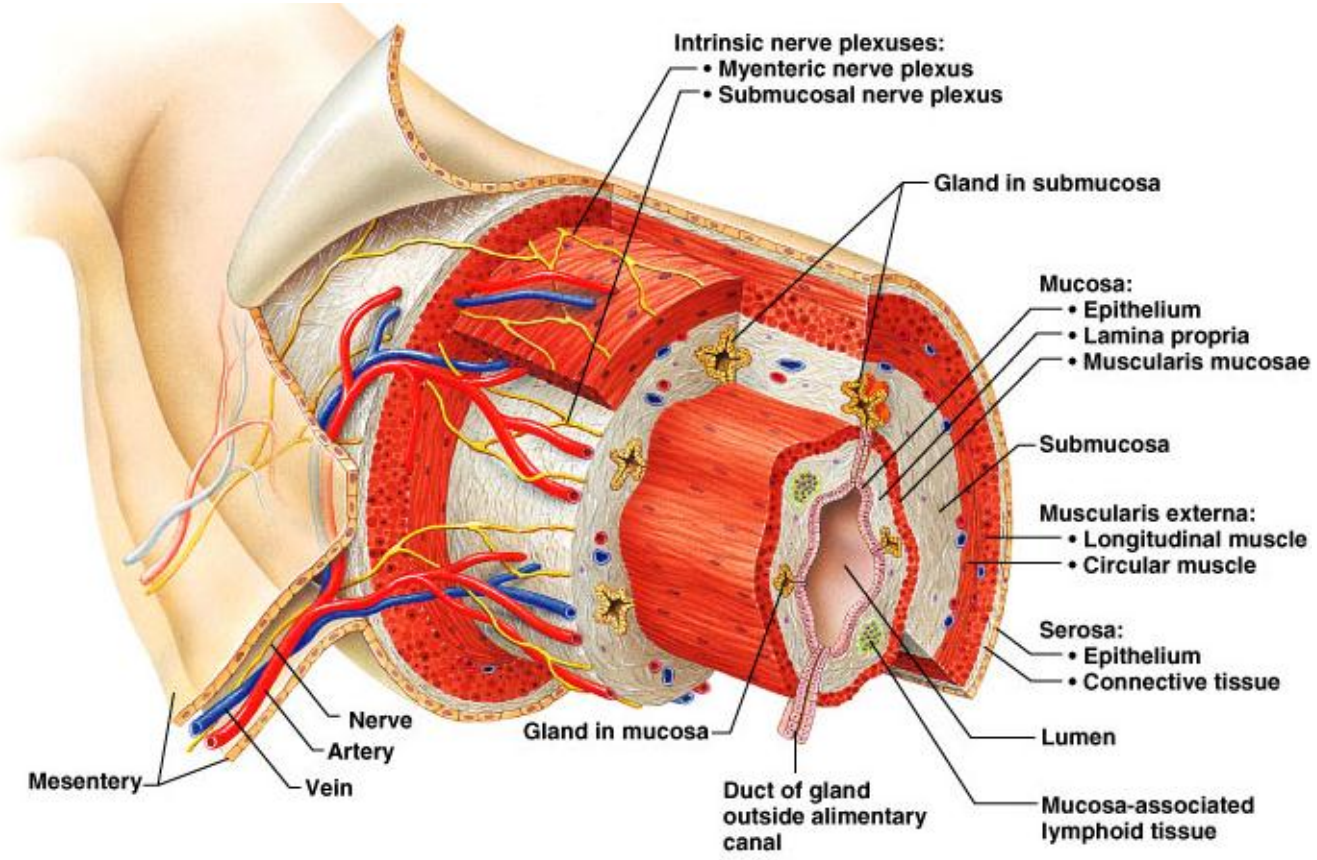
Copyright © John Wiley and Sons, Inc. All rights reserved.

6 functions of the digestive system

1. **Ingestion** – taking of food into the body
2. Secretion of water, acid, buffers, and enzymes into lumen
3. **Peristalsis** – Mixing and propulsion; pushing of food along digestive tract
4. **Digestion**
   - Mechanical – churns food
   - Chemical – hydrolysis
5. **Absorption** – passing into blood or lymph for distribution to the body cells
6. **Defecation** – elimination of feces (indigestible or cannot be absorbed)

Histology of alimentary canal wall

Same four layers from esophagus to anal canal



1. Mucosa
2. Submucosa
3. Muscularis externa
4. Serosa

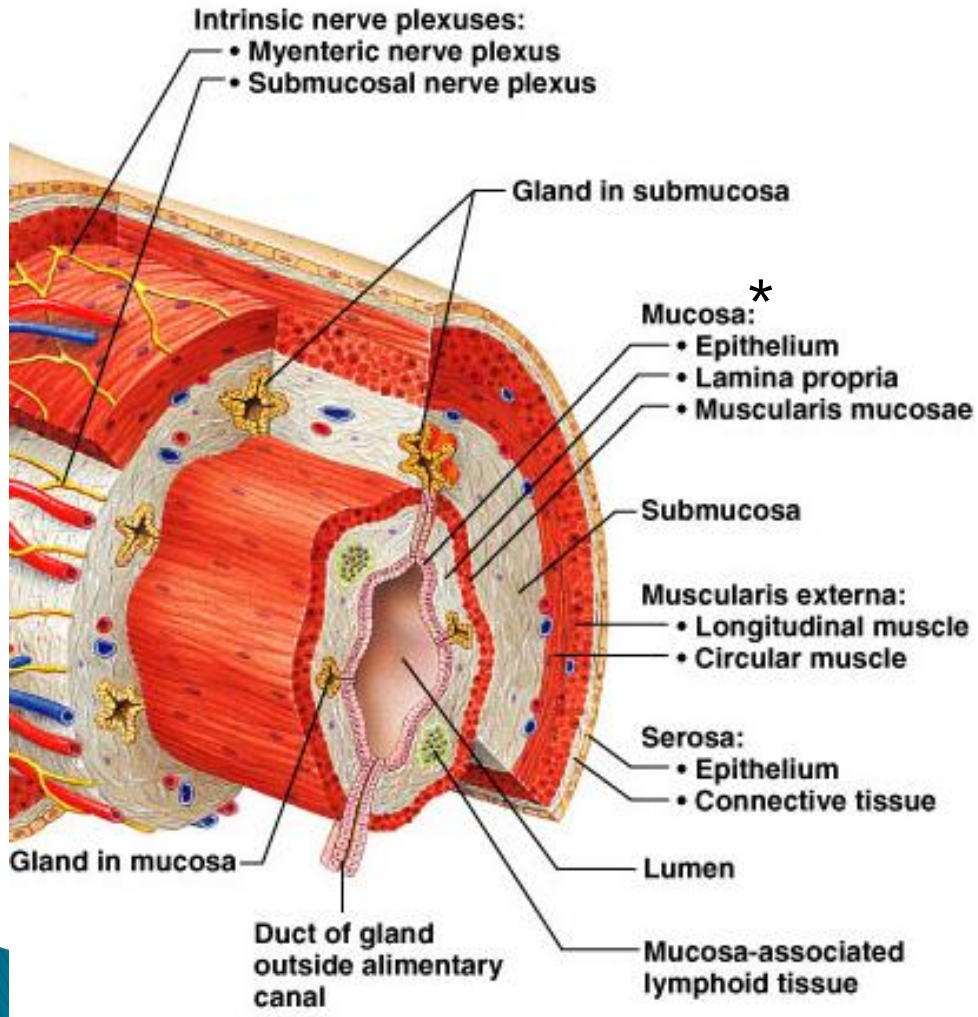
from lumen (inside) out

Layers (Tunics/Coats) of the GI tract

- Wall of GI tract from lower esophagus to anal canal has same basic 4 tissue layers.

1. **Tunica Mucosa** – inner lining
   - Epithelium protection, secretion, absorption
   - **Lamina propria** – connective tissue with blood and lymph support
   - **Muscularis mucosae** – thin layer of smooth muscle making folds to increase surface area
2. **Tunica Submucosa**
   - Connective tissue binding mucosa to muscularis
   - Contains many blood and lymphatic vessels

Inner layer: the mucosa*
(mucous membrane)



Three sub-layers

1. Lining epithelium
2. Lamina propria
3. Muscularis mucosae

Layers of the GI tract

3. Tunica Muscularis

- Contains the nerves
- **Voluntary** skeletal muscle found in mouth, pharynx, & upper 2/3 of esophagus for voluntary swallowing.
- **Involuntary** smooth muscle for physical breakdown of food, mixing with digestive secretions, and peristalsis.
  - Arranged in inner circular fibers and outer longitudinal fibers

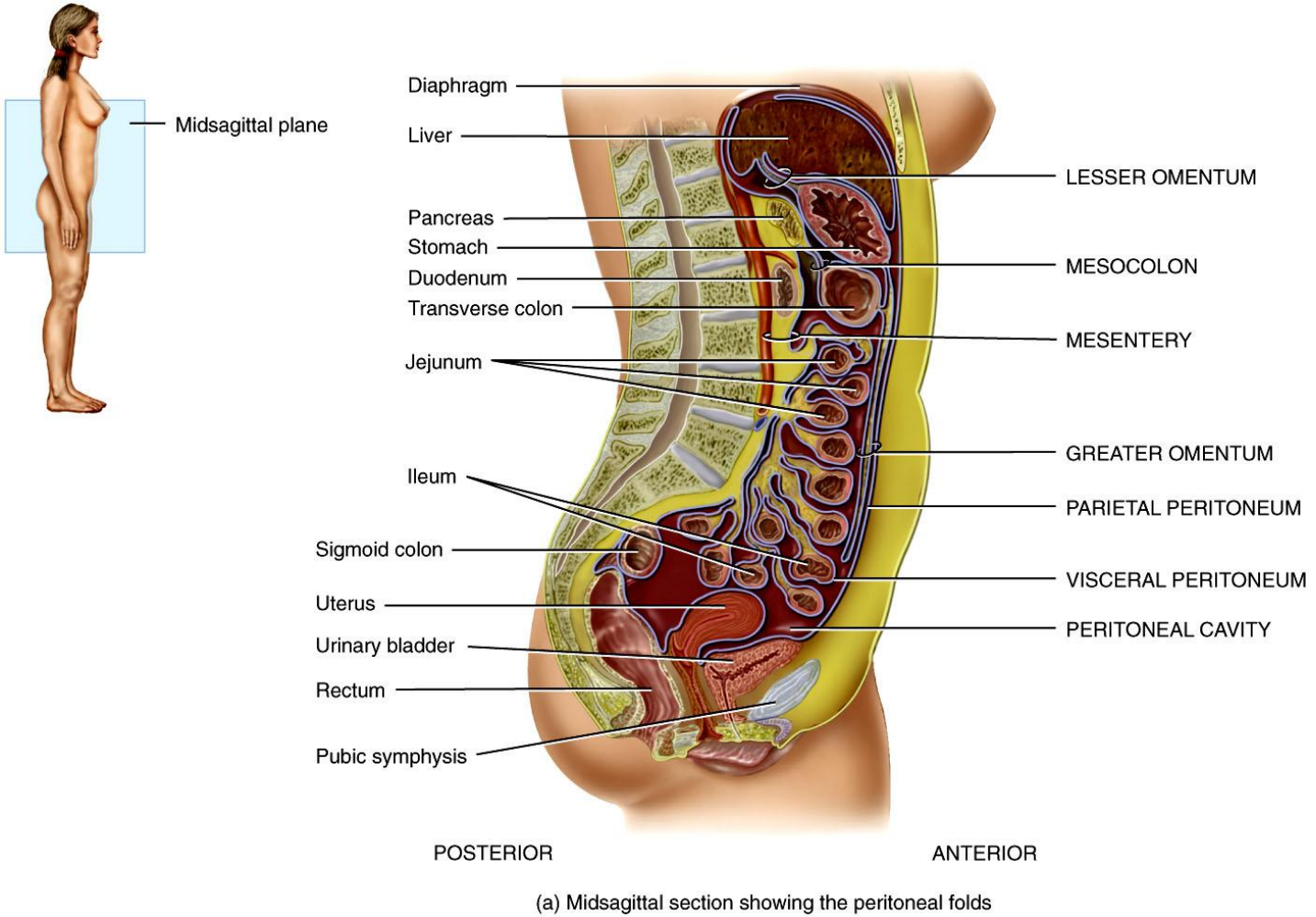
4. Tunica Serosa also called Visceral Peritoneum

- Outermost covering of organs suspended in abdominopelvic cavity
- Connective and epithelial tissue with vessels and nerves
- **Mesentery – extension**

Peritoneum

- Largest serous membrane of the body
- Divided into
  - Parietal peritoneum – lines wall of cavity
  - Visceral peritoneum – covers some organs
    - Also called serosa
  - Space between is peritoneal cavity
  - 5 major peritoneal folds
    - Greater omentum, falciform ligament, lesser omentum, mesentery, and mesocolon
    - Weave between viscera binding organs together

Peritoneal Folds



(a) Midsagittal section showing the peritoneal folds

Figure 24.04a Tortora - PAP 12/e

Copyright © John Wiley and Sons, Inc. All rights reserved.

Phases of digestion

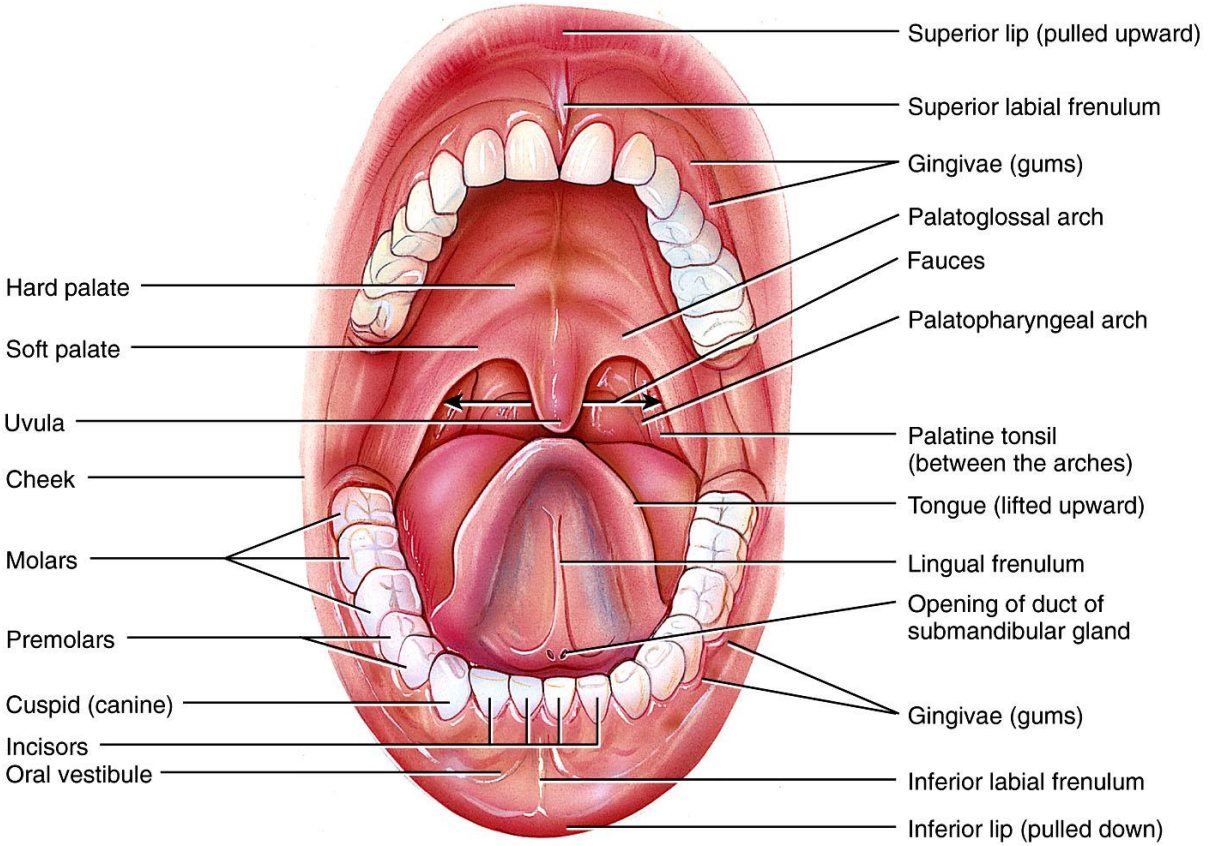
- Cephalic phase
  - Smell, sight, thought or initial taste of food activates neural centers – prepares mouth and stomach for food to be eaten
- Gastric phase
  - Neural and hormonal mechanisms promote gastric secretion and motility
- Intestinal phase
  - Begins when food enter small intestine
  - Slows exit of chyme from stomach
  - Stimulates flow of bile and pancreatic juice

Mouth

Mouth

- Oral or Buccal cavity
- Formed by cheeks, hard (bony) and soft (muscular) palates, and tongue
- Lips and cheeks help keep food between upper and lower teeth and assist in speech
- Uvula – cone shaped hanging muscular structure that prevents food from backing up into nasal area during swallowing.

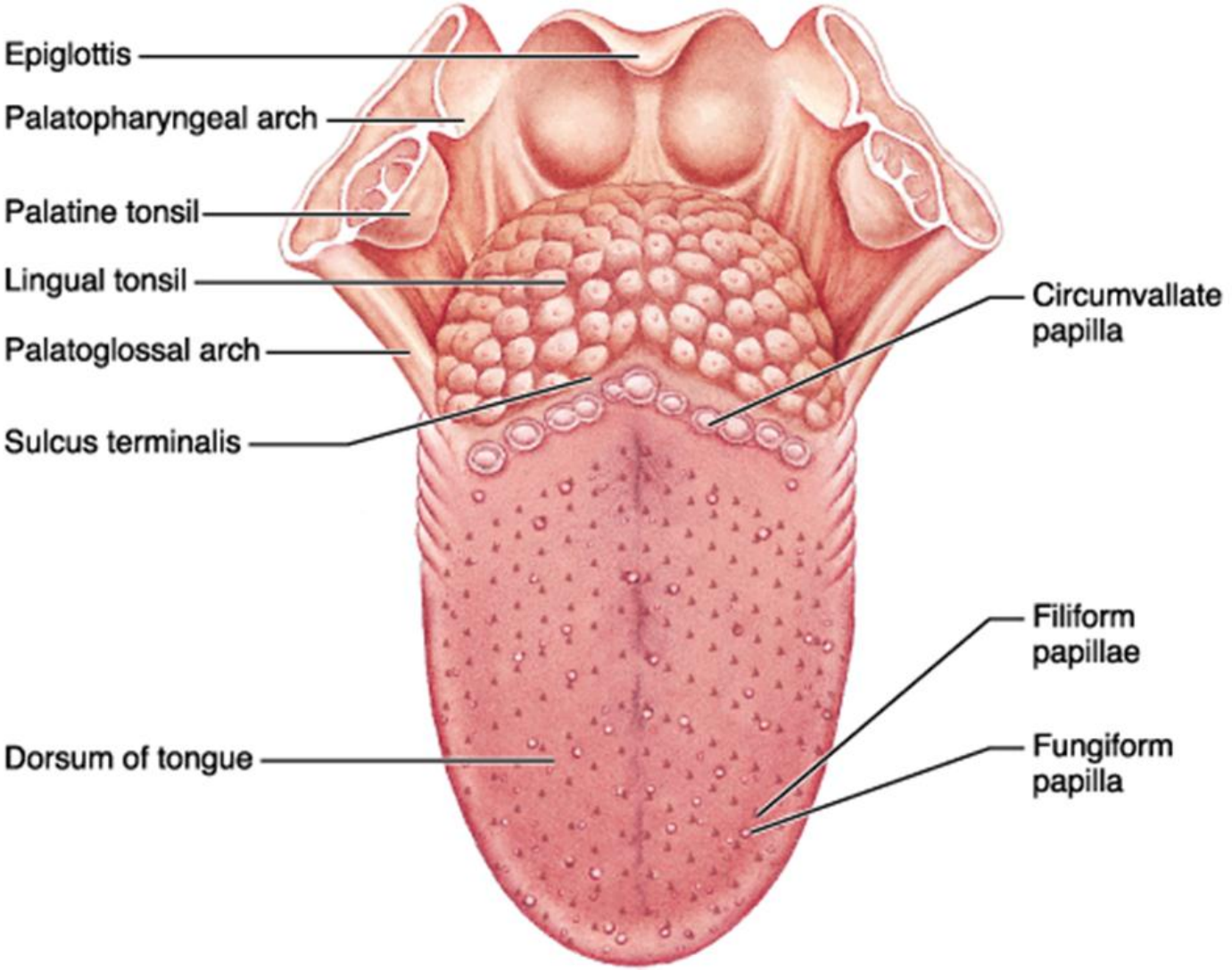
Structures of the mouth (oral cavity)



Anterior view

Figure 24.05 Tortora - PAP 12/e

Copyright © John Wiley and Sons, Inc. All rights reserved.



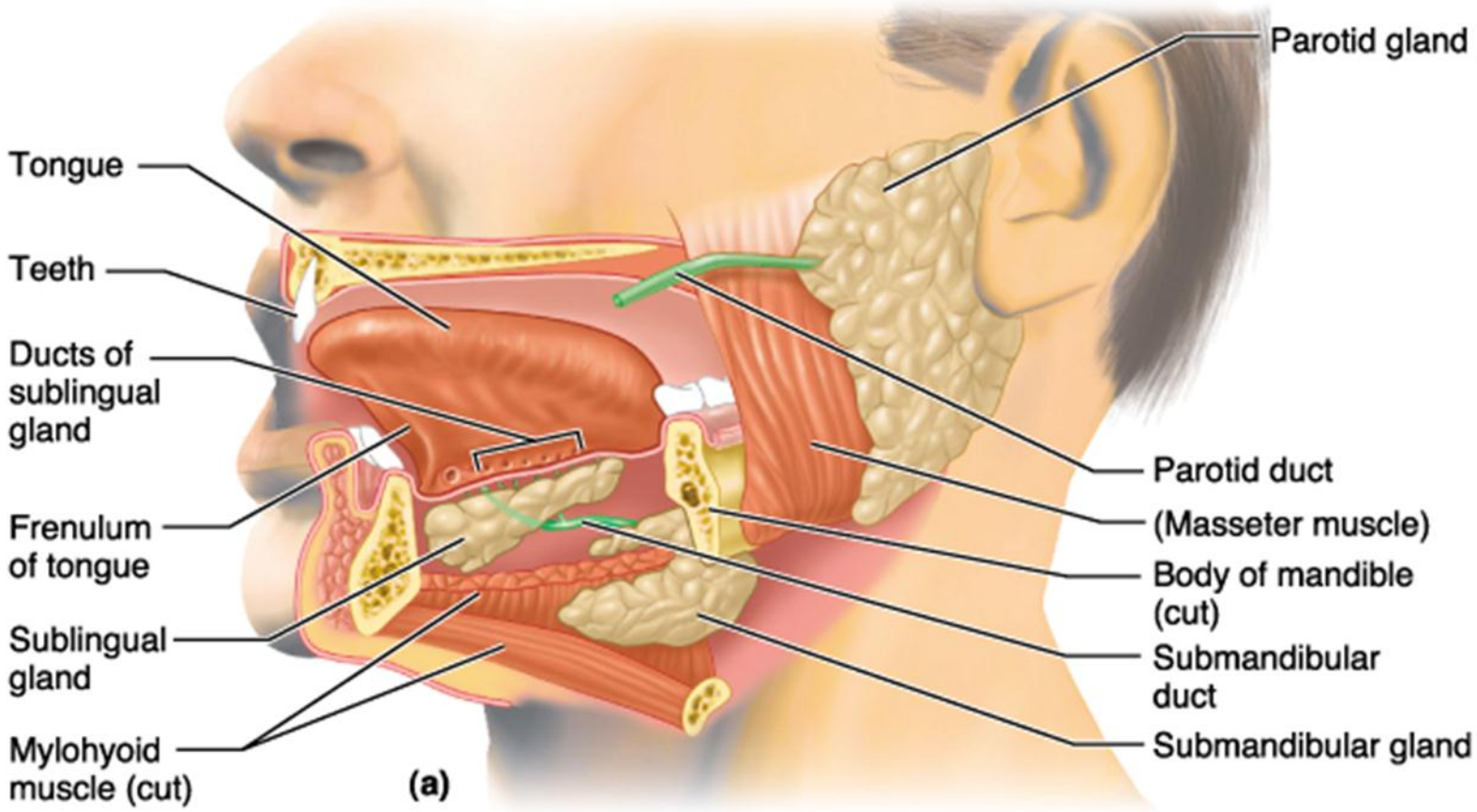
Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

Salivary Glands

1. **Buccal Glands** – small glands in lining of mouth
2. 3 pairs of **major salivary glands** secrete most of the saliva thru ducts that empty into the mouth
   - Parotid, submandibular, and sublingual

- **Salivation –** release saliva
  - Ordinarily, just enough is secreted to keep mouth and pharynx moist and clean
  - When food enters mouth, secretion increases to lubricate, dissolve and begin chemical digestion

The three major salivary glands–parotid, sublingual, and submandibular



Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

Saliva

- Mostly water 99.5% to dissolve food
- 0.5% solutes – ions, dissolved gases, urea, uric acid, mucus, immunoglobulin A, lysozyme (destroys bacteria), and ***salivary amylase*** (acts on starch)
- Not all salivary glands produce the same saliva

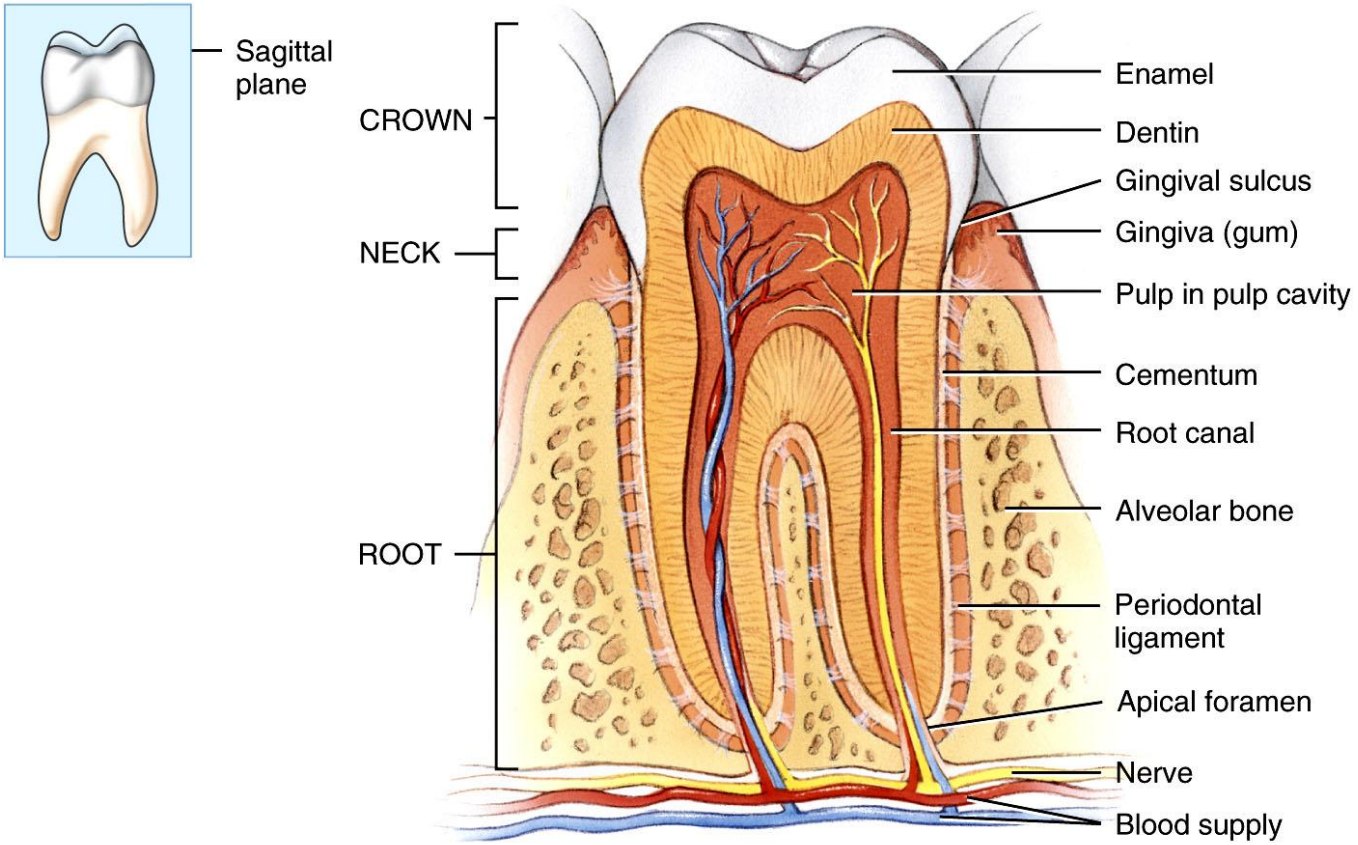
Tongue

- Accessory digestive organ
- Lingual frenulum – divides tongue into two symmetrical halves
- Skeletal muscle covered by mucous membrane
- Maneuvers food for chewing, shapes mass, forces food back for swallowing
- Papillae – projections that make the rough surface of tongue
  - Taste buds – sweet, sour, salt, umami (savory) and bitter
  - Several different types of papillae
- Lingual glands secrete salivary lipase

Teeth

- **Teeth or dentes**
  - Break up food by chewing **(mastication)**
  - Accessory digestive organ
  - Sockets of the alveolar processes of the mandible and maxillae bones
  - **Gingivae** – gums
- 3 major regions – **crown, root, and neck**
  - Made of **Dentin** (bone like substance) that encloses the **pulp cavity** in the crown.
  - Crown covered by **Enamel**
  - **Root Canals** – extensions of pulp cavity into the root

A typical tooth and surrounding structures



Sagittal section of a mandibular (lower) molar

Figure 24.07 Tortora - PAP 12/e

Copyright © John Wiley and Sons, Inc. All rights reserved.

Teeth

- 20 temporary or deciduous teeth
- 32 permanent teeth by age 13
  - Incisors
  - Canine Teeth
  - Cuspids
  - Molar Teeth – premolars, bicuspids, tricuspids
  - "Wisdom Teeth" – **molars**; usually appear between the ages of 16 and 25

Digestion in the mouth

- **Mechanical digestion** in the mouth
  - Chewing or mastication
  - Food manipulated by tongue, ground by teeth, and mixed with saliva
  - Forms bolus
- **Chemical digestion** in the mouth
  - Salivary amylase secreted by salivary glands acts on starches
    - Inactivated by stomach acid
  - Lingual lipase secreted by lingual glands of tongue acts on triglycerides
    - Activated in acidic environment of stomach

Lipase breaks down triglycerides (fats)

Amylase breaks down starches (glycogen) into simple sugars

Pharynx, Esophagus, and Stomach

Pharynx

- Passes from mouth into pharynx
- **Deglutition** – process of swallowing which moves food from the mouth to the stomach
- 3 parts
  - Oropharynx
    - Digestive and respiratory functions; voluntary swallowing
  - Nasopharynx
    - Functions only in respiration, closed off during swallowing by uvula and soft palate; breathing is stopped; involuntary swallowing
  - Laryngopharynx
    - Digestive and respiratory functions
    - Epiglottis seals of the glottis to prevent food going into the trachea

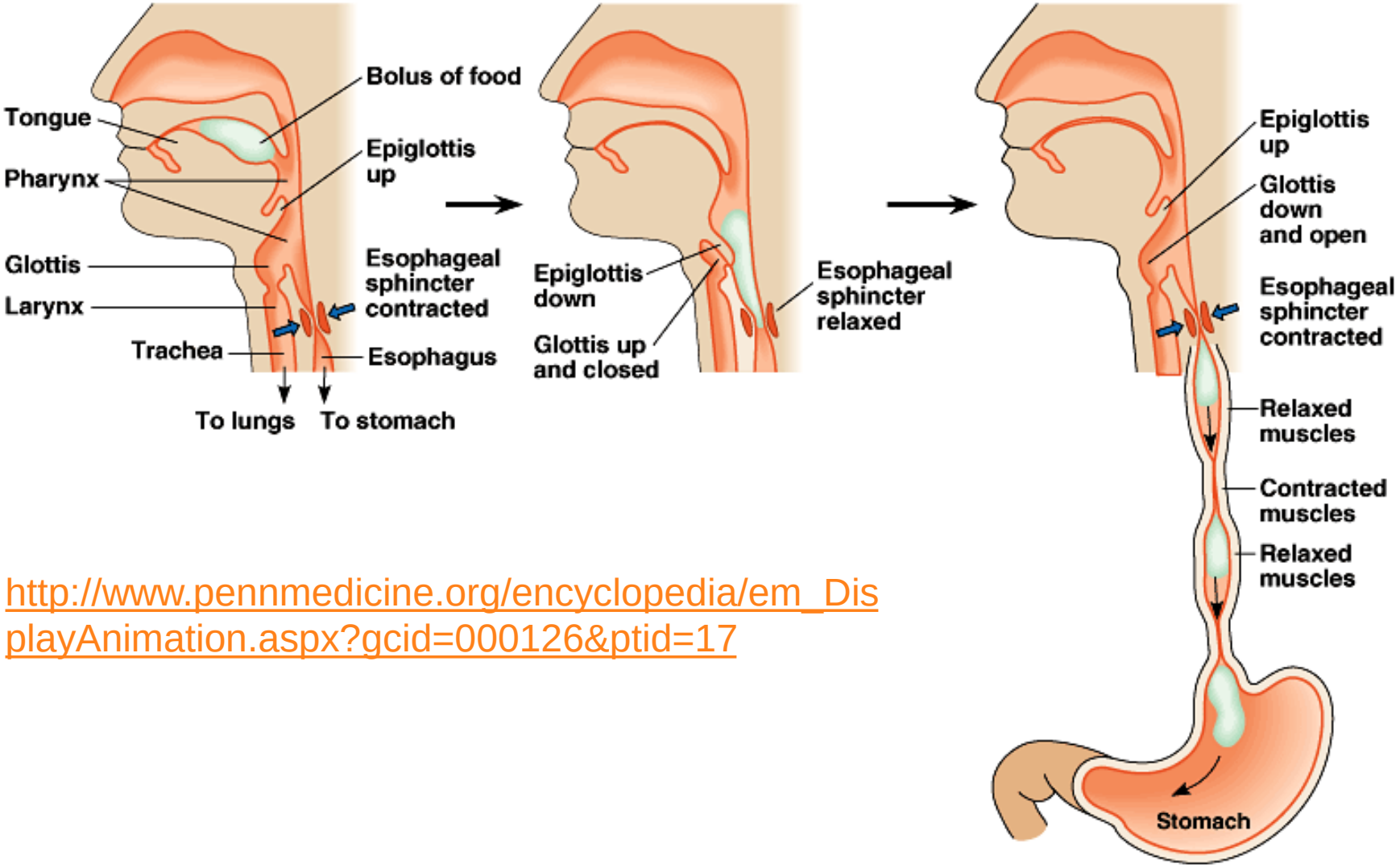
Esophagus

- Collapsible muscular tube that is behind the trachea
- 10 inches long
- Secretes mucous, transports food – no enzymes produced, no absorption
- 2 sphincters
  - Upper Esophageal Sphincter (UES) or Esophageal Hiatus regulates movement into esophagus
  - Lower Esophageal Sphincter (LES) or Gastroesophageal regulates movement into stomach
- 4 – 8 seconds – time from mouth to stomach for solid or semisolid food
- 1 second –time for liquids

Deglutition

- Act of swallowing
- Facilitated by secretions of saliva and mucus
- Involves mouth, pharynx, and esophagus
- 3 stages
  - Voluntary – bolus passed to oropharynx
  - Pharyngeal – involuntary passage through pharynx into esophagus
  - Esophageal – involuntary passage through esophagus to stomach
    - Peristalsis pushes bolus forward

Deglutition (swallowing)



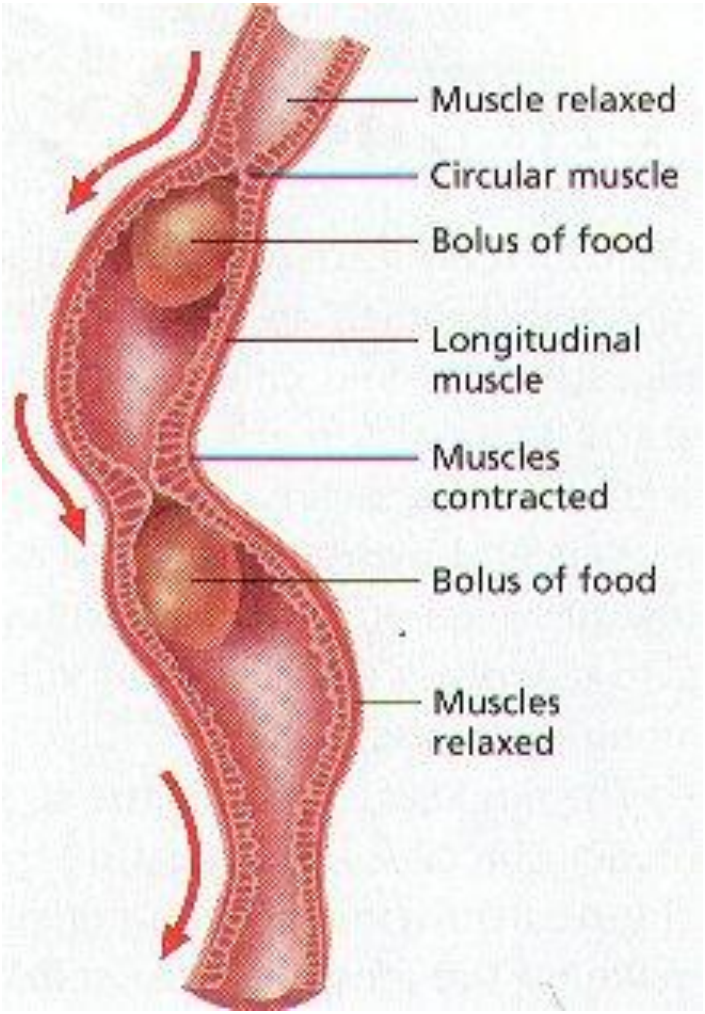
http://www.pennmedicine.org/encyclopedia/em_DisplayAnimation.aspx?gcid=000126&ptid=17

Stomach

- Serves as mixing chamber and holding reservoir
- Upper part of the abdominal cavity under the diaphragm muscle
- Shaped like a “J”; stretches to accommodate large amounts of food
- 4 main regions
  - Cardia
  - Fundus
  - Body
  - Pylorus or antrum

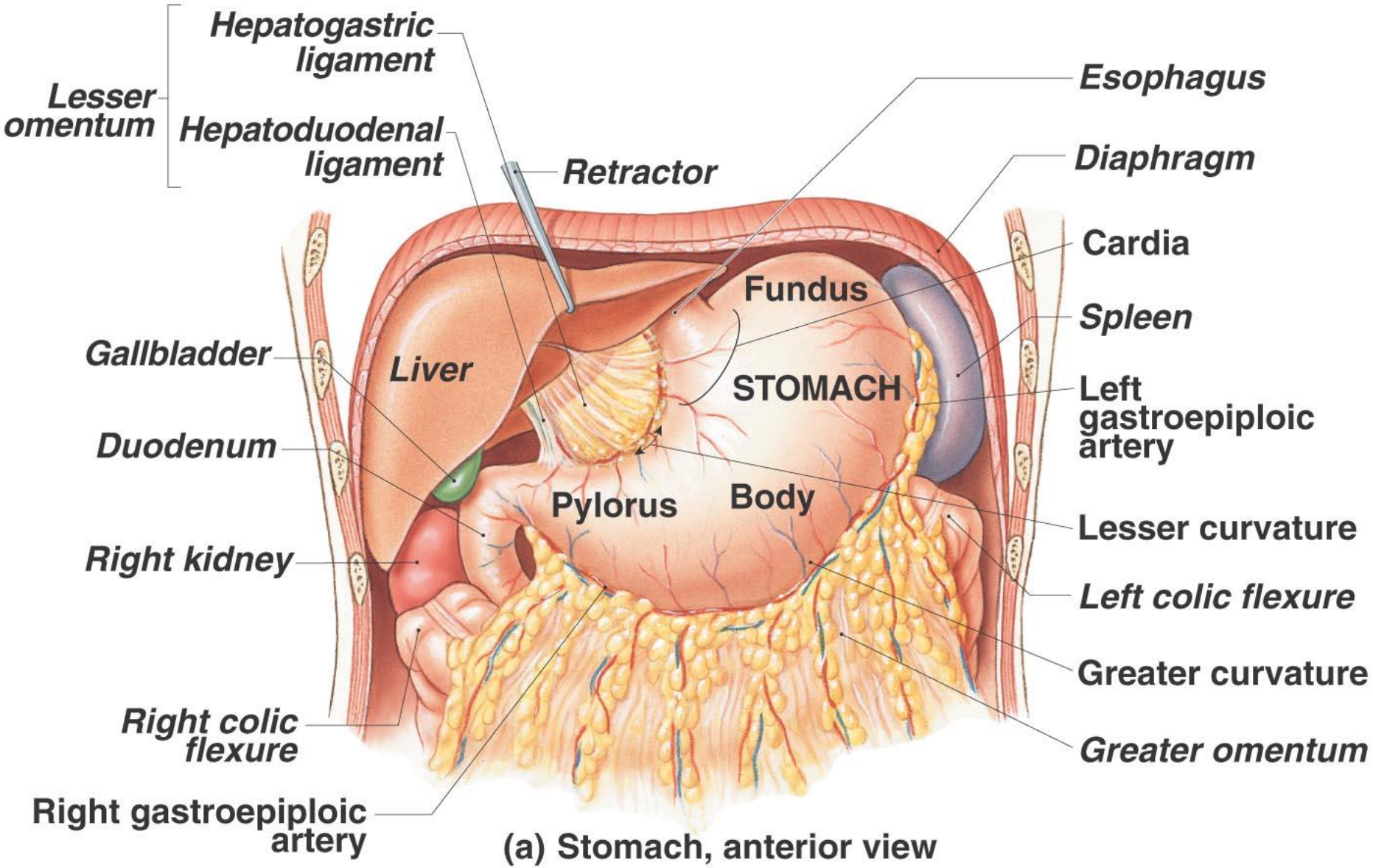
Peristalsis

- series of involuntary wave-like muscle contractions which move food along the digestive tract



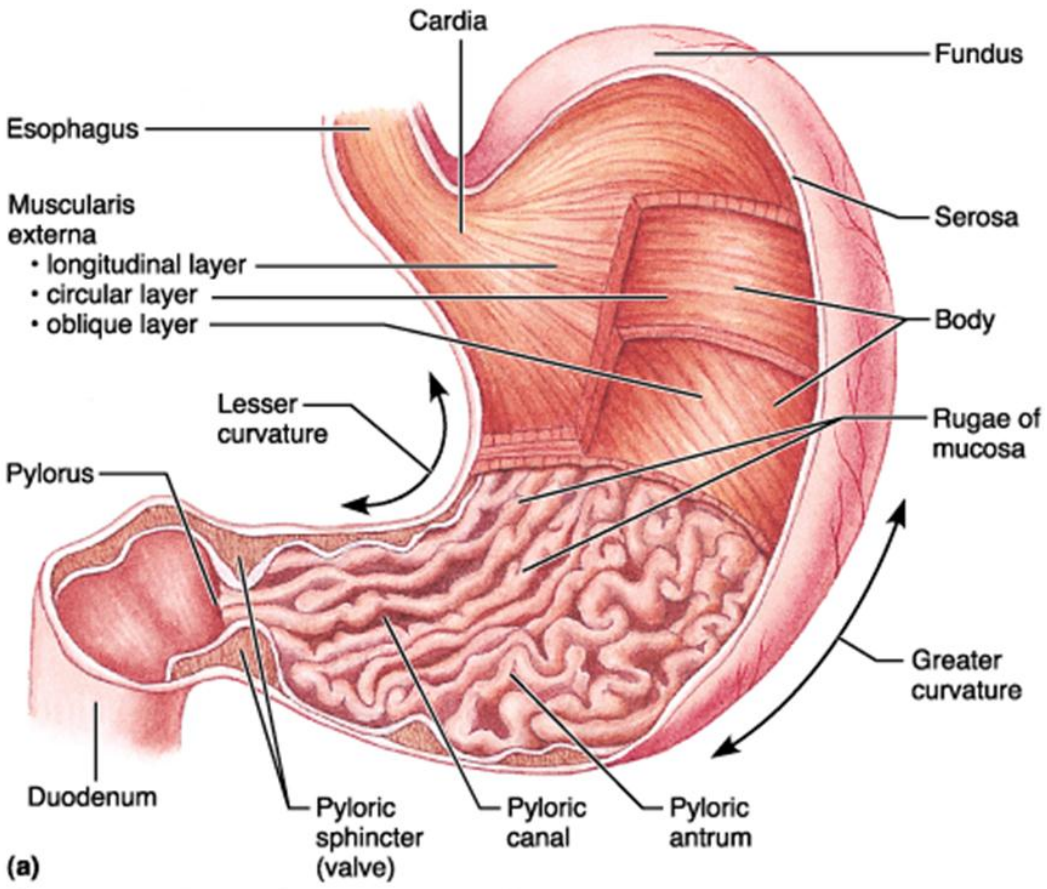
Peristalsis

- http://www.pennmedicine.org/encyclopedia/em_DisplayAnimation.aspx?gcid=000097&ptid=17
- http://www.youtube.com/watch?NR=1&v=o18UycWRsaA&feature=endscreen



Copyright © 2009 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

Stomach



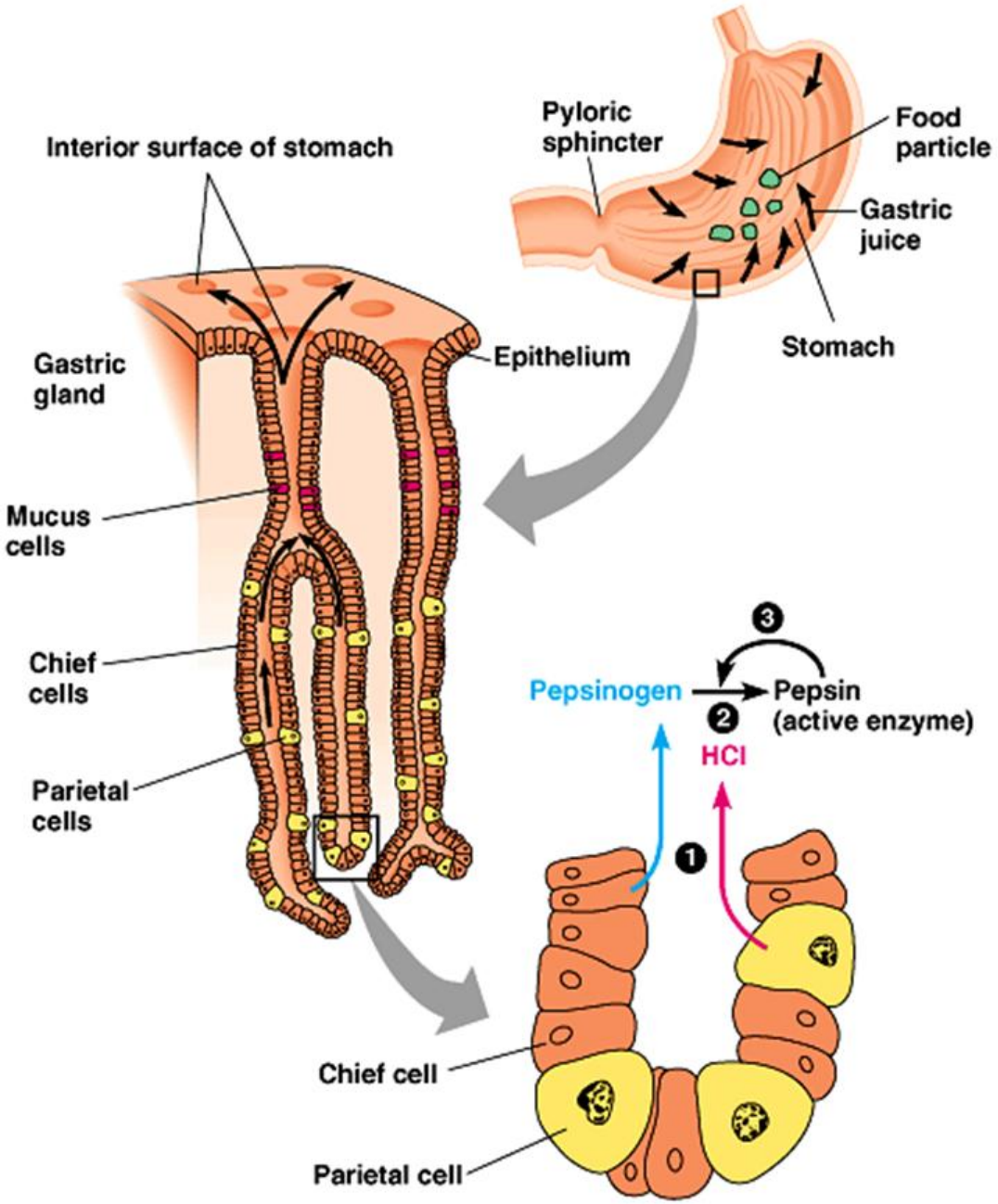
Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

Inside the Stomach

Pepsinogen + HCl = Pepsin which breaks down proteins

- Rugae – mucosa in folds when empty
  - Smooth out as stomach fills
- Pits and Gastric Glands that have secreting cells
  - Chief cells (zymogenic) – pepsinogen
  - Parietal Cells – HCl
  - Mucous Cells – protect stomach cells
- "Gastric Juice" – all the secretions
- 3 Layers of Smooth Muscle to break up food, churn it, and mix with gastric juices.
- Absorbs some water and salts; aspirin and alcohol

Histology


Interior surface of stomach
Pyloric sphincter
Food particle
Gastric juice
Stomach
Gastric gland
Epithelium
Mucus cells
Chief cells
Parietal cells
3
Pepsinogen
Pepsin (active enzyme)
2
HCl
1
Chief cell
Parietal cell

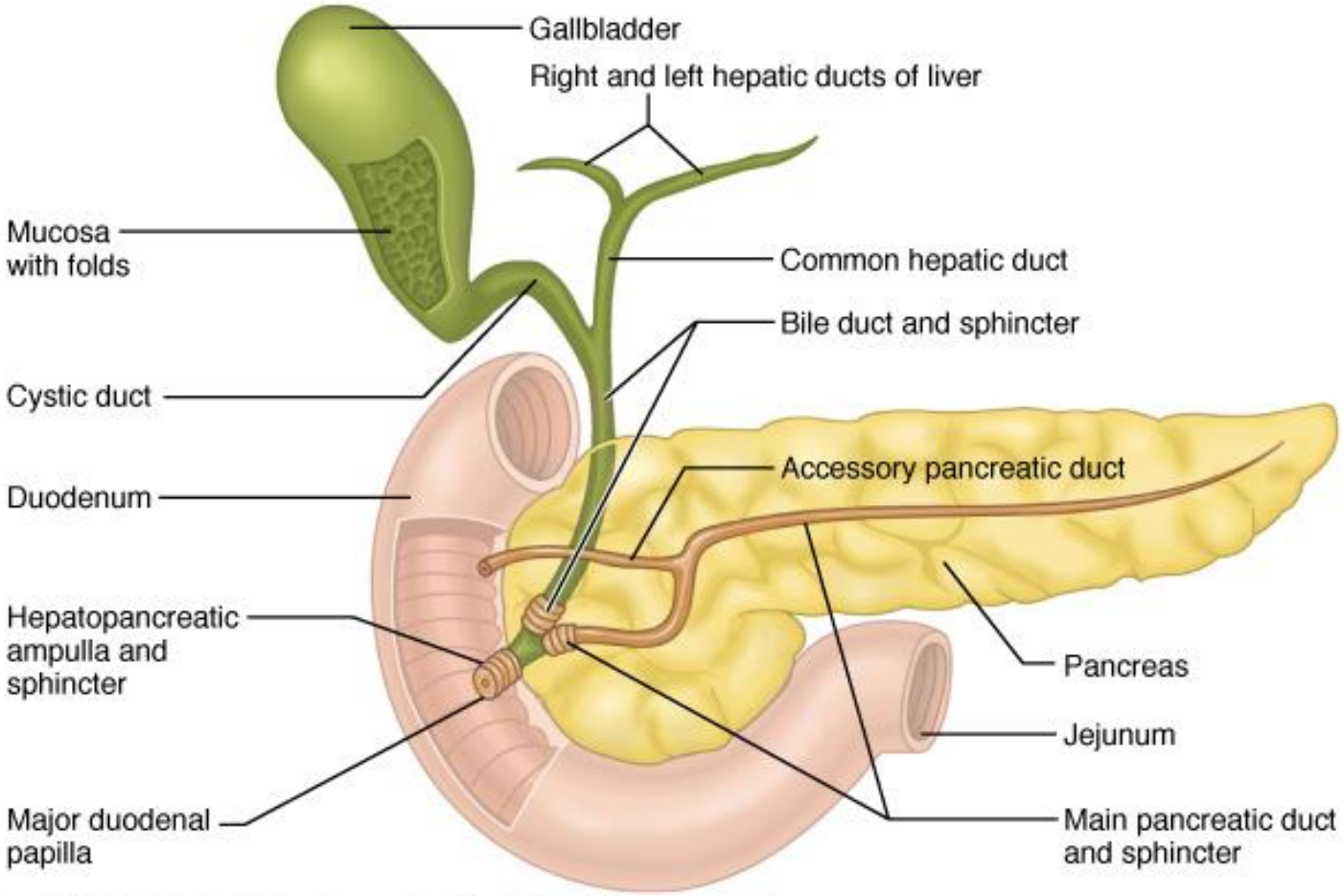
Mechanical and Chemical Digestion in the Stomach

- Mechanical digestion
  - Mixing waves – gentle, rippling peristaltic movements – creates **chyme** – digested, viscous, semifluid contents of the intestine
- Chemical digestion
  - Digestion of carbohydrates – pass through stomach first because digestion begins in mouth
  - Proteins are slower – digestion begins in stomach
  - Fat take the longest to get to the small intestine

Stomach is empty 2-6 hours after ingestion.

Digestive Organs

Pancreas, gallbladder & duodenum



Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

Pancreas

- Lies posterior to greater curvature of stomach
- Soft, oblong gland 6 inches long, 1inch thick
  - Head, body, and tail
  - Glandular epithelial cells

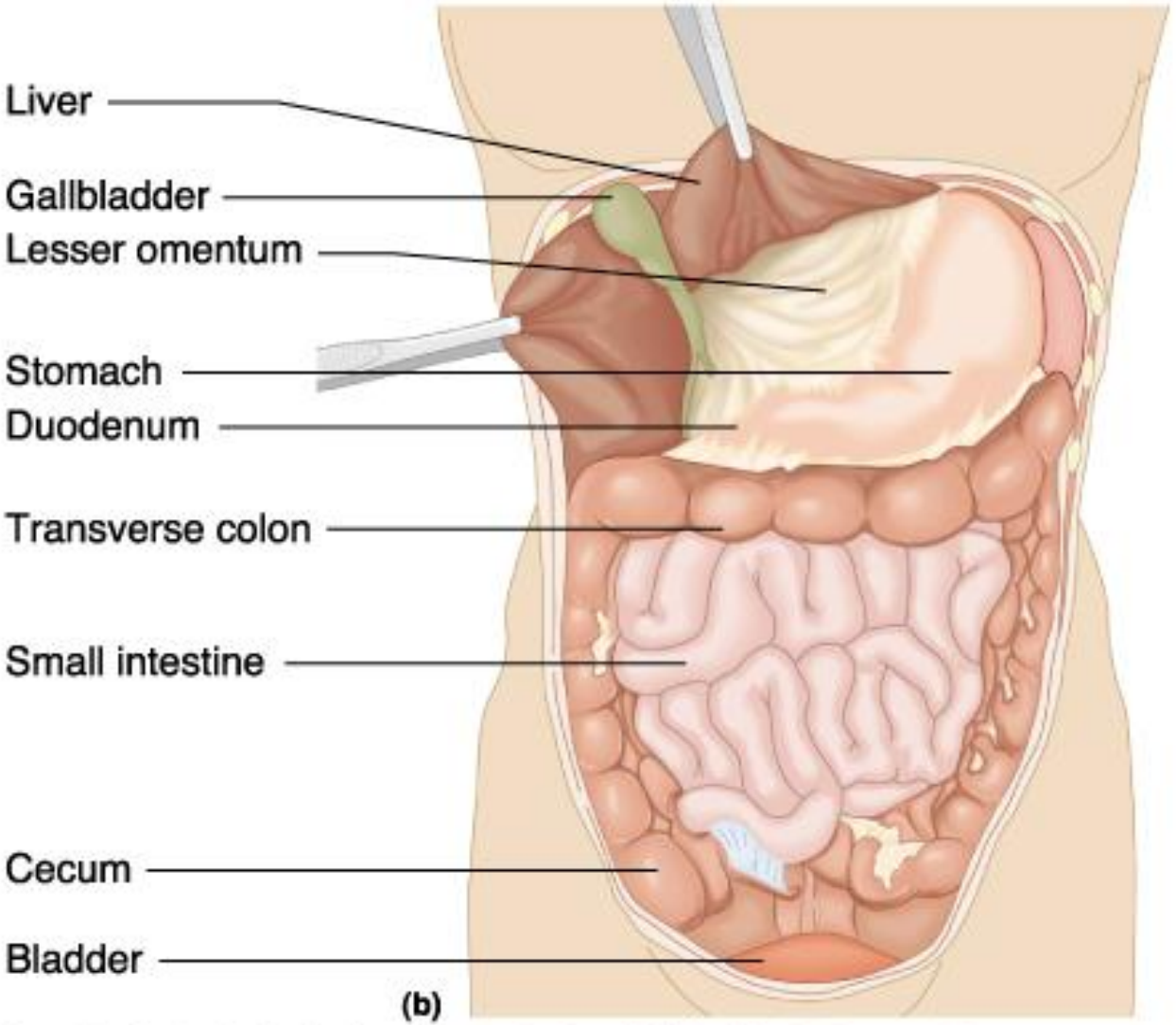
- **Functions**:
  - Secrete enzymes that continue the digestion of food in the small intestine
  - Secrete the hormones glucagon and insulin that regulate and control blood sugar levels

Pancreatic juice

- Secreted into pancreatic duct and accessory duct and to duodenum of the small intestine
  - Pancreatic duct joins common bile duct and enters duodenum at hepatopancreatic ampulla
- 1200-1500ml daily
- Mostly water with:
  - Sodium bicarbonate – buffers acidic stomach chyme
  - Enzymes

Pancreatic Histology

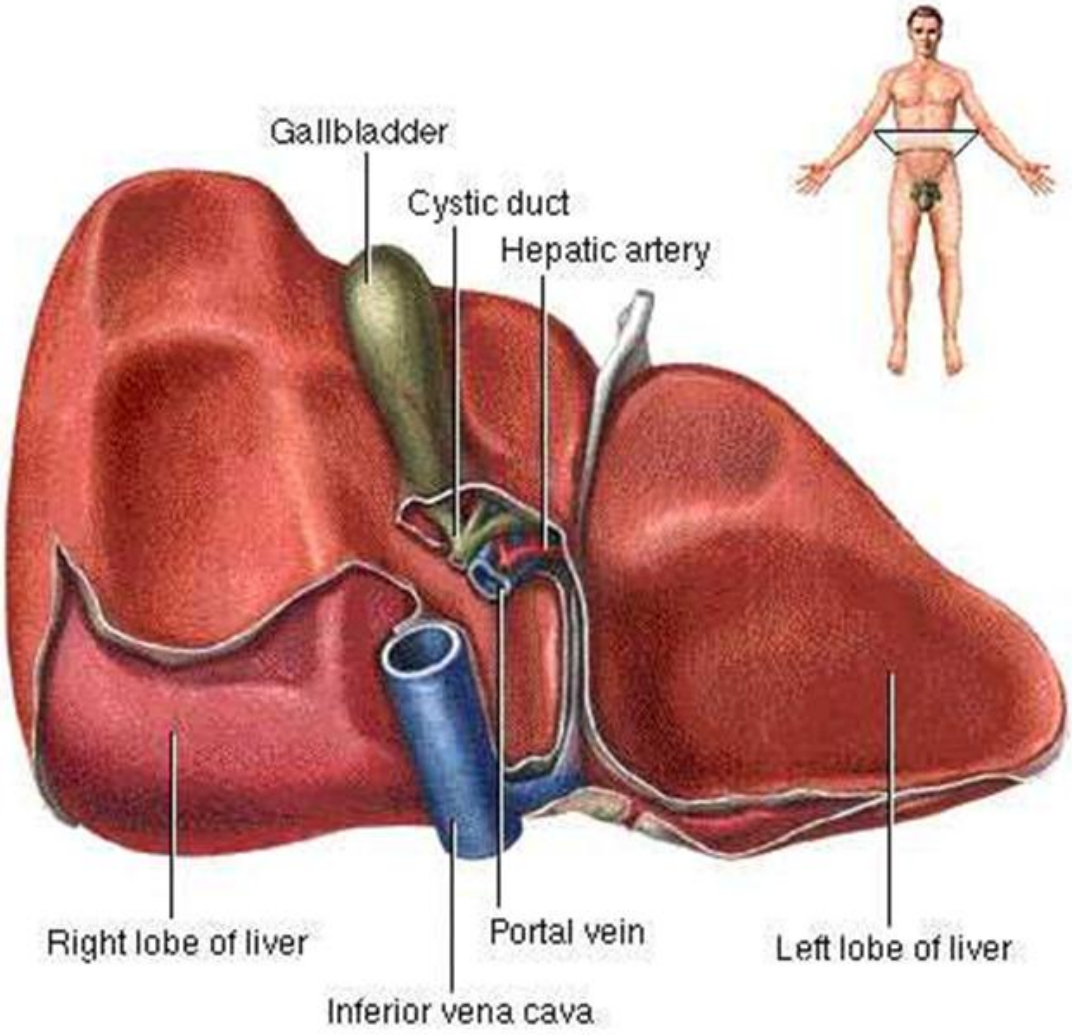
- **Acini Cells**
  - 99% of cells
  - Exocrine
  - Secrete pancreatic juice
- **Pancreatic Islets (Islets of Langerhans)**
  - 1% of cells
  - Endocrine
  - Secrete hormones: glucagon & insulin



Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

Liver

- Liver is the heaviest gland of the body
- Weighs 4 pounds
- Right and Left Lobe separated by the falciform ligament
- Liver is composed of
  - Hepatocytes – major functional cells of liver
  - Bile Canaliculi – ducts between hepatocytes that collect bile
  - Hepatic Sinusoids – highly permeable blood capillaries


Gallbladder
Cystic duct
Hepatic artery
Right lobe of liver
Portal vein
Left lobe of liver
Inferior vena cava

Liver Functions

- Manufactures anticoagulant **heparin** along with prothrombin and thrombin (blood clotting)
- **Kupffer Cells** – eat some bacteria and old RBC and WBC
- Enzymes that break down poisons (ammonia to urea)
- Collects excessive nutrients as glycogen or fat and change to glucose as needed
- Stores copper, iron and vitamins A, D, E, & K
- Produces Bile Salts that break down fats

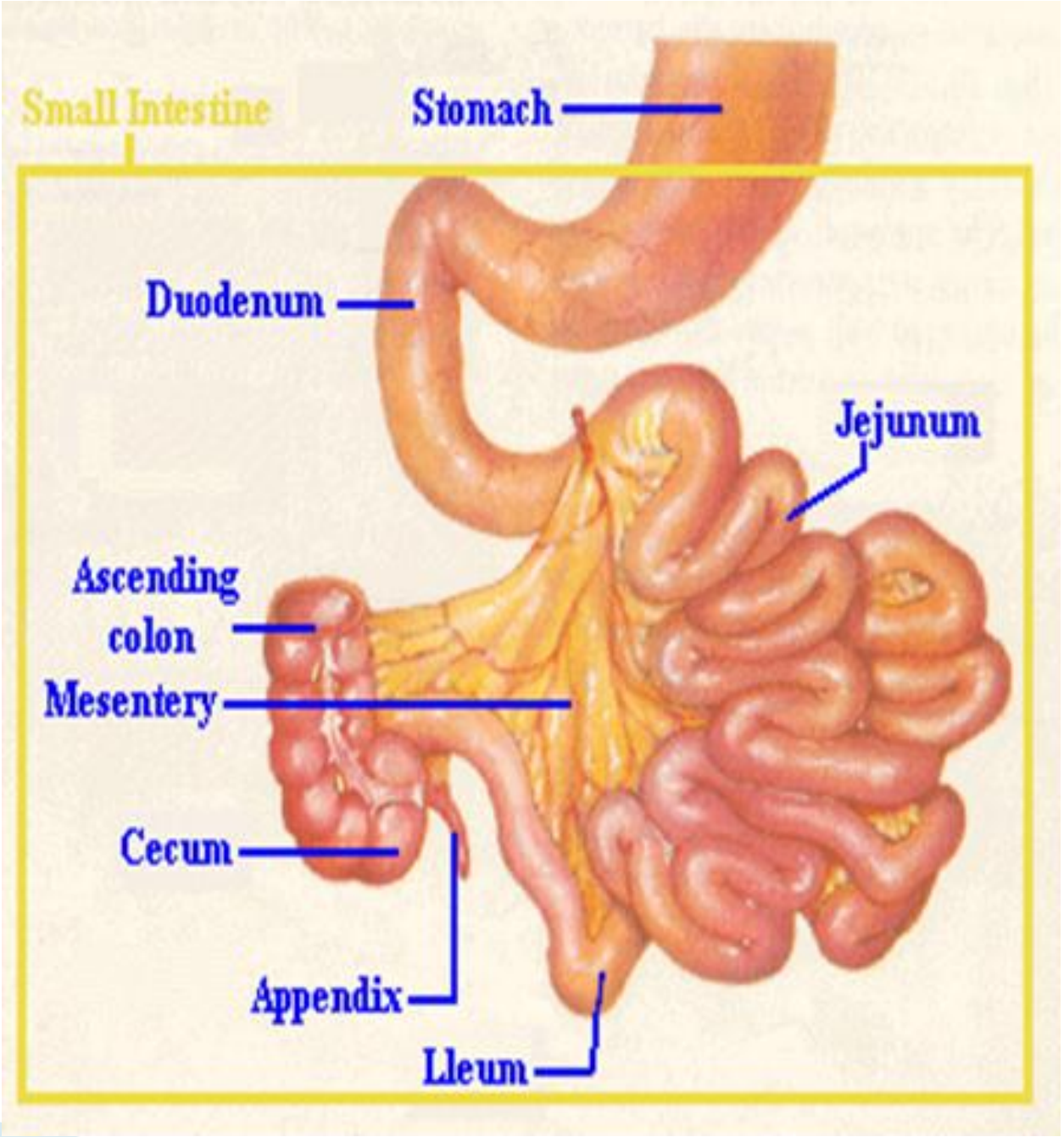
Gallbladder

- Pear shaped sac 3-4 inches long
- Located in a depression on the surface of the liver
- Functions to store and concentrate **Bile** produced by the liver until it is needed in the small intestine
- Bile enters the duodenum by the **Common Bile Duct**

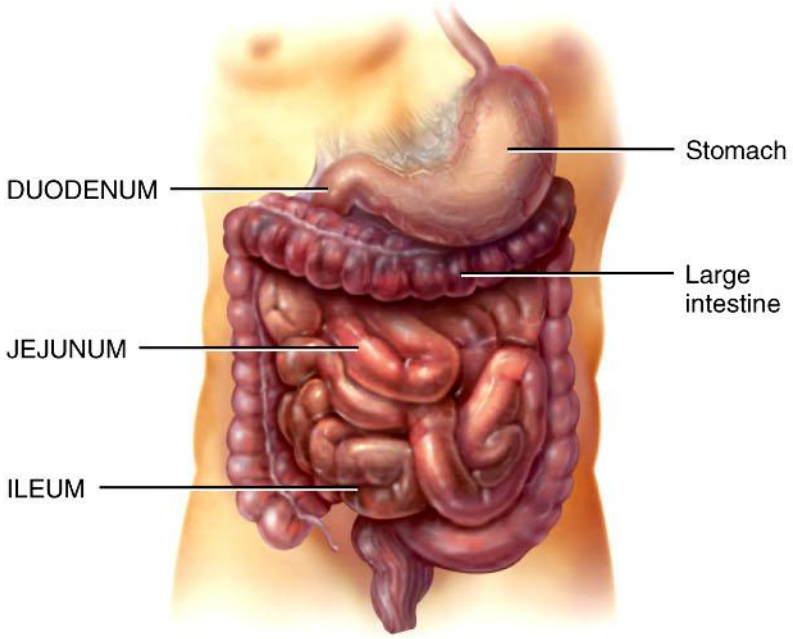
Intestines

Small intestine

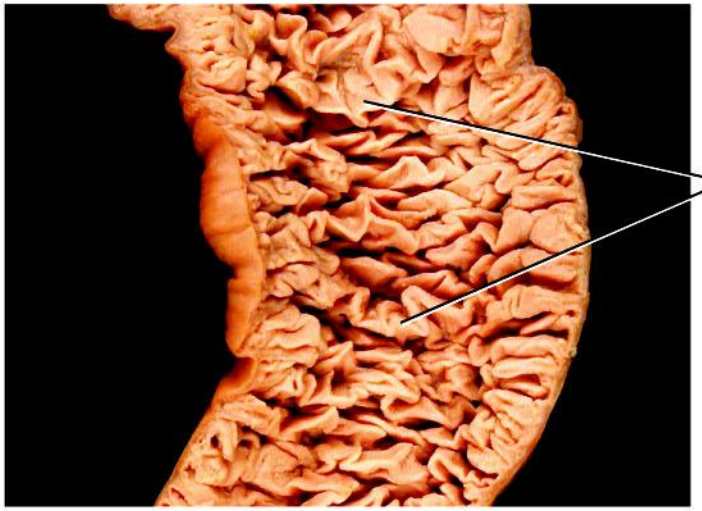
- 21 feet and 1 inch in diameter
- 3 regions:
  - Duodenum – 10 inches
    - Originates at pyloric sphincter
  - Jejunum – 8 feet
  - Ileum – 12 feet
    - Joins large intestine at the ileocecal valve
- Major portion of absorption and digestion
  - Crypts of Lieberkuhn (intestinal glands) – digestive enzymes
  - Brunner's glands – alkaline mucus


Small Intestine
Stomach
Duodenum
Jejunum
Ascending
colon
Mesentery
Cecum
Appendix
Lleum

Anatomy of the small intestine



(a) Anterior view of external anatomy



(b) Internal anatomy of jejunum

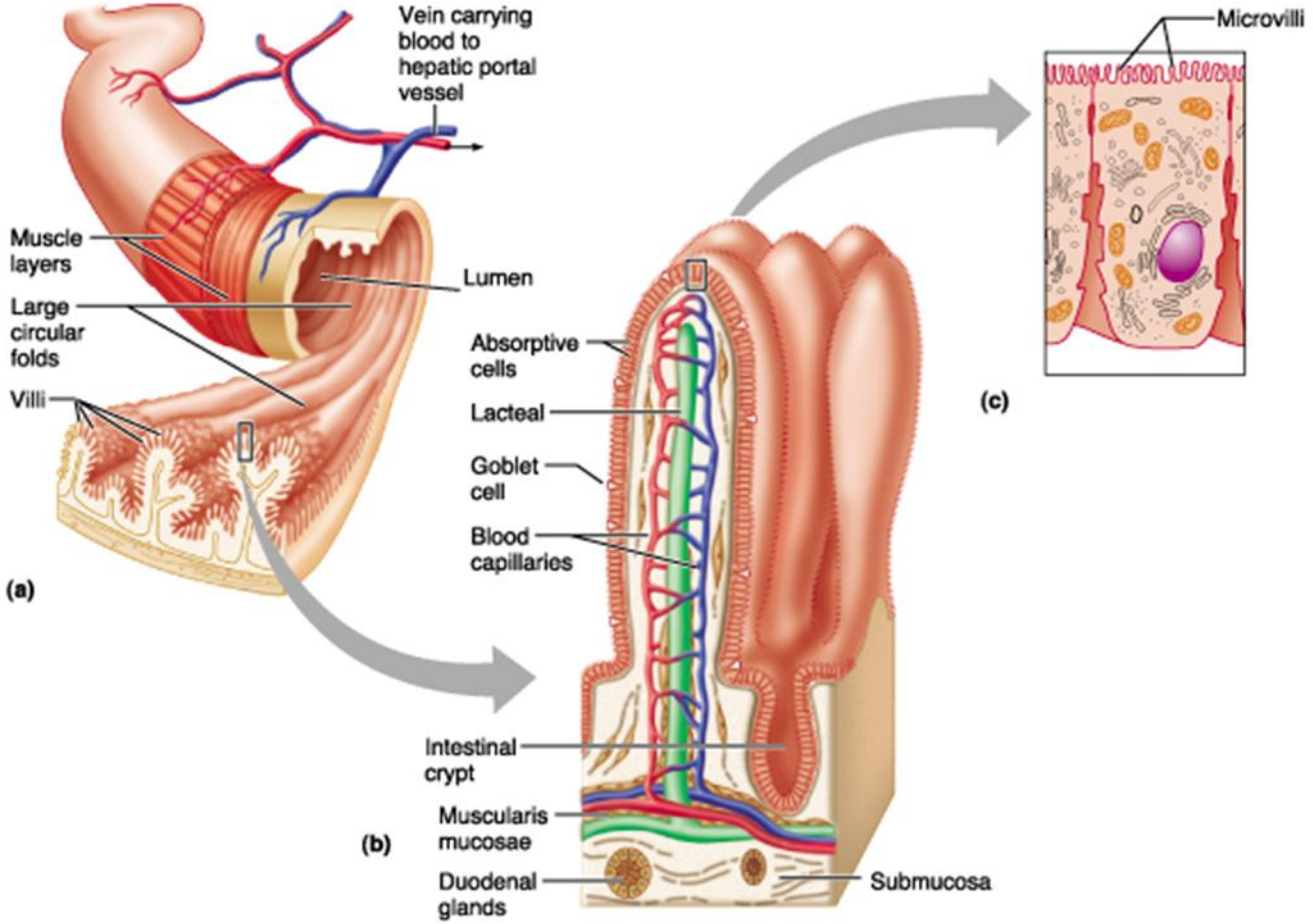
Figure 24.17 Tortora - PAP 12/e

Copyright © John Wiley and Sons, Inc. All rights reserved.

Special structural features increase surface area for digestion and absorption

- **Plicae** – Permanent ridges of mucosa and submucosa
  - Cause **Chyme** (digested, viscous, semifluid contents of the intestine) to spiral
- **Villi** – Fingerlike projections of mucosa
  - Contains arteriole, venule, blood capillary, and lacteal
  - 4 –5 million
- **Microvilli** on the surface of each Villi
  - Projects of apical membrane of absorptive cells
  - Brush border with brush border enzymes

Histology of the duodenum and ileum



Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.

Large Intestine

- 5 feet long and 2.5 inches in diameter
- “Bowel”
- Functions:
  - Complete absorption of water
  - Produce certain vitamins
  - Form and expel feces

4 major regions to large intestine

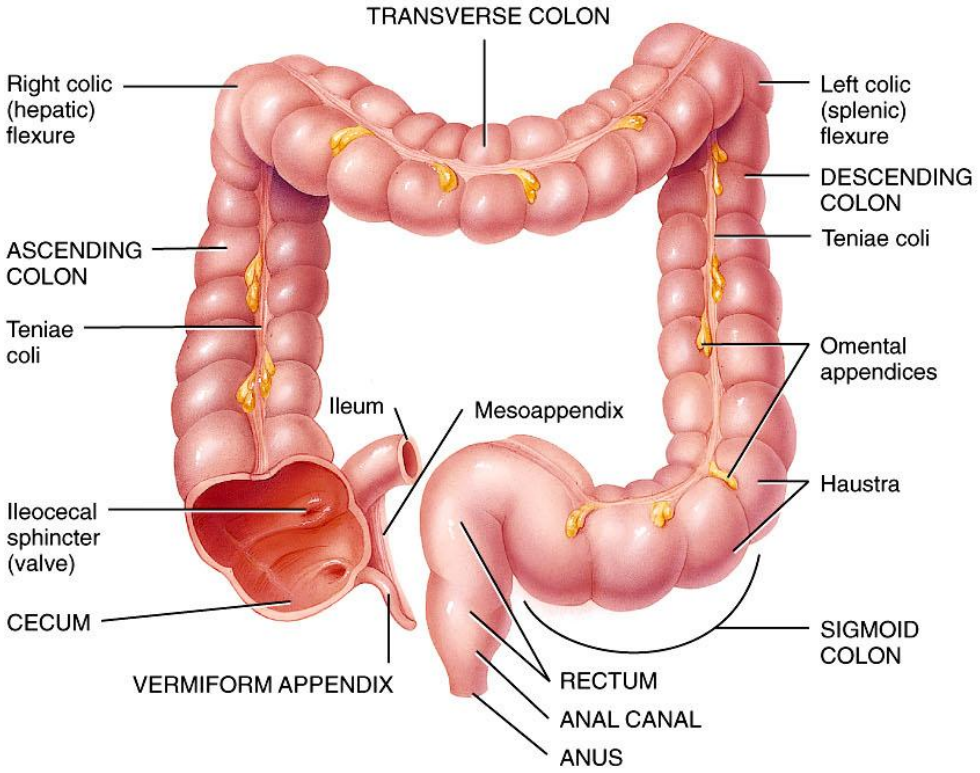
- **Cecum** – pouch-like first part, 2-3 inches
  - Veriform Appendix – 3 inches
- **Colon** – largest part
- **Rectum**
- **Anal Canal**

- Mesocolon – part of visceral peritoneum that attaches large intestine to the abdominal wall

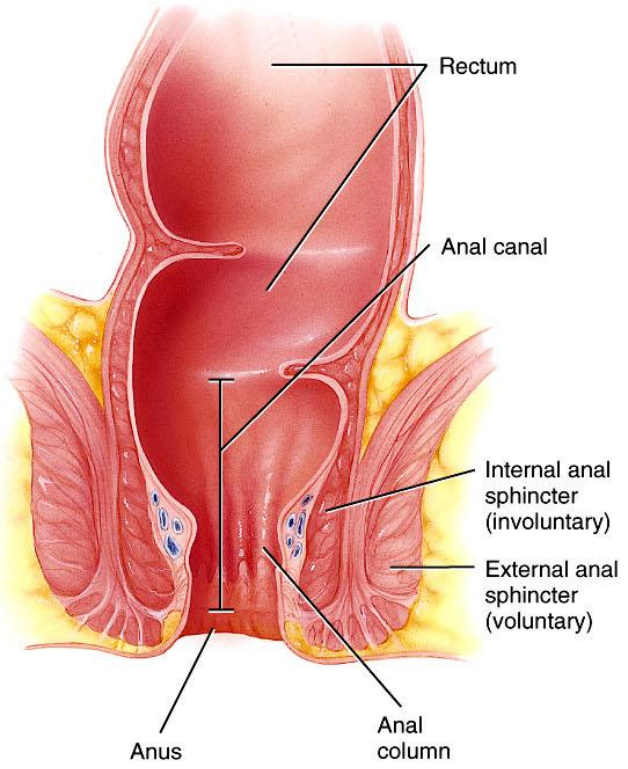
Large Intestine

- **Ileocecal Sphincter** between small and large intestine
- Colon divided into four parts:
  - Ascending – right side
  - Transverse
  - Descending
  - Sigmoid
- Opening of anal canal (anus) guarded by internal anal sphincter of smooth muscle and external anal sphincter of skeletal muscle

Anatomy of the large intestine



(a) Anterior view of large intestine showing major regions



(b) Frontal section of anal canal

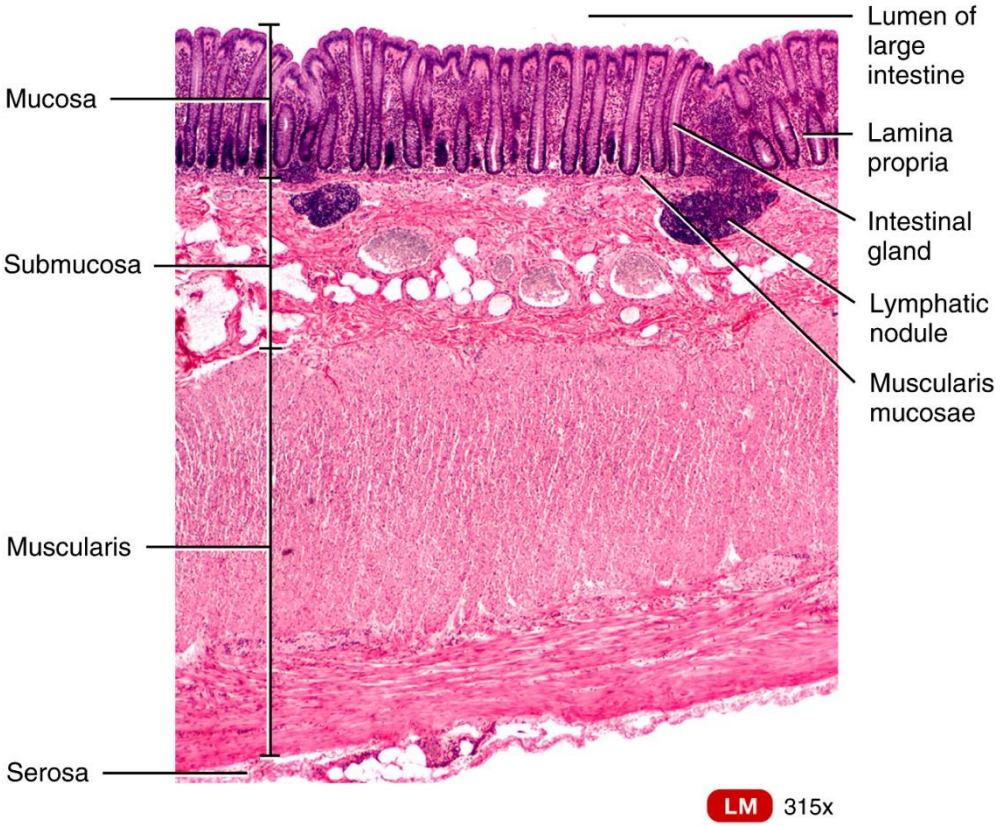
Figure 24.22 Tortora - PAP 12/e

Copyright © John Wiley and Sons, Inc. All rights reserved.

Digestion of the Large Intestine

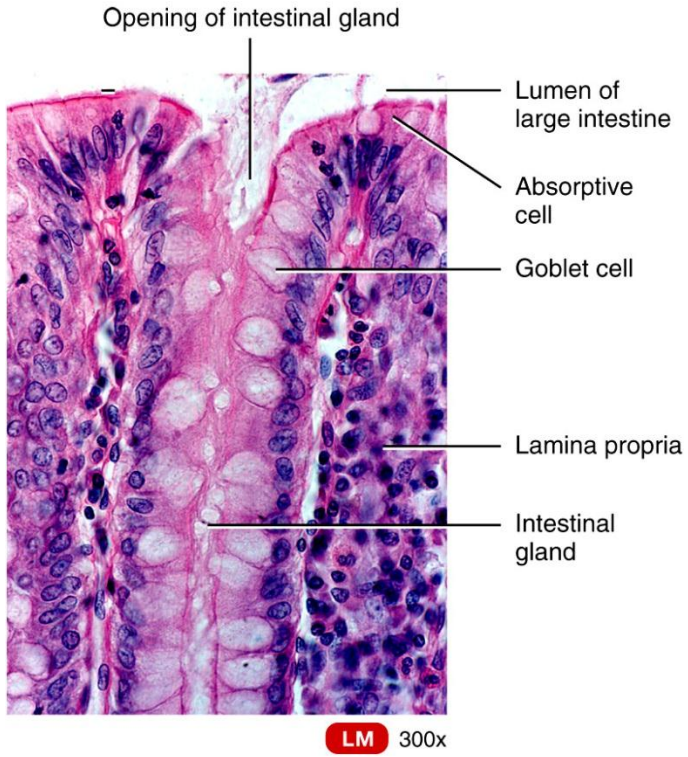
- Mechanical digestion
  - Haustral churning (haustra – pouches in colon)
  - Peristalsis
  - Mass peristalsis – drives contents of colon toward rectum
- Chemical digestion
  - Final stage of digestion through bacterial action
    - Ferment carbohydrates, produce some B vitamins and vitamin K (blood clotting)
  - Mucus but no enzymes secreted
- Remaining water absorbed along with ions and some vitamins

Histology of the large intestine



(c) Portion of the wall of the large intestine

Figure 24.23c Tortora - PAP 12/e
Copyright © John Wiley and Sons, Inc. All rights reserved.



(d) Details of mucosa of large intestine

Figure 24.23d Tortora - PAP 12/e
Copyright © John Wiley and Sons, Inc. All rights reserved.

Formation of Feces

- Chyme in large intestine for 3-10 hours to become feces
- Water, inorganic salts, epithelial cells
- Bacteria – *Escherichia coli* or E.coli
  - Feeds on undigested materials
- Defecation – act of emptying the rectum