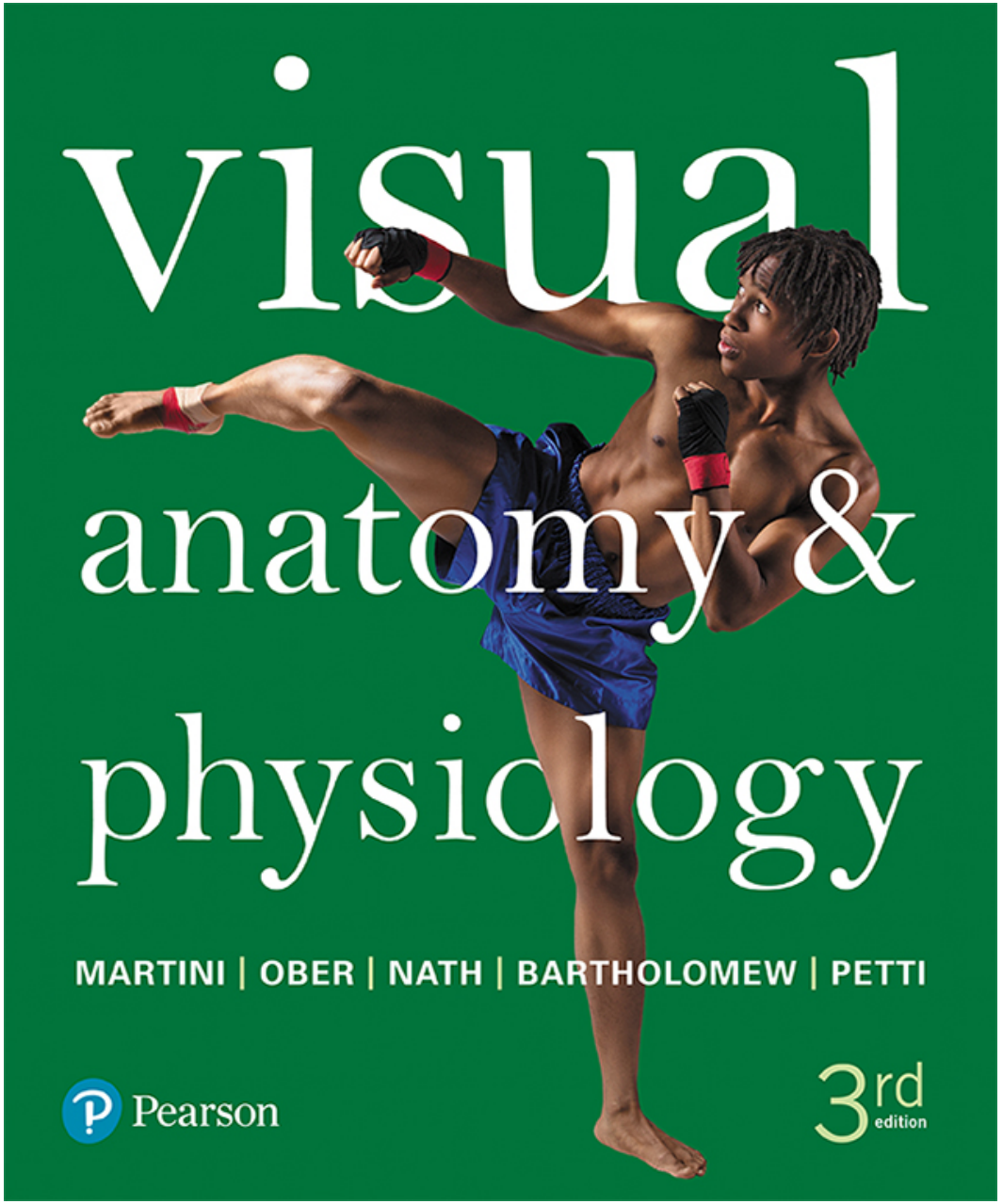

22

The Digestive System

Lecture Presentation by
Lori Garrett

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Section 1: Organization of the Digestive System

Learning Outcomes

22.1 Name the major and accessory organs of the digestive system.

22.2 Describe the functional histology of the digestive tract.

22.3 Describe the structural and functional features of smooth muscle tissue.

22.4 Explain the processes by which materials move through the digestive tract.

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Module 22.1: The digestive system consists of the digestive tract and accessory organs

Digestive system

- Provides nutrients for cell maintenance and growth
- Consists of muscular tube called *digestive tract*—also called *gastrointestinal (GI) tract*, or *alimentary canal*

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Module 22.1: Digestive system organization

Digestive system (continued)

- Supports tissues with no direct contact with the outside environment
  - Cardiovascular system
  - Respiratory system
    - Works with the cardiovascular system to supply oxygen to and remove carbon dioxide from cells
  - Urinary system
    - Removes organic wastes generated by cell activity

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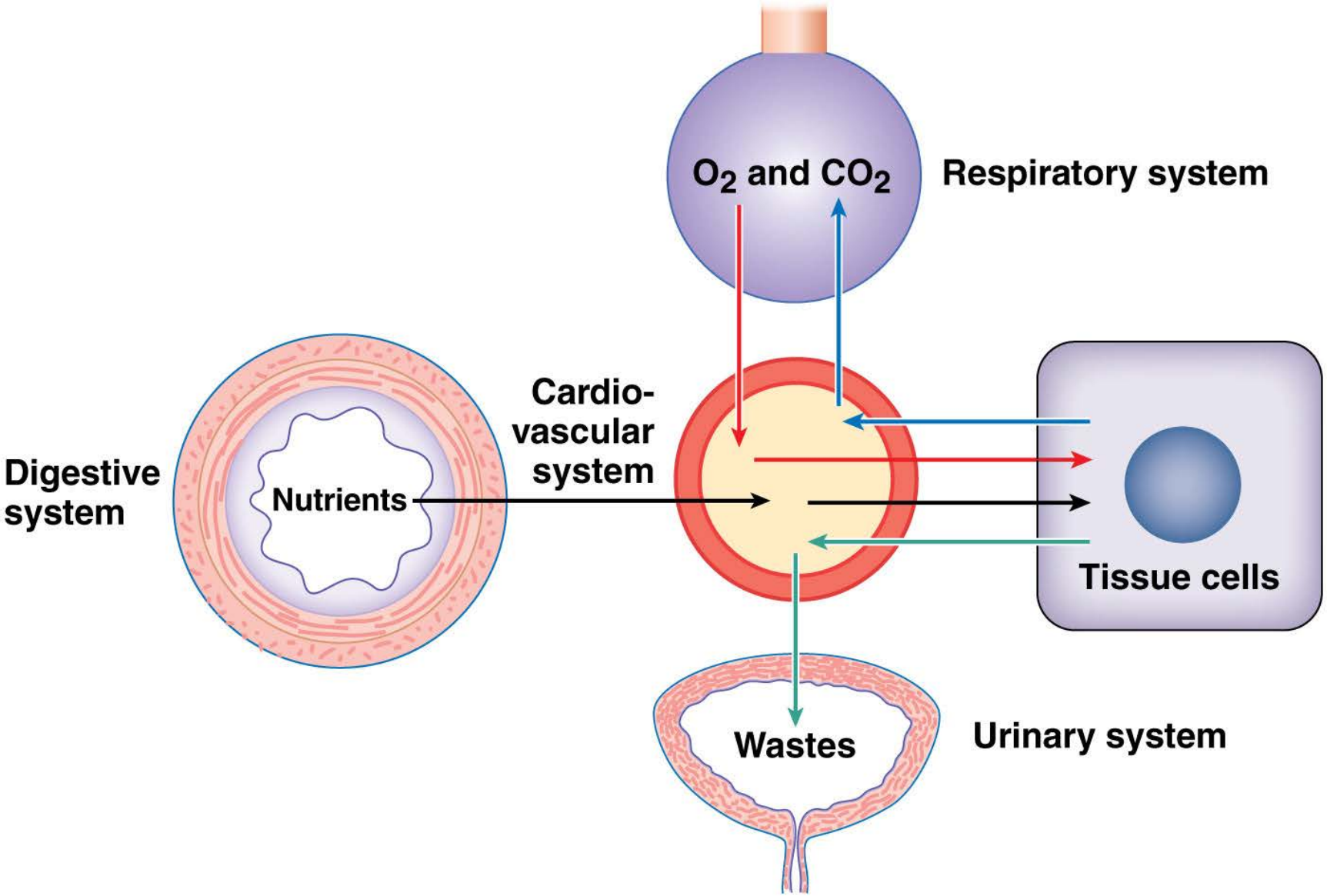
Digestive system works with other systems



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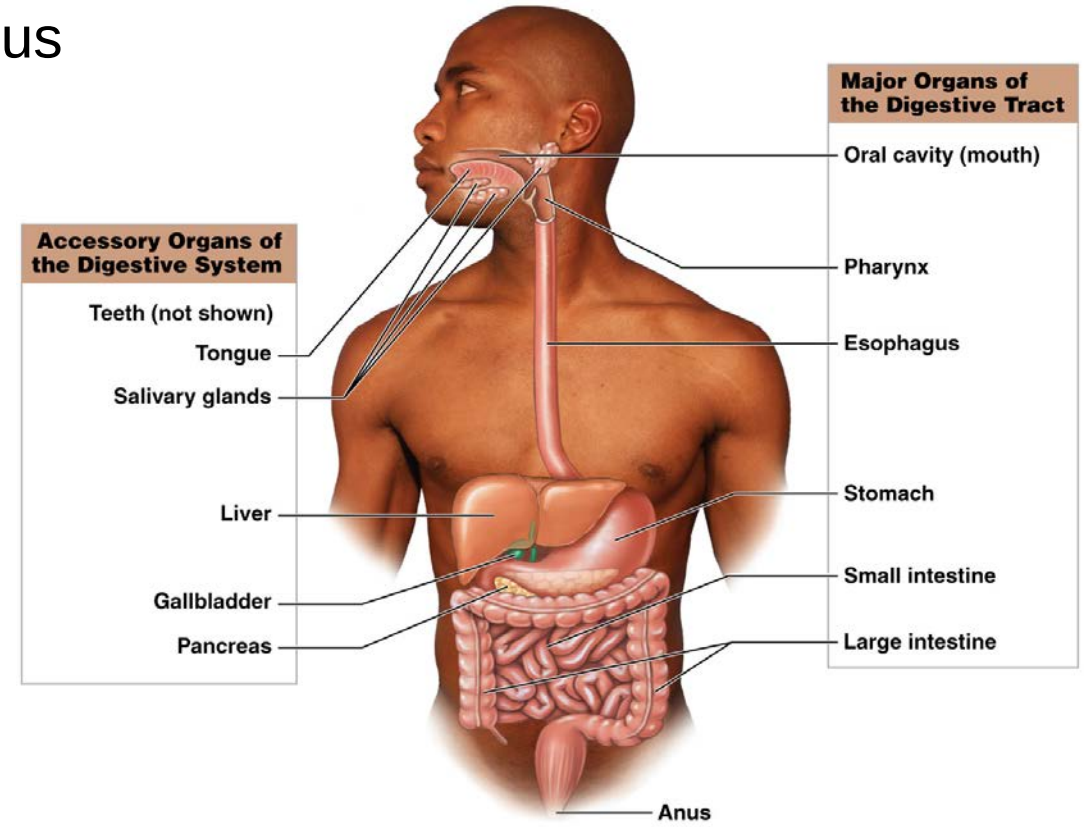
Module 22.1: Digestive system organization

Digestive system (continued)

- Composed of:
  - **Digestive tract**
    - Food passes along length from mouth to anus
  - Accessory organs
    - Secrete products into the digestive tract



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Module 22.1: Review

A. Which other systems work with the digestive system to support the cells and tissues of the human body?
B. Starting at the mouth, identify the major organs of the digestive tract.
C. List the accessory organs of the digestive system.

Learning Outcome: Name the major and accessory organs of the digestive system.

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Module 22.2: The digestive tract is a muscular tube lines by a mucous epithelium

Digestive tract description

- Long muscular tube
- Lined with permanent ridges and temporary folds
  - Both features increase surface area for absorbing nutrients

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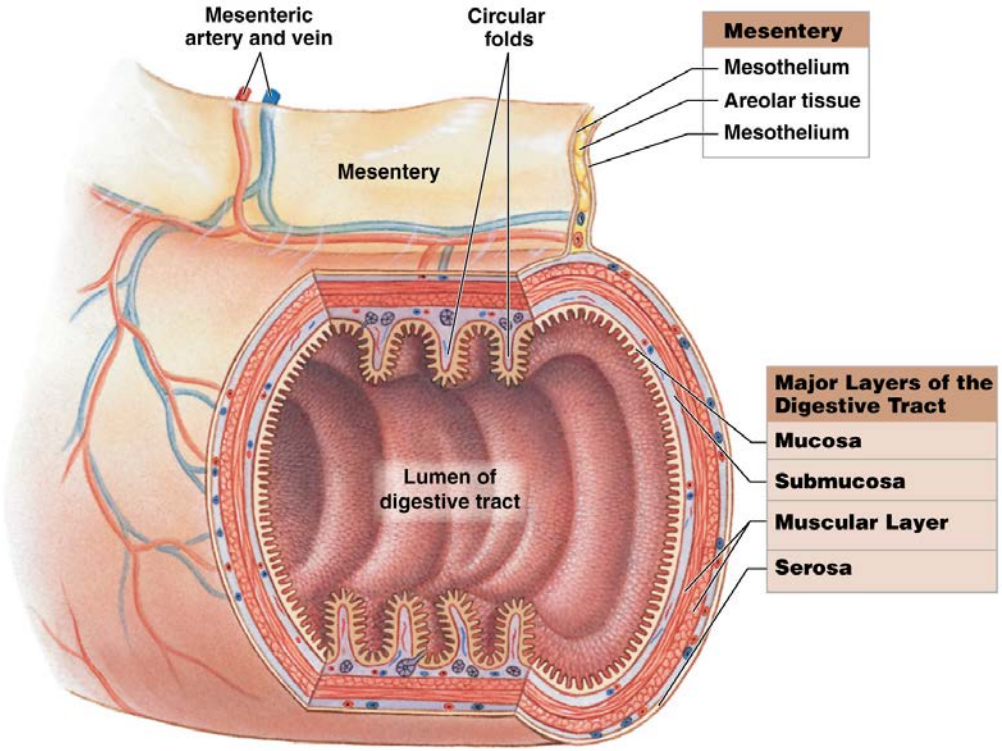
Module 22.2: Digestive tract structure

Mesentery

- Double sheets of peritoneal membrane
  - Areolar tissue lies between mesothelial layers
    - Provides access route for blood vessels, nerves, and lymphatics
  - Stabilizes attached organs
  - Prevents entanglement of intestines



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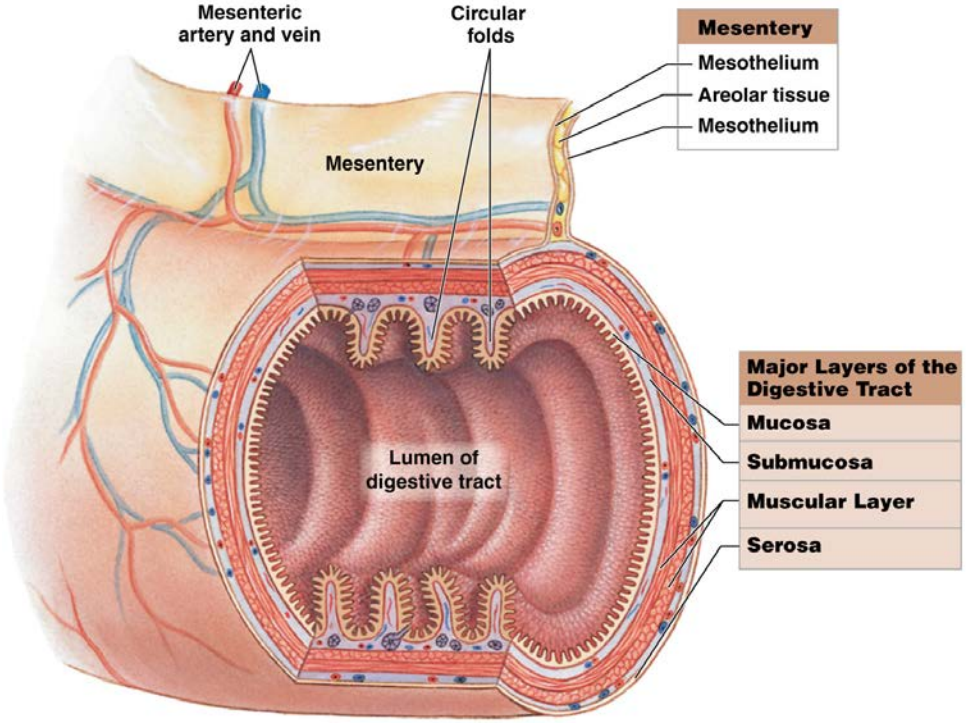
Module 22.2: Digestive tract structure

Four major layers of the digestive tract

1. **Mucosa** (inner lining)
   - Mucous membrane of epithelium, moistened by glandular secretions, and lamina propria of areolar tissue



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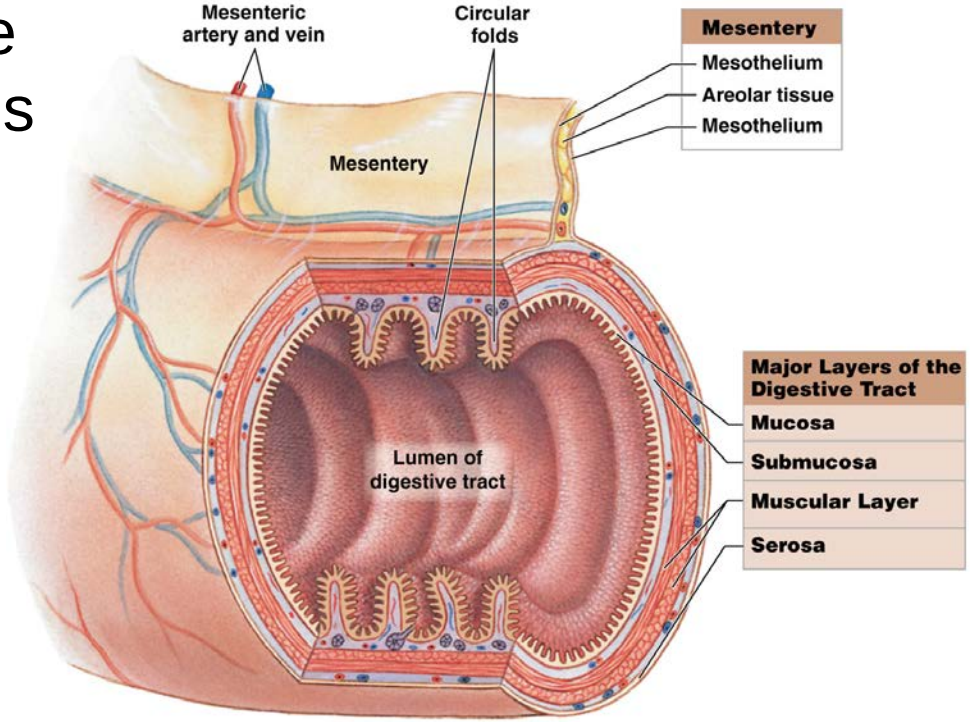
Module 22.2: Digestive tract structure

Four major layers of the digestive tract (continued)

2. **Submucosa**
   - Layer of dense irregular connective tissue
   - Contains blood vessels and lymphatic vessels
   - Also contains exocrine glands in some regions
     - Secrete buffers and enzymes into the digestive tract



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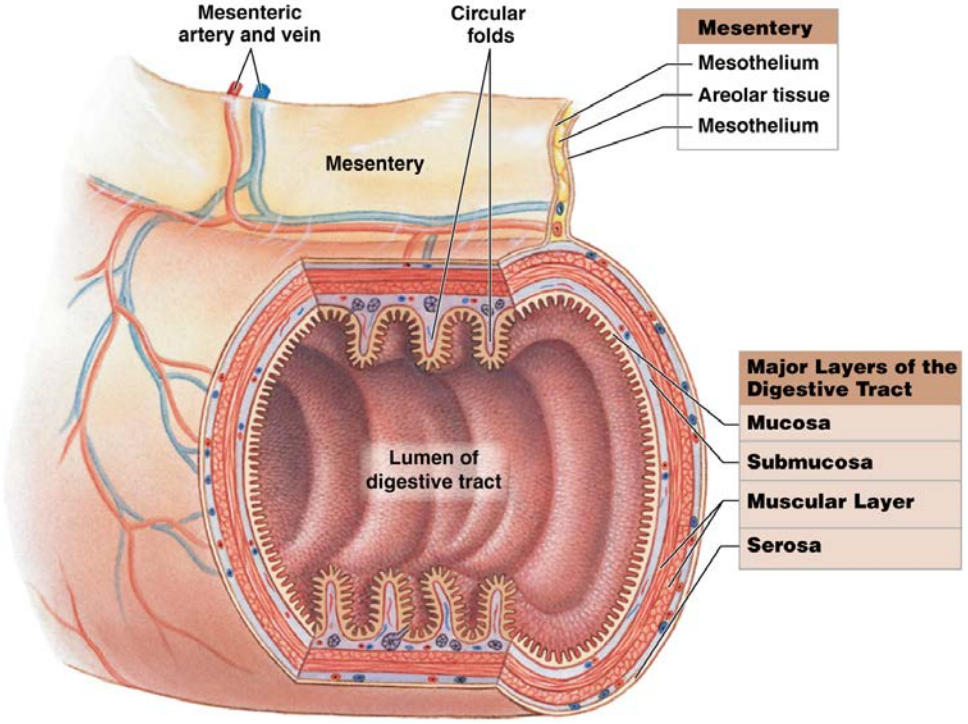
Module 22.2: Digestive tract structure

Four major layers of the digestive tract (continued)

3. **Muscular layer**
   - Smooth muscle in two layers (inner circular layer; outer longitudinal layer)
   - Involved in mechanical processing and movement along tract



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Module 22.2: Digestive tract structure

Four major layers of the digestive tract (continued)

4. **Serosa**
   - Layer of visceral peritoneum along the digestive tract in the abdominal cavity
   - No serosa in oral cavity, pharynx, esophagus, and rectum
     - Covered instead by **adventitia** (sheath formed from a dense network of collagen fibers)
     - Firmly attaches tract to adjacent structures

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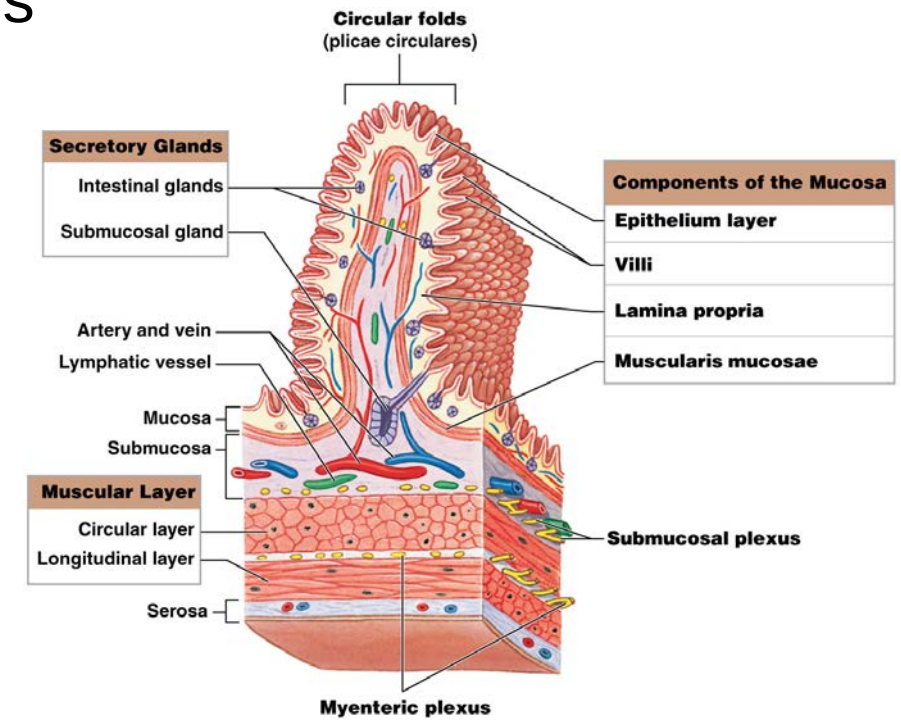
Module 22.2: Digestive tract structure

Components of the mucosa

- Mucosal epithelium
  - Tract begins and ends with stratified squamous epithelium
  - Stomach, small and large intestines are simple columnar with goblet cells



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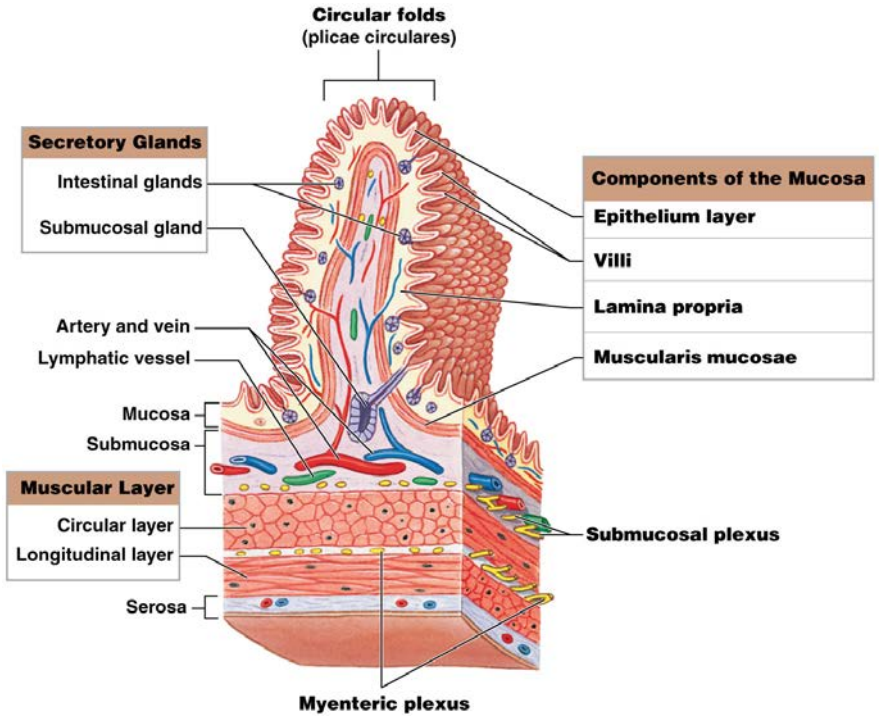
Module 22.2: Digestive tract structure

Components of the mucosa (continued)

- **Villi** (singular, *villus*)
  - Small mucosal projections that increase surface area for absorption



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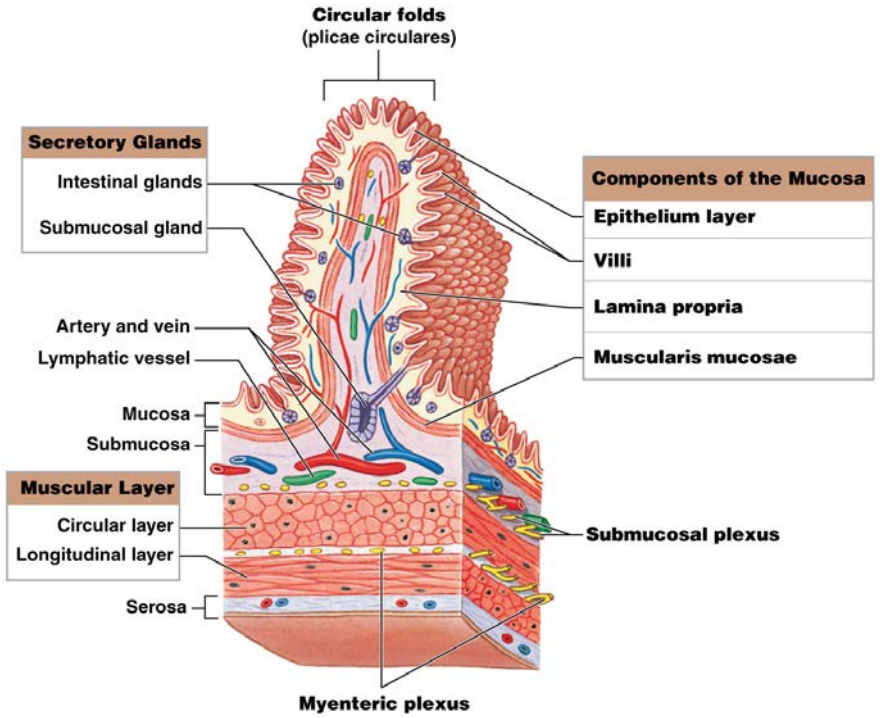
Module 22.2: Digestive tract structure

Components of the mucosa (continued)

- **Lamina propria**
  - Areolar tissue containing blood vessels, sensory nerve endings, lymphatic vessels, smooth muscle cells, lymphoid tissue, and some mucous glands



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Module 22.2: Digestive tract structure

Components of the mucosa (continued)

- **Muscularis mucosae**
  - Two concentric layers of smooth muscle
    1. Inner circular layer
    2. Outer longitudinal layer
  - Alter shape of lumen and move the circular folds and villi
    - **Circular folds** (plicae circulares)
      - Permanent transverse folds in the intestinal lining

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Module 22.2: Digestive tract structure

Nerve plexuses

- Involved in local control of digestive activities
  - Parasympathetic stimulation increases digestive muscle tone and activity
  - Sympathetic stimulation decreases muscle tone and activity
- **Submucosal neural plexus**
  - Located in the submucosal layer
  - Innervates the mucosa and submucosa
  - Contains sensory neurons, autonomic nerve fibers

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Module 22.2: Digestive tract structure

Nerve plexuses (continued)

- **Myenteric plexus** (*mys*, muscle + *enteron*, intestine)
  - Network of sensory neurons and autonomic nerve fibers
  - Located in the muscularis externa between the circular and longitudinal layers
  - Works with the submucosal plexus to coordinate local control of digestive activity

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Module 22.2: Review

A. What is the importance of the mesenteries?
B. Name the four layers of the digestive tract beginning from the lumen of the digestive tract.
C. Compare the submucosal neural plexus with the myenteric plexus.

Learning Outcome: Describe the functional histology of the digestive tract.

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Module 22.3: Smooth muscle tissue is found throughout the body, but it plays a particularly prominent role in the digestive tract

Smooth muscle

- Found throughout the body
- Forms sheets, bundles, or sheaths around tissues
  - Around blood vessels, regulates blood flow
  - Ring-shaped sphincters regulate movement along passageways in the digestive and urinary systems
- In the digestive tract, organized into inner circular layer and outer longitudinal layer
  - Within each layer, cells are aligned parallel to each other

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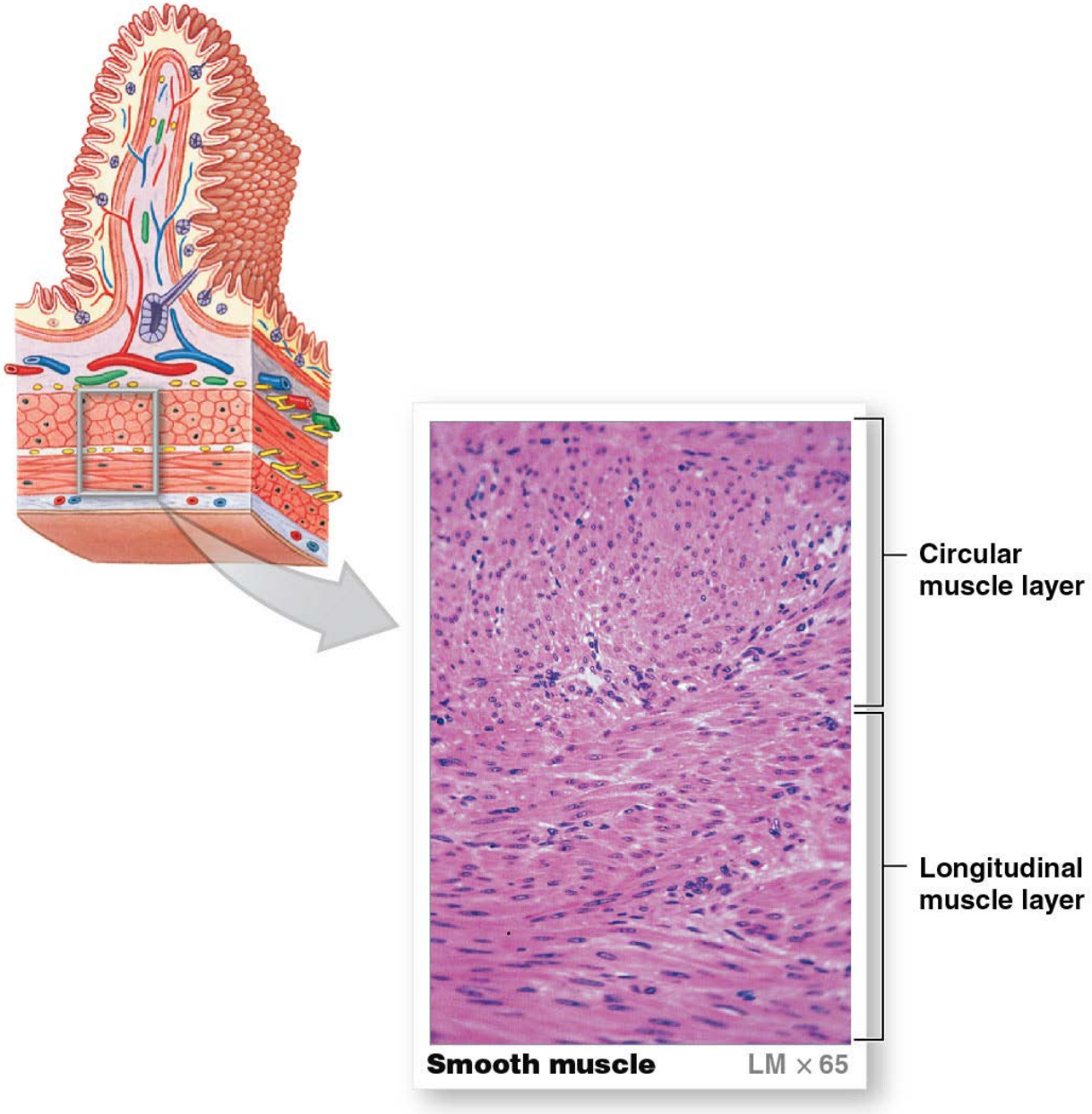
Smooth muscle of the digestive tract



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Module 22.3: Smooth muscle in the digestive tract

Smooth muscle cells

- Relatively long and slender
  - Diameter 5–10 µm; length 30–200 µm
- Contain actin and myosin filaments
  - Organization of actin and myosin filaments differs from skeletal and cardiac muscle
  - Contain no T tubules
  - Sarcoplasmic reticulum forms loose network throughout the sarcoplasm
  - Have no myofibrils or sarcomeres
  - No striations, giving the tissue a “smooth” microscopic appearance

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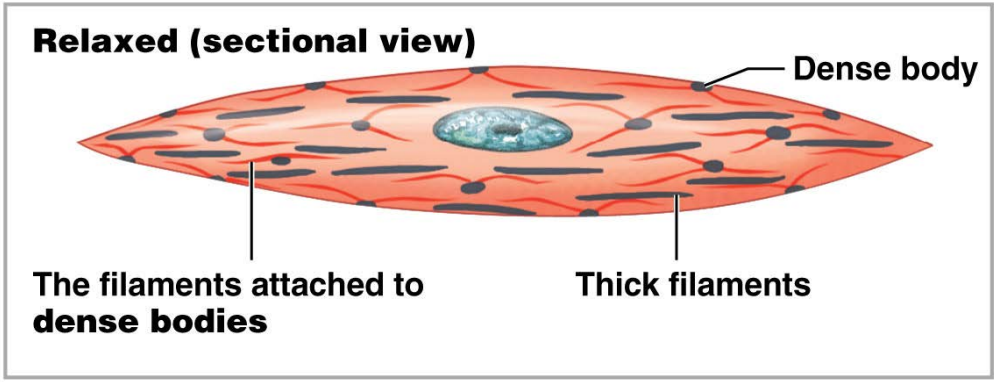
Module 22.3: Smooth muscle in the digestive tract

Smooth muscle cell contraction

- Thin filaments are attached to **dense bodies**
  - Distributed throughout sarcoplasm
  - Similar to Z lines of skeletal muscle tissue
  - Attachment points for adjacent smooth muscle cells
- Thick filaments scattered throughout the sarcoplasm
  - More myosin heads per thick filament than in skeletal or cardiac muscle



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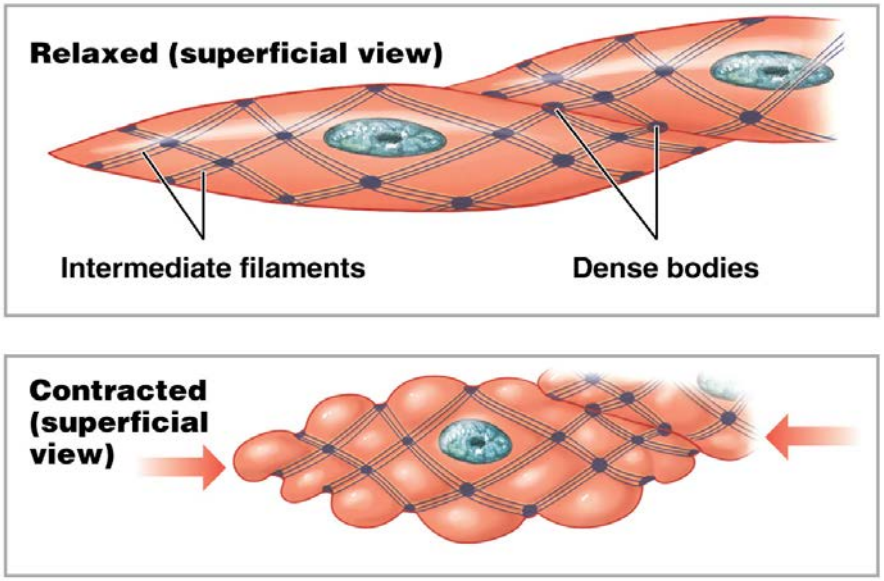
Module 22.3: Smooth muscle in the digestive tract

Smooth muscle cell contraction (continued)

- Contraction still involves interaction of thin and thick filaments
  - Cell shortens, but not in a straight line
  - Cell twists like a corkscrew as it contracts



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Module 22.3: Smooth muscle in the digestive tract

Two types of smooth muscle

1. **Multi-unit smooth muscle cells**
   - Innervated in motor units like skeletal muscle
     - But each cell may be connected to more than one motor neuron
   - Locations
     - Iris of eye (regulates diameter of the pupil)
     - Portions of male reproductive system
     - Walls of large arteries
     - Arrector pili muscles of skin

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Module 22.3: Smooth muscle in the digestive tract

Two types of smooth muscle (continued)

2. **Visceral smooth muscle cells**
   - Lack any direct connection with motor neuron
   - Arranged in sheets or layers
   - Electrically connected by gap junctions and mechanically connected by dense bodies
     - Cells contract in a wave as a single unit
   - Stimulation can be neural, hormonal, or chemical
     - Some rhythmically stimulated by **pacesetter cells**
   - Located in digestive tract walls, the gallbladder, urinary bladder, and many other internal organs

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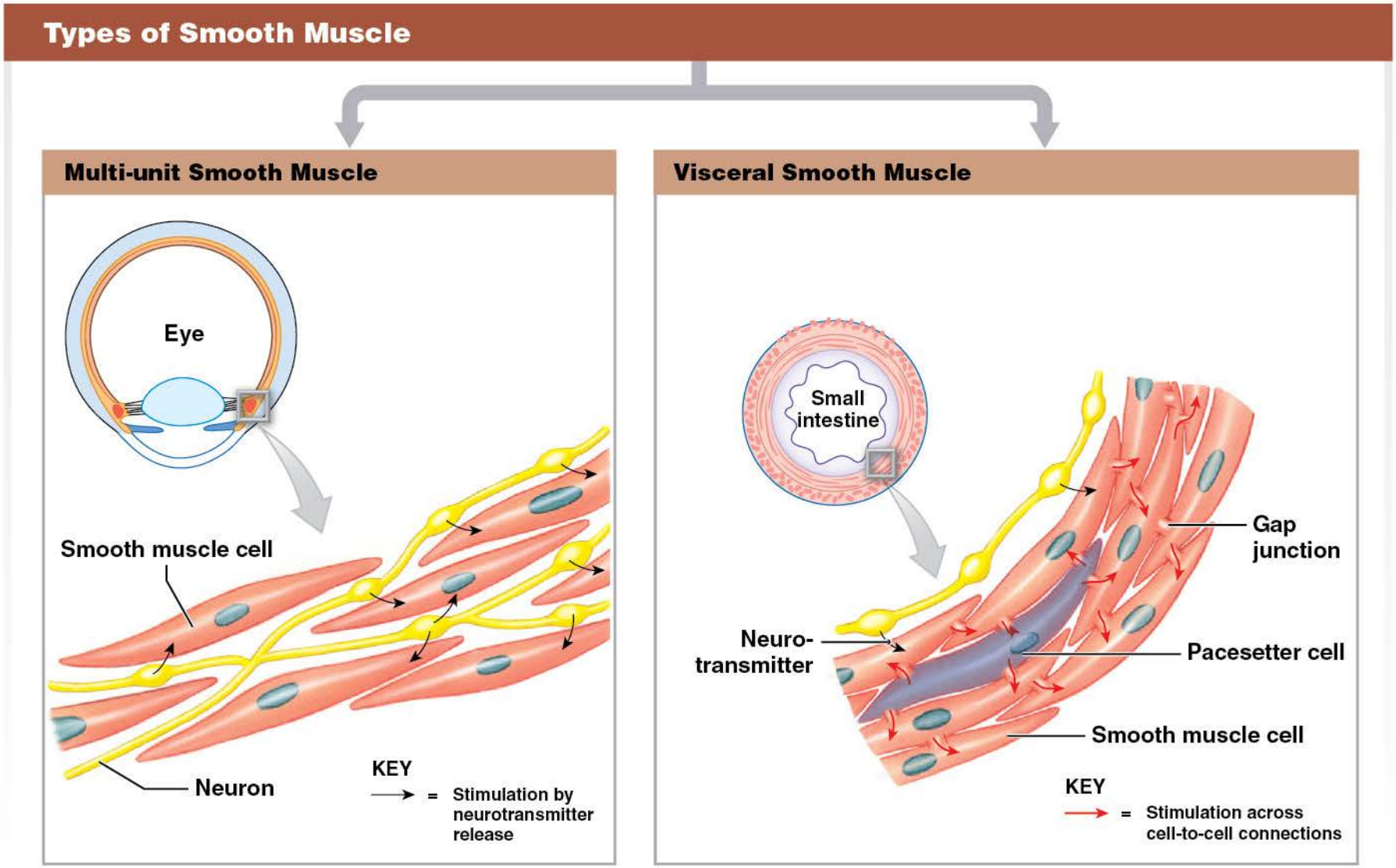
Types of smooth muscle



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Module 22.3: Smooth Muscle in the digestive tract

Functional characteristics of smooth muscle

- **Plasticity**
  - Ability to function over a wide range of lengths
    - Due to the scattered arrangement of thick and thin filaments
    - Tension development and resting length are not directly related
  - Important for digestive tract and other organs that change size and shape
- **Smooth muscle tone**
  - Normal background activity and tension due to various stimulations

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Module 22.3: Review

A. Describe the orientation of smooth muscle fibers in the muscular layer of the digestive tract.
B. Identify the structural characteristics of smooth muscle fibers.
C. Why can smooth muscle contract over a wider range of resting lengths than skeletal muscle?

Learning Outcome: Describe the structural and functional features of smooth muscle tissue.

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Module 22.4: Smooth muscle contractions produce motility of the digestive tract . . .

Peristalsis

- Wave of muscle contraction
- Food enters the digestive tract as a **bolus**
  - Moist, compact mass of material
- Bolus is propelled along the tract by contractions of the muscularis externa (**peristalsis**)
  - Circular muscles contract behind bolus
  - Longitudinal muscles ahead of bolus contract
  - Process repeats

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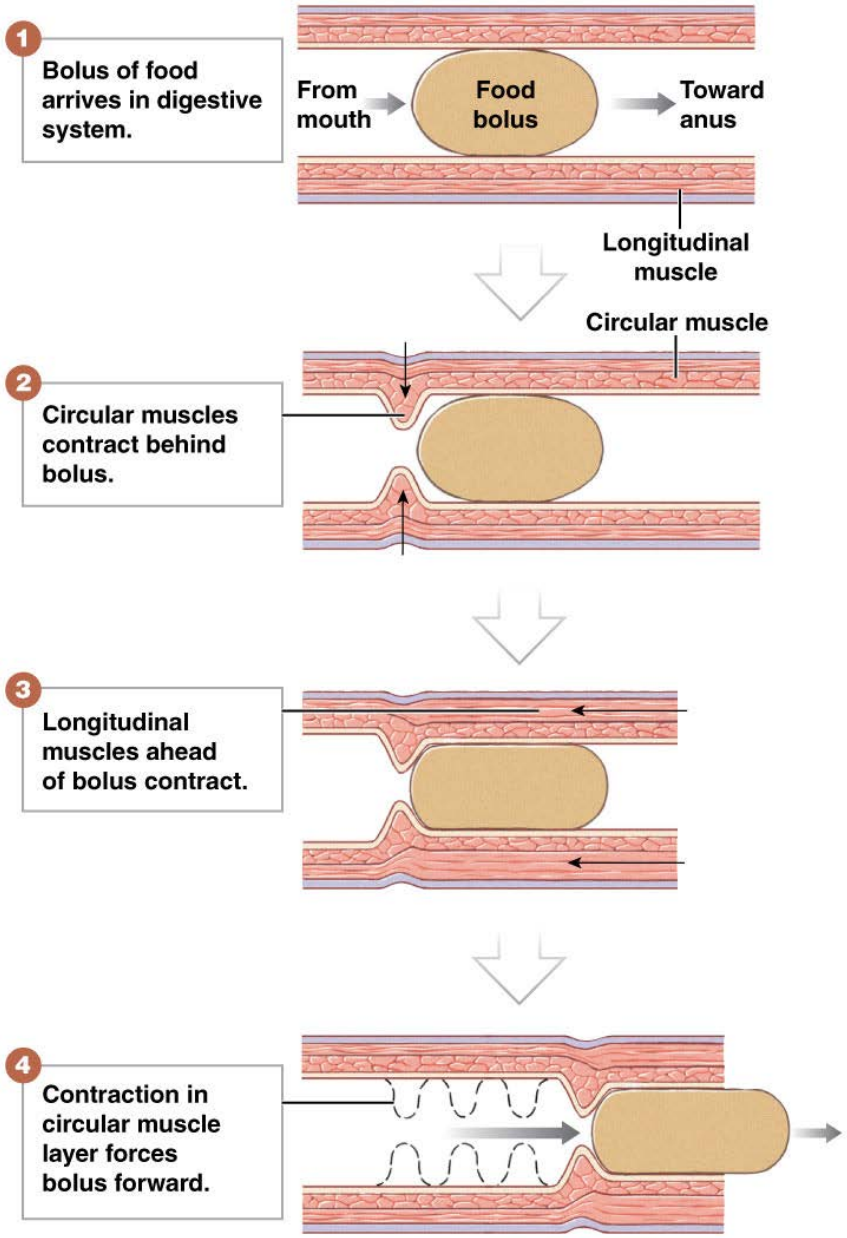
Peristalsis



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Module 22.4: Movement along the digestive tract

Segmentation

- Cycles of contraction
- Churn and fragment bolus
- Mix contents with intestinal secretions
- No set pattern of contractions, so no particular direction of movement
- Occurs in most areas of the small intestine and some portions of the large intestine

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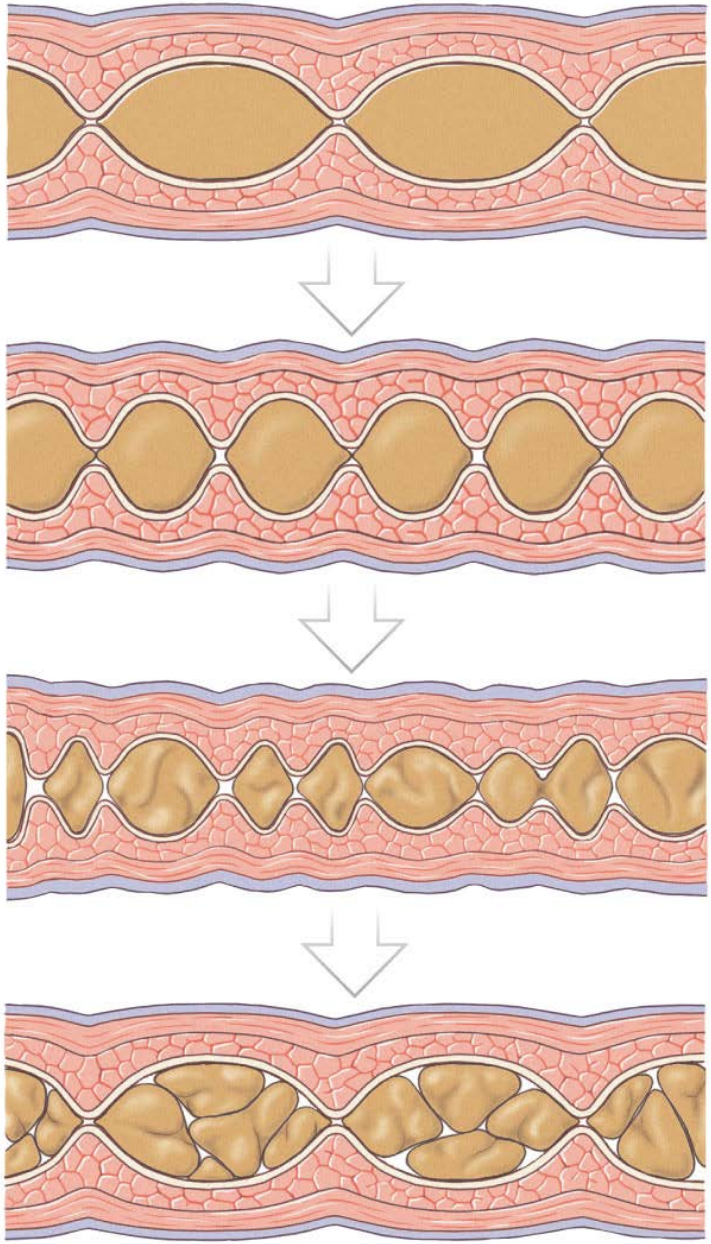
Segmentation



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Module 22.4: . . . and local factors interact with neural and hormonal mechanisms to regulate digestive activities

Digestive regulation mechanisms

1. **Local factors**
   - Primary stimulus for digestive activities
   - Examples:
     - Changes in pH of contents in lumen
     - Physical distortion of digestive tract wall
     - Presence of chemicals (specific nutrients or chemical messengers released by the mucosa)

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Module 22.4: Movement along the digestive tract

Digestive regulation mechanisms (continued)

2. **Neural control mechanisms**
   - Short reflexes (**myenteric reflexes**)
     - Triggered by chemoreceptors or stretch receptors in digestive tract walls
     - Controlling neurons located in the myenteric plexus
   - Long reflexes
     - Higher level of control involving interneurons and motor neurons of the CNS
       - Generally control large-scale peristalsis, moving material from one region of the tract to another
     - May involve parasympathetic motor fibers that synapse in the myenteric plexus

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Module 22.4: Movement along the digestive tract

Digestive regulation mechanisms (continued)

3. **Hormonal control mechanisms**
   - Involve at least 18 hormones that affect digestive function
     - Some affect other systems as well
   - Hormones are peptides produced by **enteroendocrine cells** (endocrine cells in the epithelium of the digestive tract)

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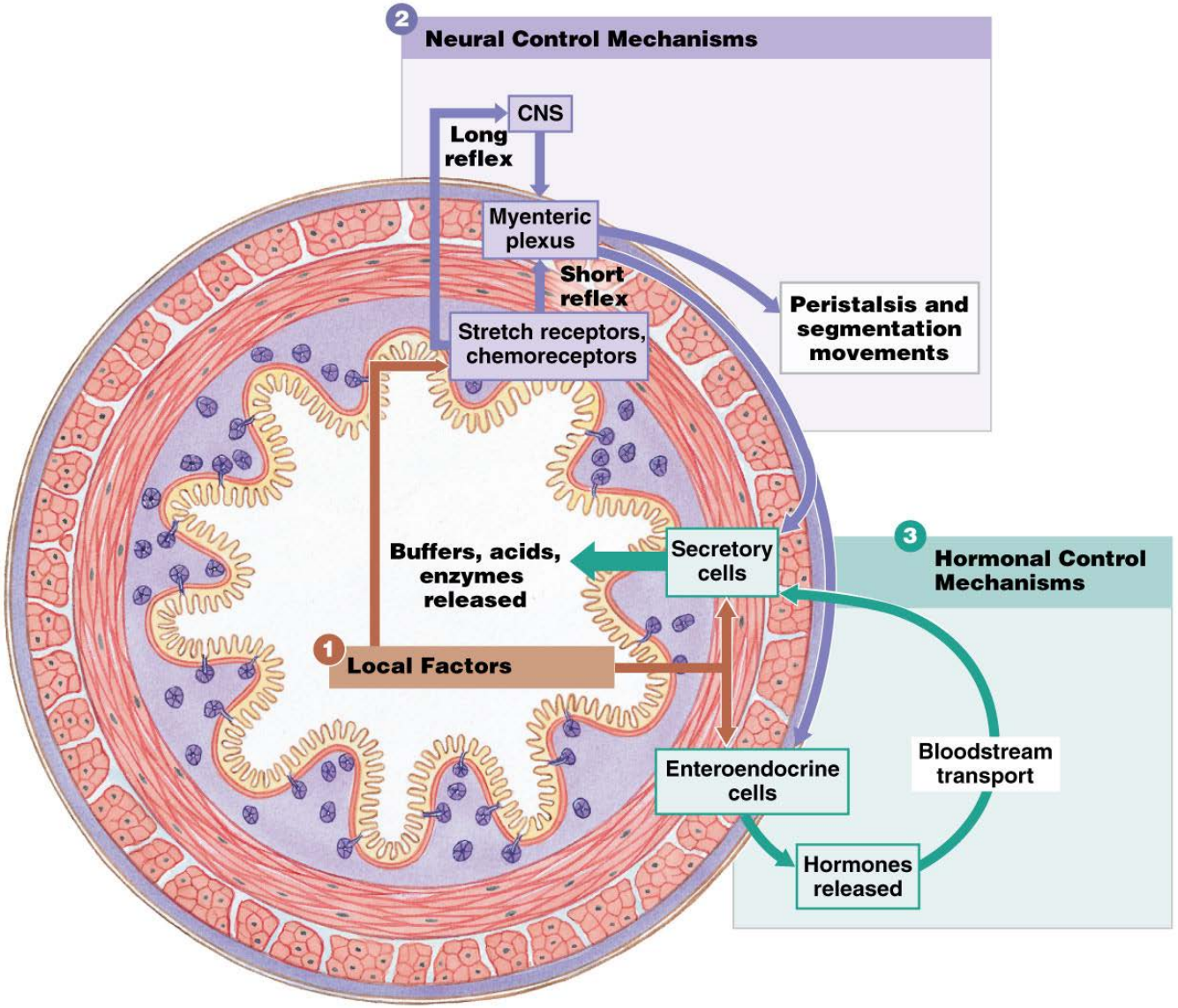
Digestive regulation mechanisms



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Module 22.4: Movement along the digestive tract

Congenital megacolon (*Hirschsprung disease*)

- Characterized by absences or marked reduction in number of ganglion cells in the myenteric plexus of rectum
- Causes paralysis of smooth muscle (absence of peristaltic movement)
  - Abnormal dilation and hypertrophy of colon
  - Chronic constipation, bloating, abdominal pain

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Module 22.4: Review

A. Which is more efficient in propelling intestinal contents along the digestive tract: peristalsis or segmentation? Why?
B. Cite the major mechanisms that regulate and control digestive activities.
C. Describe enteroendocrine cells.

Learning Outcome: Explain the processes by which materials move through the digestive tract.

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Section 2: Digestive Tract

Learning Outcomes

22.5 Name the structures and primary functions of the digestive tract organs.

22.6 Describe the anatomy of the oral cavity, and discuss the functions of its structures.

22.7 Describe the types of teeth, and differentiate between deciduous teeth and permanent teeth.

22.8 Describe the anatomy and functions of the pharynx and esophagus, and explain the swallowing process.

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Section 2: Digestive Tract

Learning Outcomes (continued)

22.9 Explain the embryonic development of the mesenteries, and describe the mesenteries that remain in adulthood.

22.10 Describe the anatomy of the stomach and its histological features.

22.11 Describe the anatomy of the stomach relating to its role in digestion and absorption.

22.12 Describe the anatomy of the intestinal tract and its histological features.

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Section 2: Digestive Tract

Learning Outcomes (continued)

22.13 Describe the anatomy and physiology of the small intestine.

22.14 Discuss the major digestive hormones and their primary effects.

22.15 Explain the regulation of gastric activity by central and local mechanisms.

22.16 Describe the gross anatomy of the three segments of the large intestine.

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Section 2: Digestive Tract

Learning Outcomes (continued)

22.17 Describe the large intestine's histology and role in fecal compaction, and explain the defecation reflex.

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Module 22.5: The digestive tract begins with the mouth and ends with the anus

Description and major organs

- Muscular tube about 10 m (33 ft) long
- Major organs and their functions
  - **Oral cavity** (mouth)
    - Mechanical processing (with the teeth and tongue), moistening, mixing with salivary secretions
  - **Pharynx**
    - Muscular propulsion of food into the esophagus
  - **Esophagus**
    - Transport of materials to the stomach

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Module 22.5: The digestive tract

Description and major organs (continued)

- **Stomach**
  - Chemical breakdown and mechanical processing
- **Small intestine**
  - Enzymatic digestion and absorption
- **Large intestine**
  - Dehydration and compaction of indigestible materials

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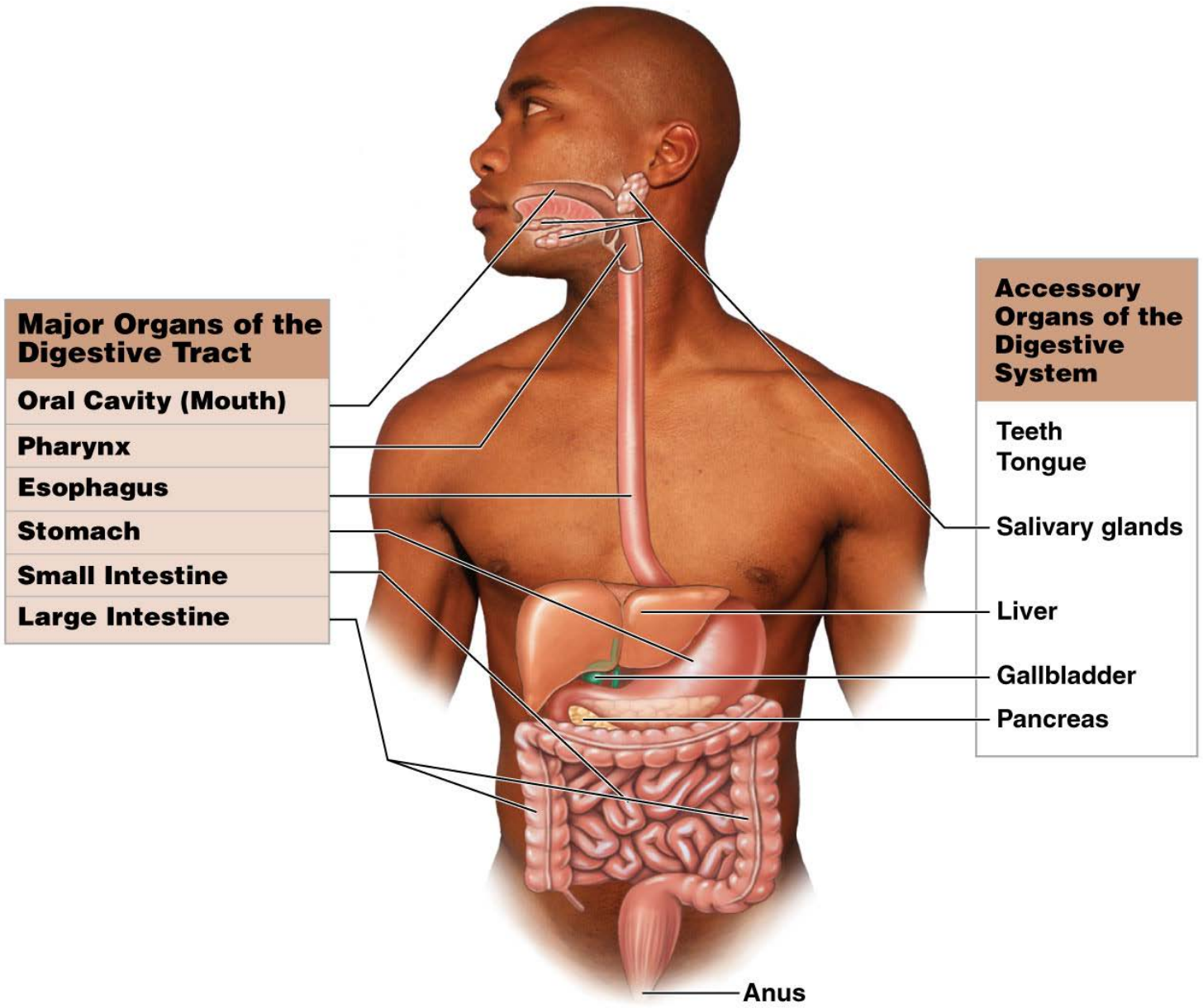
Digestive organs



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Module 22.5: The digestive tract

Functions of the digestive tract

- **Ingestion**
  - Occurs when solid food and liquid enter the oral cavity
- **Mechanical digestion and propulsion**
  - Involves crushing and shredding of food in the oral cavity and mixing and churning in the stomach
- **Chemical digestion**
  - Chemical and enzymatic breakdown of food into small organic molecules that can be absorbed by the digestive epithelium

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Module 22.5: The digestive tract

Functions of the digestive tract (continued)

- **Secretion**
  - The release of water, acids, enzymes, buffers, and salts by the digestive tract epithelium and by accessory digestive organs
- **Absorption**
  - Movement of nutrients across the digestive epithelium and into the bloodstream
- **Defecation**
  - Indigestible food is compacted into material waste called **feces**, which are eliminated by **defecation**

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Module 22.5: Review

A. Define *ingestion*.
B. Distinguish between chemical digestion and absorption.
C. Describe the function of the large intestine.

Learning Outcome: Name the structures and primary functions of the digestive tract organs.

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Module 22.6: The oral cavity is a space that contains the tongue, teeth, and gums

Oral cavity (mouth)

- Lined by **oral mucosa** (stratified squamous epithelium)
  - Keratinized in areas that are exposed to severe abrasion (superior tongue surface, hard palate)
  - Thin, nonkeratinized lining on cheeks, lips, and inferior tongue surface
    - Thin mucosa inferior to the tongue allows for rapid absorption of lipid-soluble drugs (example: nitroglycerin)
- Nutrients are not absorbed here
- Digestion of carbohydrates and lipids begins here

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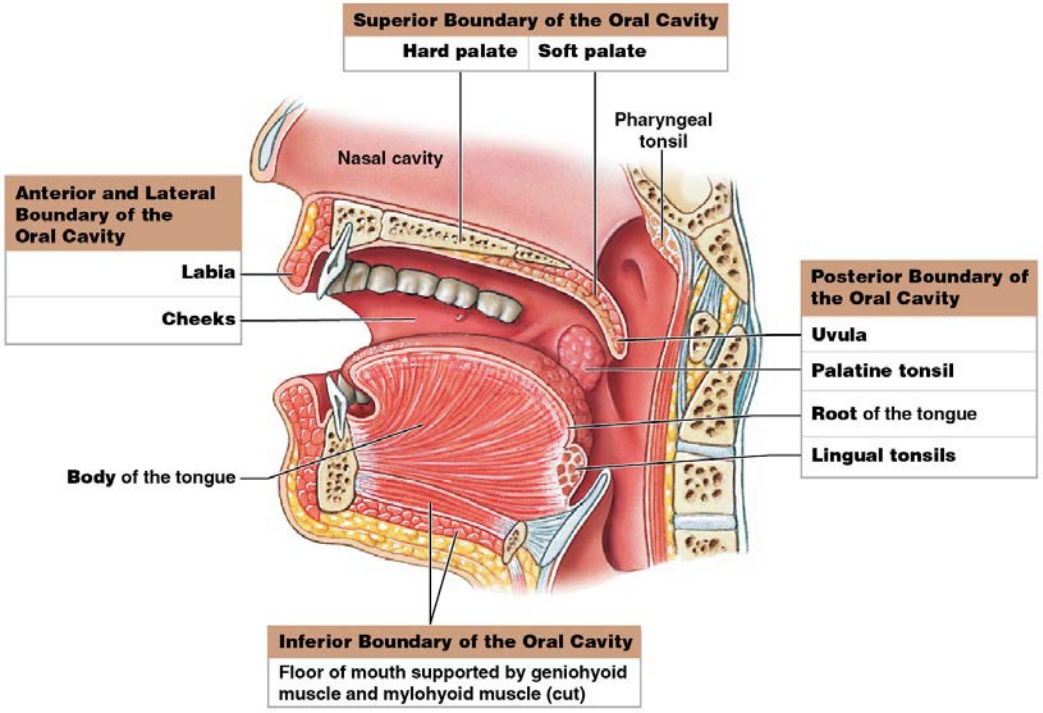
Module 22.6: The oral cavity

Oral cavity boundaries

- **Superior boundary**
  - **Hard palate**
    - Formed by the palatine processes of the maxillary bones and horizontal plates of the palatine bones
  - **Soft palate**
    - Muscular region posterior to the hard palate



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Module 22.6: The oral cavity

Oral cavity boundaries (continued)

- **Anterior and lateral boundary**
  - **Cheeks**
    - Form the lateral walls of the oral cavity
      - Supported by pads of fat and the buccinator muscles
    - Anteriorly, cheek mucosa is continuous with the labia
  - **Labia** (lips)
    - Form anterior boundary

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Module 22.6: The oral cavity

Oral cavity boundaries (continued)

- **Posterior boundary**
  - **Uvula**
    - Dangling process extending from the soft palate
    - Helps prevent food from entering pharynx prematurely
    - Swings upward during swallowing to prevent food from entering the nasopharynx
  - Palatine tonsils (one located on either side of the oropharynx)

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Module 22.6: The oral cavity

Oral cavity boundaries (continued)

- **Posterior boundary** (continued)
  - **Root** of tongue
    - Fixed portion projecting into the oropharynx
    - Marked by a V-shaped line of vallate papillae
  - **Lingual tonsils** (located in the root of the tongue)

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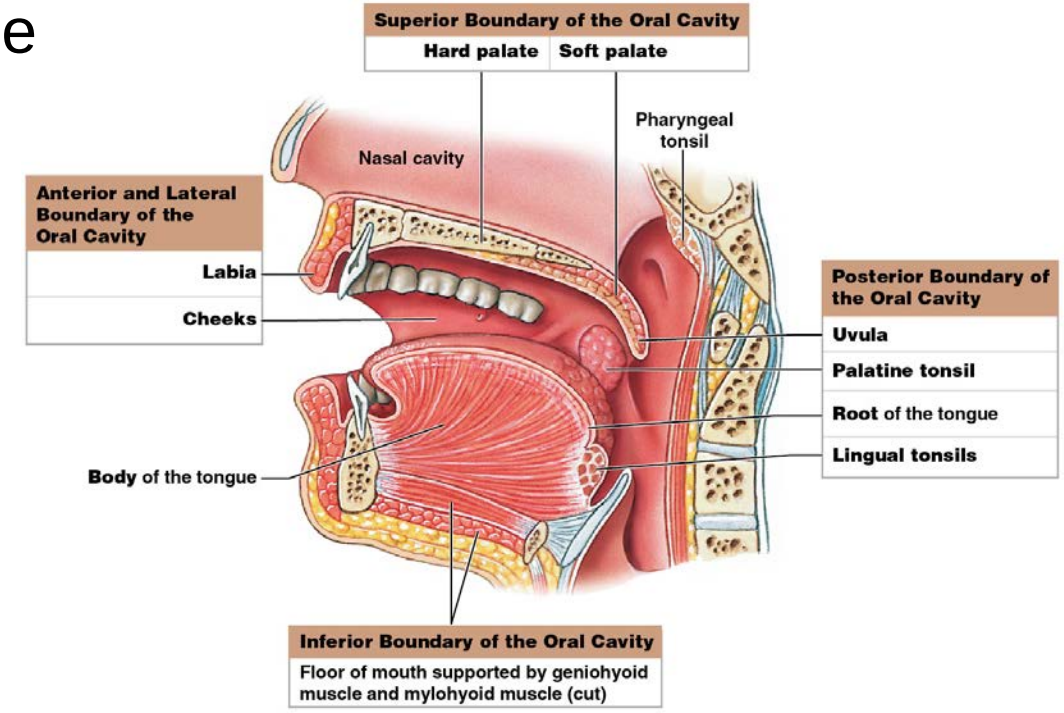
Module 22.6: The oral cavity

Oral cavity boundaries (continued)

- **Inferior boundary**
  - **Body** of the tongue
    - Anterior, mobile portion
  - Geniohyoid and mylohyoid muscles provide extra support to the inferior boundary



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Module 22.6: The oral cavity

Oral cavity structures

- **Oral vestibule**
  - The space between the cheeks (or lips) and teeth
- **Frenulum of the upper lip** (*frenulum*, a small bridle)
  - Attaches gums to upper lip
- Thick mucosa with ridges covering the hard palate
  - Provides traction for compression of food by the tongue
- **Frenulum of the lower lip**
  - Attaches gums to lower lip

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Module 22.6: The oral cavity

Oral cavity structures (continued)

- **Gingivae** (gums)
  - Ridges of oral mucosa surrounding the base of each tooth
  - Firmly attached to the periostea of the underlying bone
- **Palatal arches**
  - Located on either side of the uvula
  - **Palatoglossal arch**
    - Extends between soft palate and base of tongue
  - **Palatopharyngeal arch**
    - Extends from soft palate to pharyngeal wall

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Module 22.6: The oral cavity

Oral cavity structures (continued)

- **Fauces**
  - Space between oral cavity and oropharynx
- **Tongue**
  - Manipulates materials inside the mouth
  - Surface flushed by secretions of small glands
    - Secretions contain water, mucins, and **lingual lipase** (an enzyme that starts the digestion of lipids)
  - Attached to the floor of the mouth by the **frenulum of the tongue** (*lingual frenulum*)

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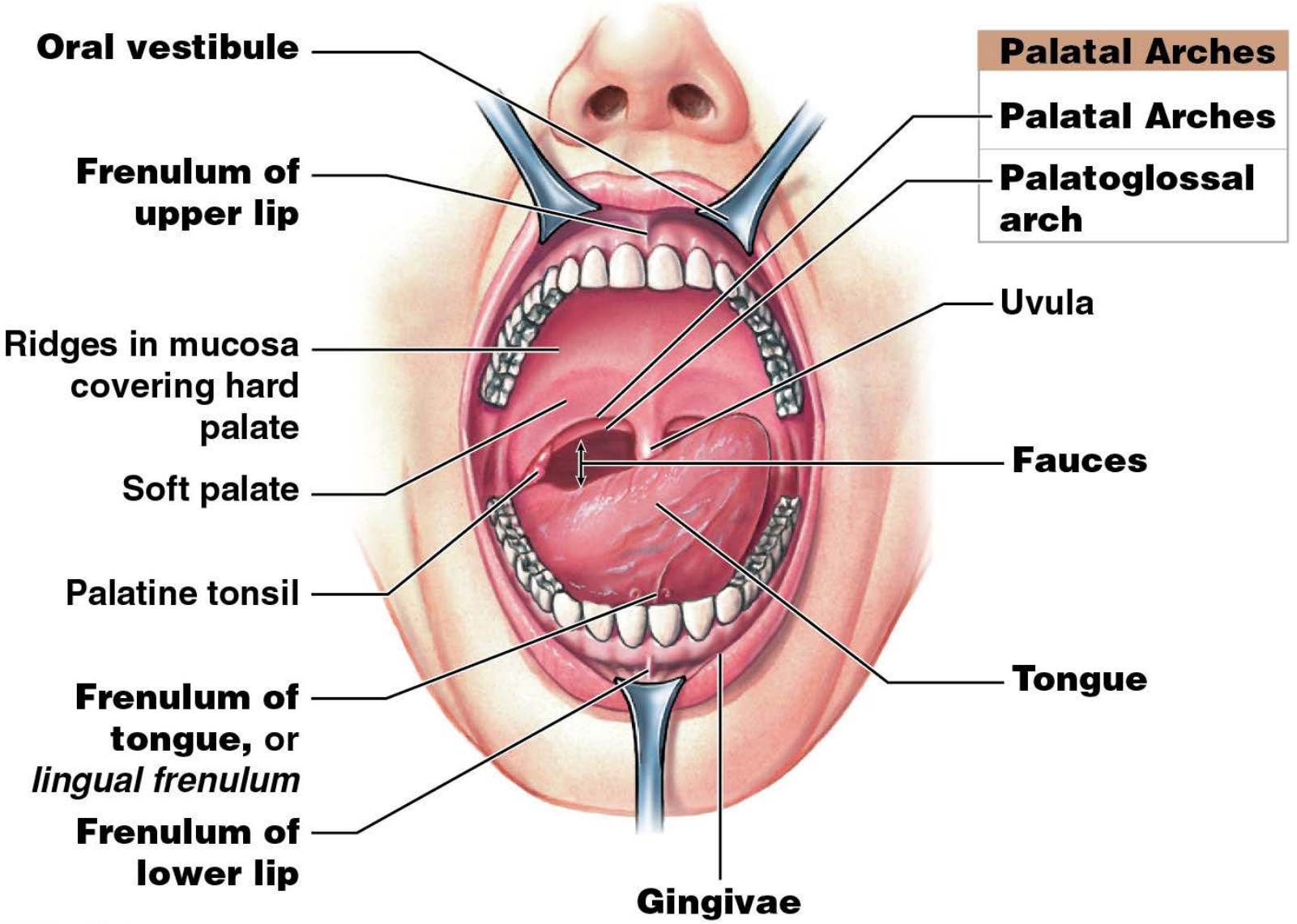
Oral cavity



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Module 22.6: The oral cavity

Ankyloglossia (tongue-tie)

- Present at birth
- Frenulum of tongue is too short
- Interferes with breastfeeding in newborns
- Interferes with learning to speak in toddlers

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Module 22.6: Review

A. The oral cavity is lined by which type of epithelium?
B. Name the structure that forms the roof of the mouth.
C. Describe the location of the fauces.
D. What effects might a shortened frenulum of tongue cause?

Learning Outcome: Describe the anatomy of the oral cavity, and discuss the functions of its structures.

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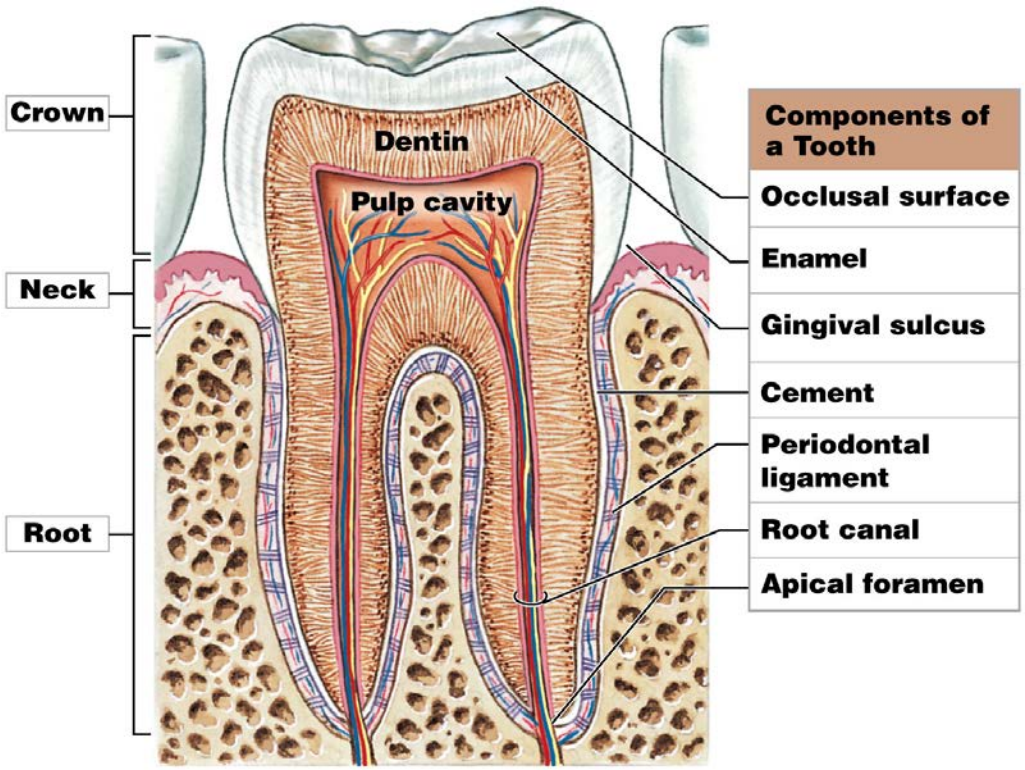
Module 22.7: Teeth in different regions of the jaws vary in size, shape, and function

Components of a tooth

- The bulk of each tooth is composed of **dentin**
  - Mineralized matrix similar to bone but contains no cells
- **Pulp cavity**
  - The interior chamber of the tooth



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Module 22.7: Teeth

Components of a tooth (continued)

- **Occlusal surface**
  - Portion of the crown used for crushing, slicing, or chewing
- **Enamel**
  - Covers the dentin of the crown
  - Hardest biologically manufactured substance
  - Composed of calcium phosphate
    - Requires calcium, phosphate, and vitamin D for formation and resistance to decay

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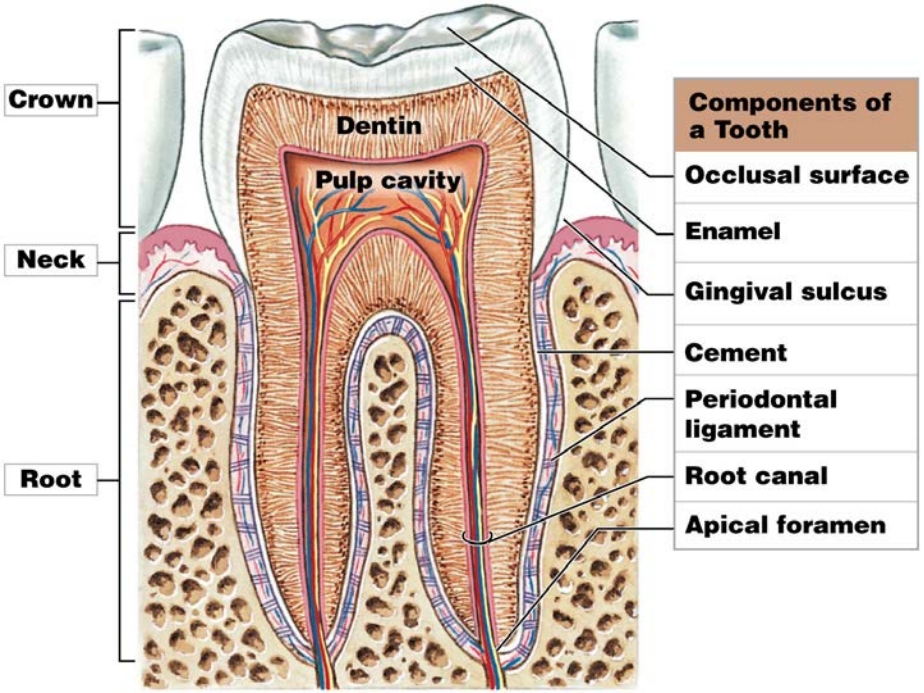
Module 22.7: Teeth

Components of a tooth (continued)

- **Gingival sulcus**
  - Shallow groove surrounding the base of the neck
  - Epithelial attachment blocks bacteria from accessing deeper tissues around the root



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Module 22.7: Teeth

Components of a tooth (continued)

- **Cement**
  - Covers the dentin in the root
  - Less resistant to erosion than dentin
- **Periodontal ligament**
  - Creates **gomphosis** articulation between root dentin and alveolar bone
- **Root canal**
  - Narrow tunnel within the root of the tooth
  - Passageway for blood vessels and nerves to the pulp cavity
  - Opening into the root canal is the **apical foramen**

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Module 22.7: Teeth

Regions of a tooth

- **Crown**
  - Portion projecting into the oral cavity from the surface of the gums
- **Neck**
  - The boundary between the crown and root
- **Root**
  - Portion below the gum line
  - Sits in a bony tooth socket called an **alveolus**

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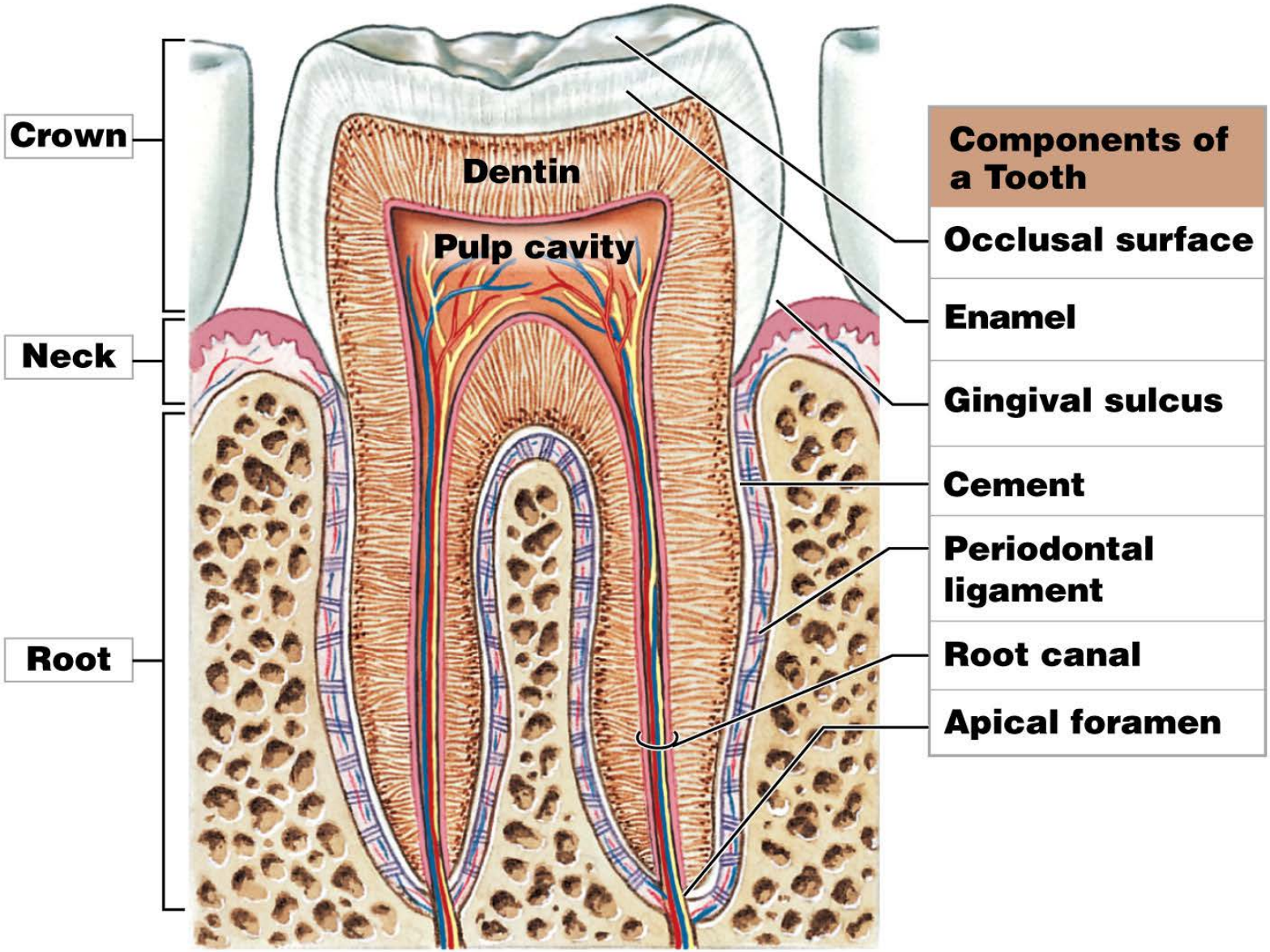
The tooth



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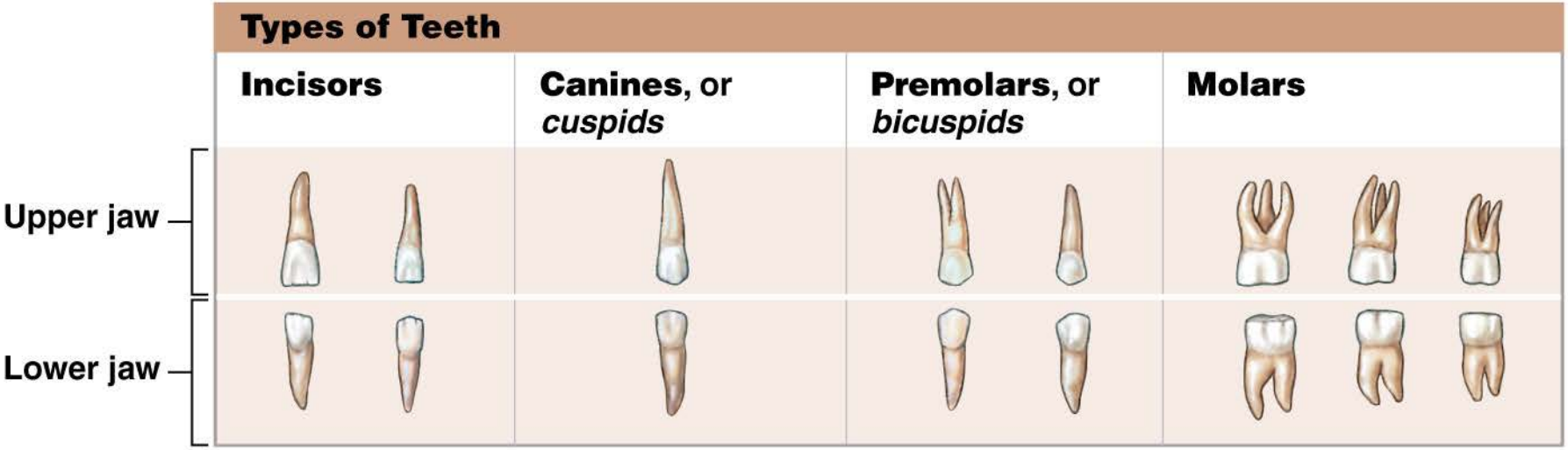
Module 22.7: Teeth

Four types of teeth

- Each with a distinctive shape and root pattern

1. **Incisors**
   - Blade-shaped teeth with a single root
   - Located at the front of the mouth
   - Useful for clipping or cutting



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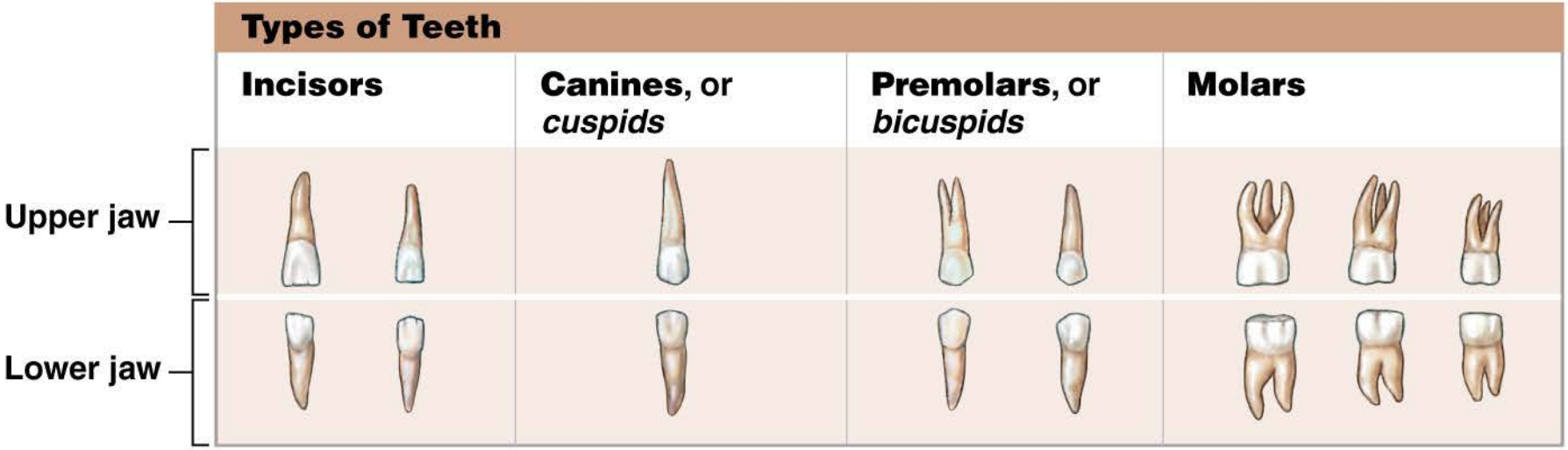
Module 22.7: Teeth

Four types of teeth (continued)

2. **Canines** (or cuspids)
   - Conical with a sharp ridgeline and pointed tip
   - Used for tearing or slashing
   - Have a single root



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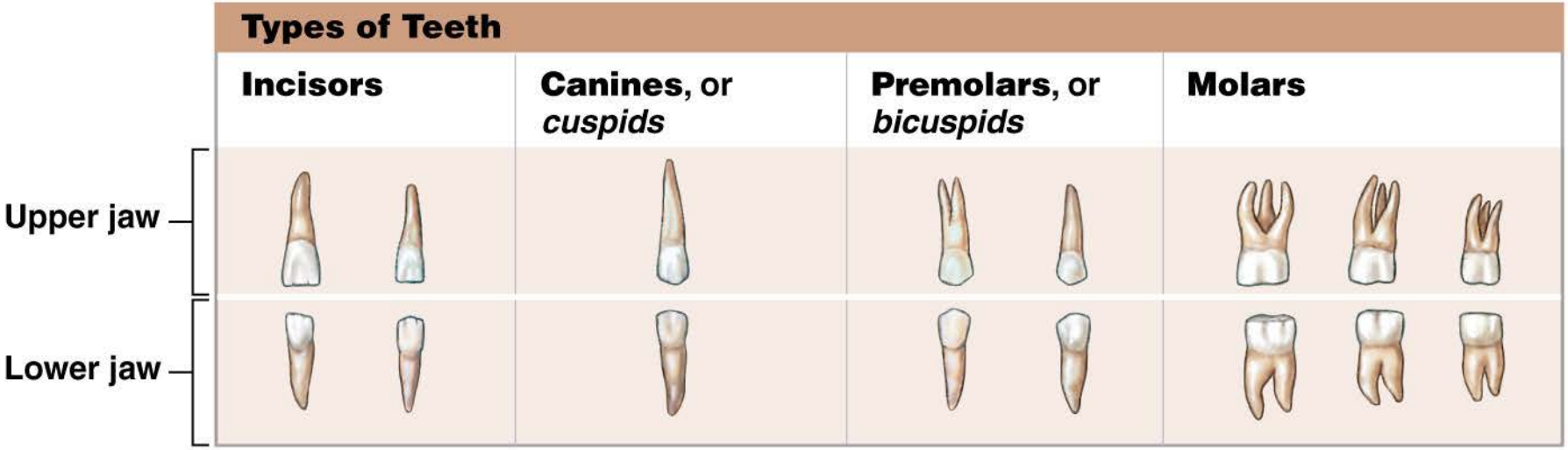
Module 22.7: Teeth

Four types of teeth (continued)

3. **Premolars** (or bicuspids)
   - Have flattened crowns with prominent ridges
   - Used for crushing, mashing, or grinding
   - Have one or two roots



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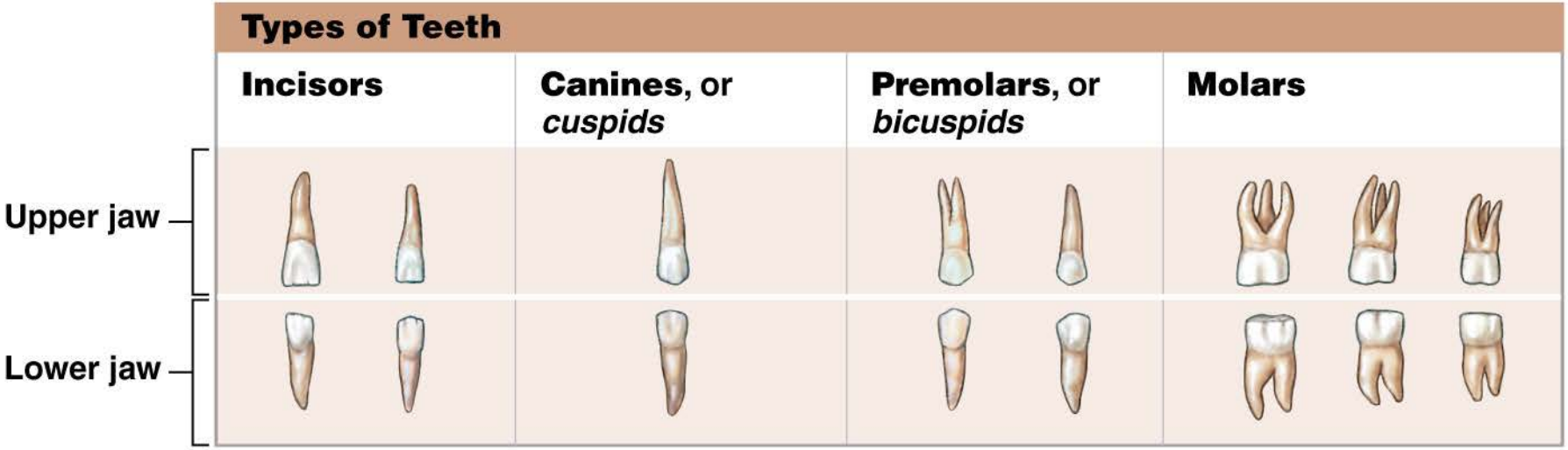
Module 22.7: Teeth

Four types of teeth (continued)

4. **Molars**
   - Very large flattened crowns with prominent ridges
   - Adapted for crushing and grinding
   - Typically have three roots (upper jaw) or two roots (lower jaw)



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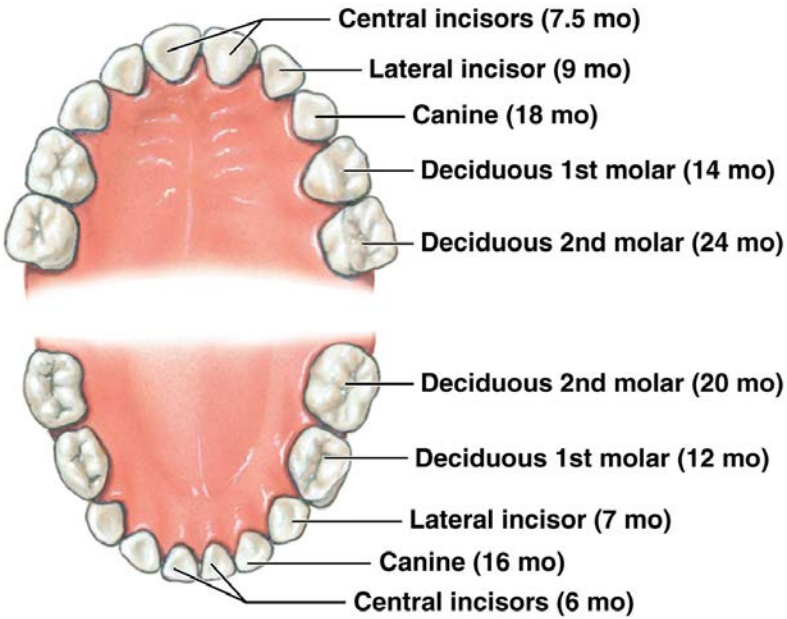
Module 22.7: Teeth

Two sets of teeth

- Formed during embryonic development

1. **Deciduous teeth**
   - Also called *primary teeth*, *milk teeth*, or *baby teeth*
   - At 2 years of age
     - 20 deciduous teeth
     - 5 on each side of upper and lower jaws
       - 2 incisors, 1 canine, 2 deciduous molars



Deciduous teeth, with the age at eruption given in months

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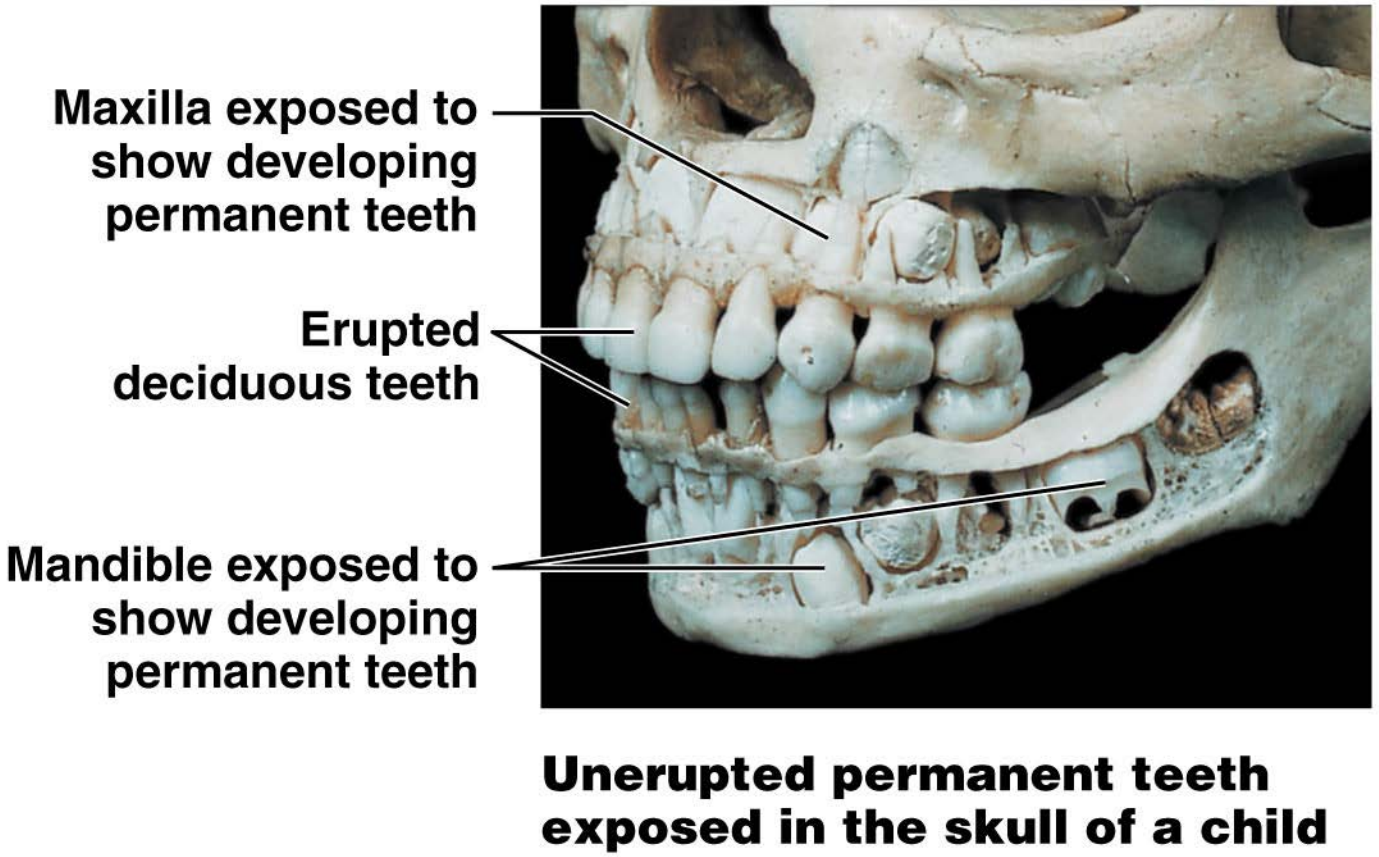
Unerupted permanent teeth exposed in child skull



Unerupted permanent teeth exposed in the skull of a child

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Module 22.7: Teeth

Two sets of teeth (continued)

2. **Permanent teeth**
   - Gradually replace deciduous teeth
     - Periodontal ligaments and roots of primary teeth erode
     - Primary teeth fall out or are pushed aside by secondary teeth
   - Three additional molars appear on each side of the upper and lower jaws
     - Third molars are called **wisdom teeth**
   - 32 total permanent teeth

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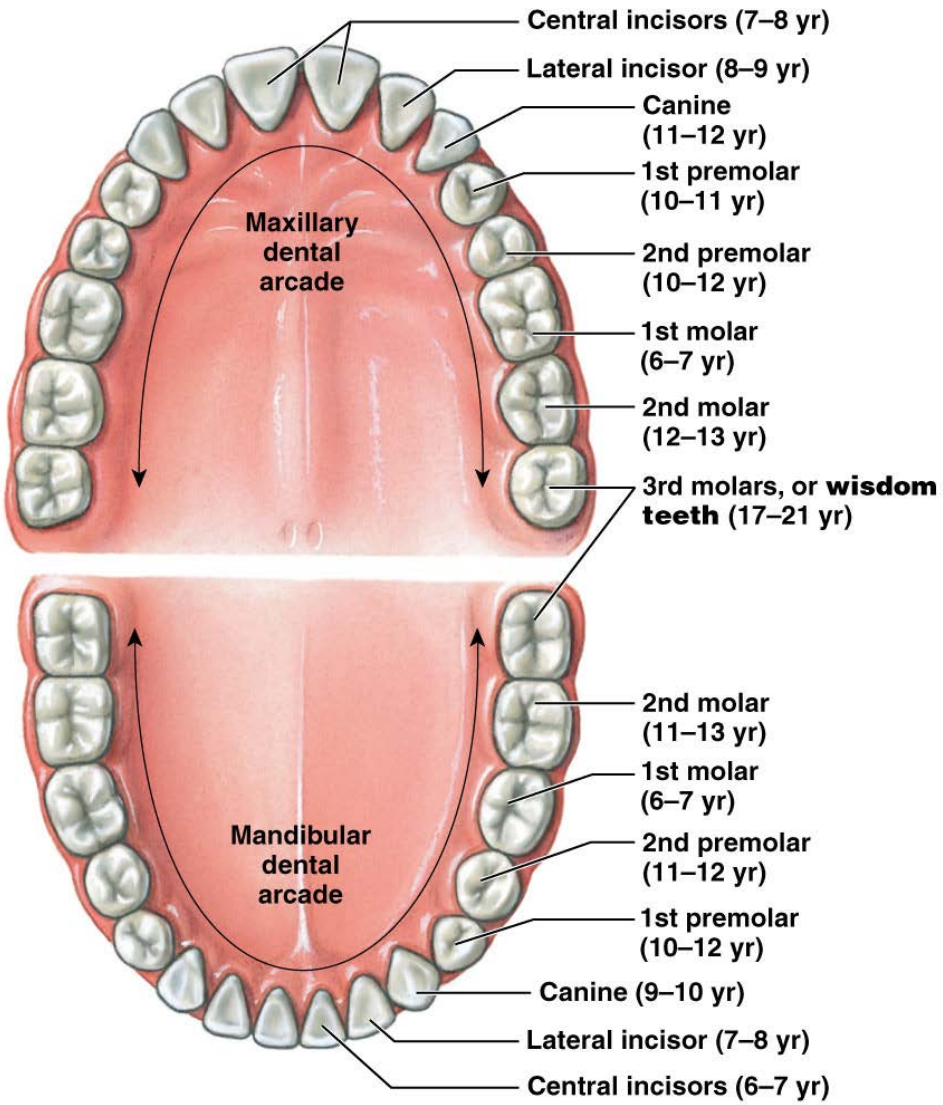
Permanent teeth



Permanent teeth, with the age at eruption given in years

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Module 22.7: Teeth

Impacted tooth

- Fails to erupt because of overcrowding from adjacent teeth or from twisting and tilting within jaw bone
- Most commonly happens with wisdom teeth
- Treatment ranges from nothing to tooth extraction

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Module 22.7: Review

A. Name the three main parts of a typical tooth.
B. What is the name sometimes given to the third set of molars?

Learning Outcome: Describe the types of teeth, and differentiate between deciduous teeth and permanent teeth.

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Module 22.8: The muscular walls of the pharynx and esophagus play a key role in swallowing

Pharynx (throat)

- Membrane-lined cavity posterior to the nose and mouth
- Continuous with the esophagus
- Common passageway for solid food, liquids, and air
- Three regions
  1. Nasopharynx
  2. Oropharynx
  3. Laryngopharynx

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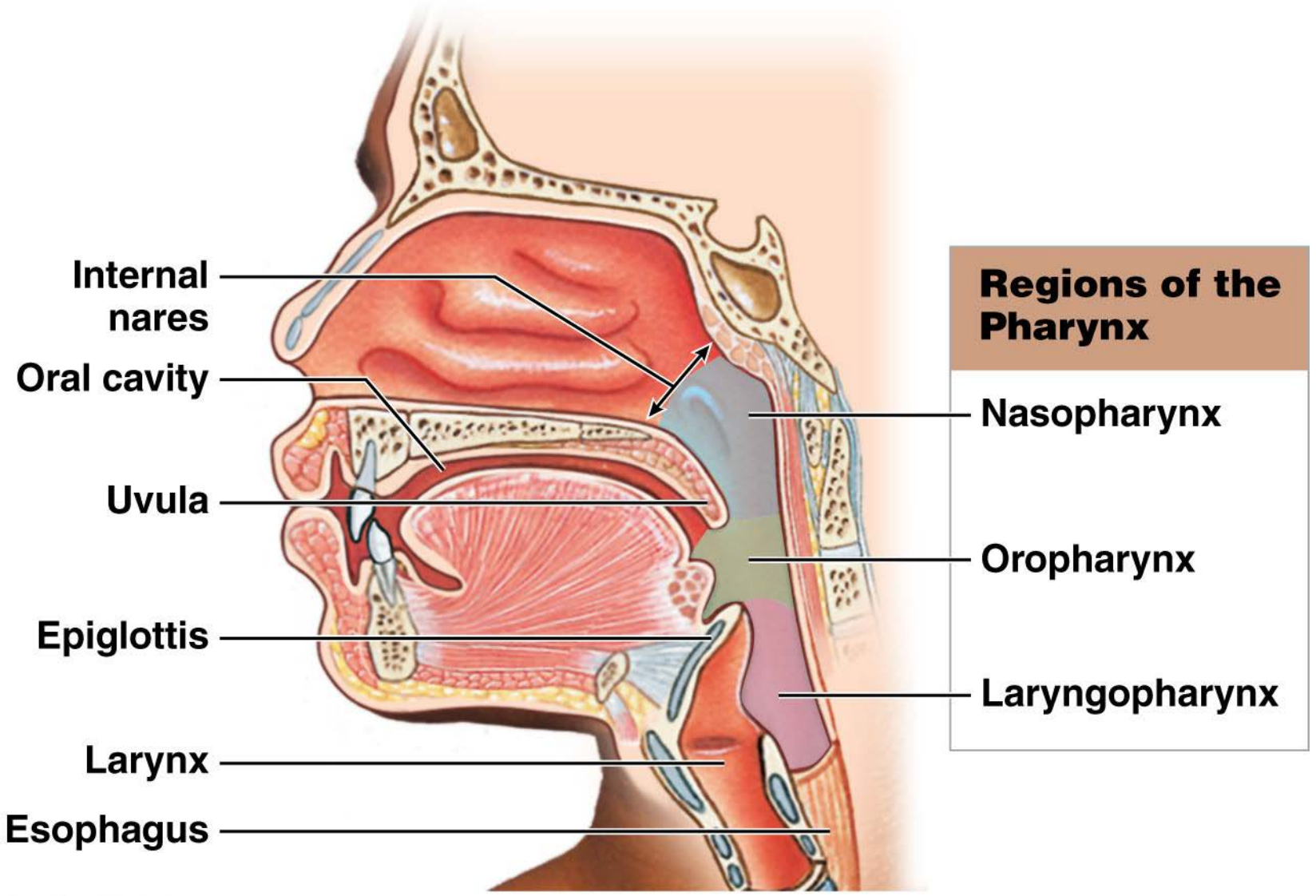
The pharynx



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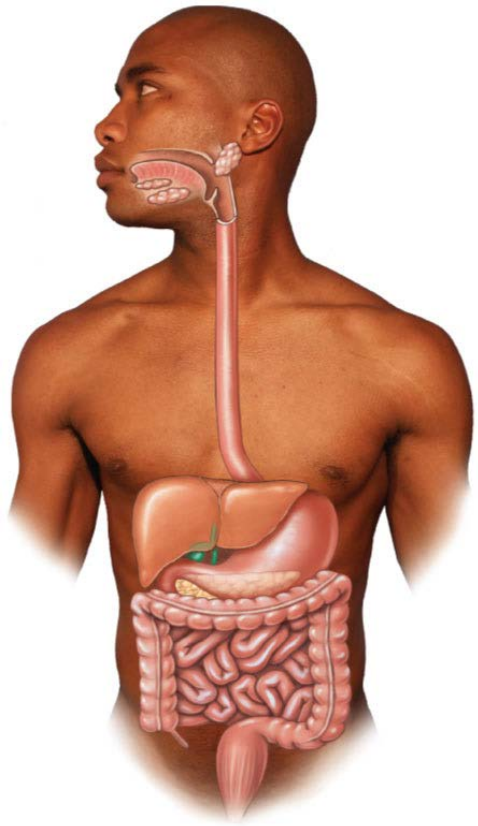
Module 22.8: The pharynx and esophagus

Esophagus

- Function
  - Actively moves food and liquids to the stomach
- Structure
  - Hollow, muscular tube ~25 cm (10 in.) long and 2 cm (0.8 in.) wide
  - Narrowest point at the beginning (posterior to cricoid cartilage)
    - Descends posterior to the trachea
    - Enters the abdominopelvic cavity through the **esophageal hiatus** (opening in the diaphragm)



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Module 22.8: The pharynx and esophagus

Esophagus (continued)

- Innervation
  - By the parasympathetic and sympathetic fibers from the esophageal plexus
  - Maintain resting muscle tone in circular muscle layer
    - Keeps the lumen closed, except when you swallow

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Module 22.8: The pharynx and esophagus

Esophagus (continued)

- Control of movement
  - **Upper esophageal sphincter**
    - Band of smooth muscle that functions as sphincter
    - Prevents air from entering the esophagus
  - **Lower esophageal sphincter** (cardiac sphincter)
    - At the inferior end of the esophagus
    - Normally contracted (prevents backflow of stomach contents)

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Module 22.8: The pharynx and esophagus

Esophagus (continued)

- Layers of the esophageal wall features
  - Mucosa (nonkeratinized stratified squamous epithelium) and submucosa form large folds extending the length of the esophagus
    - Allow for expansion with passage of a bolus
  - Muscularis externa
    - Superior third is composed of skeletal muscle
    - Middle third is a mix of skeletal and smooth muscle
    - Inferior third is composed of smooth muscle only
  - No serosa
    - **Adventitia** of connective tissue anchors esophagus to posterior body wall

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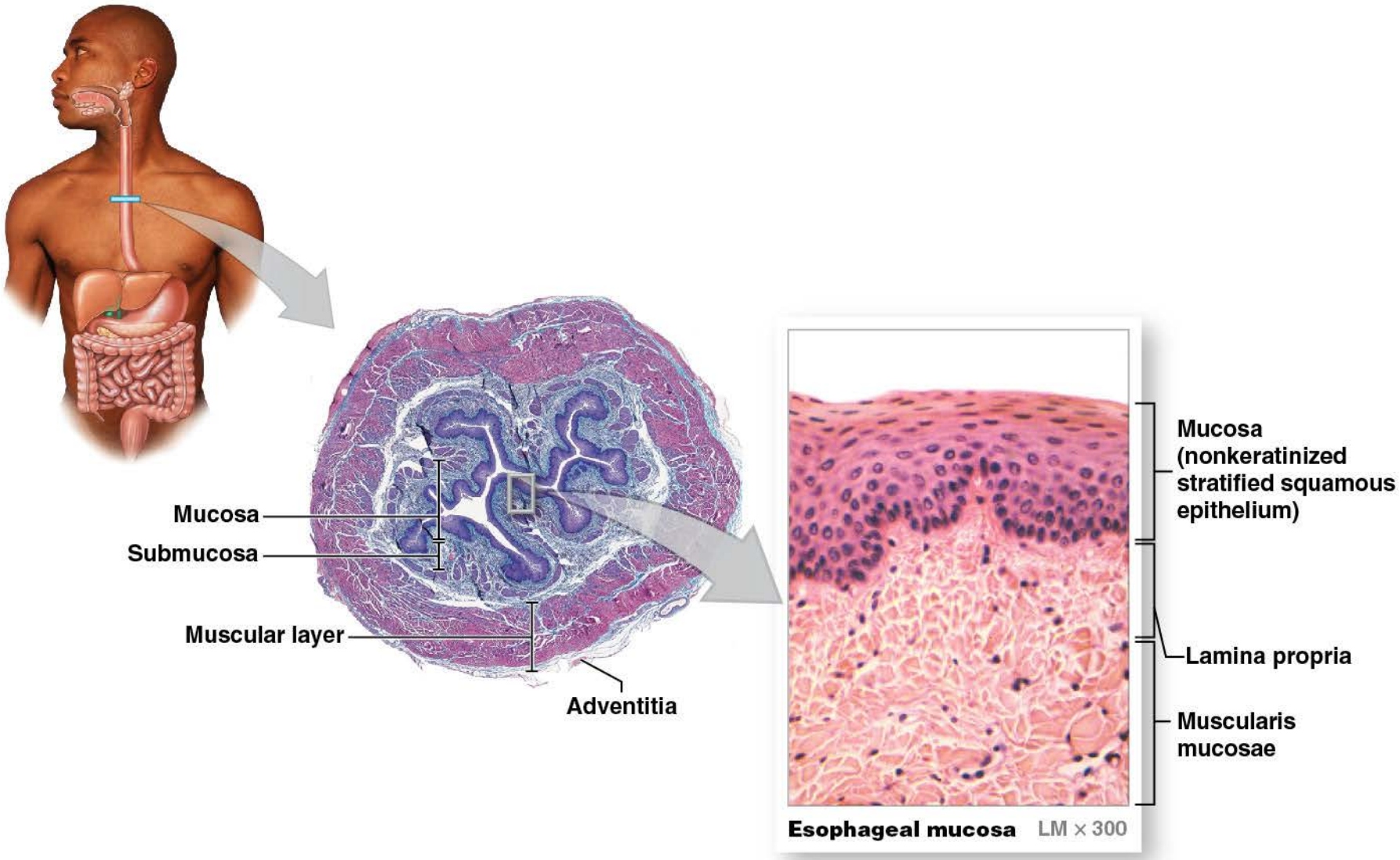
The esophagus



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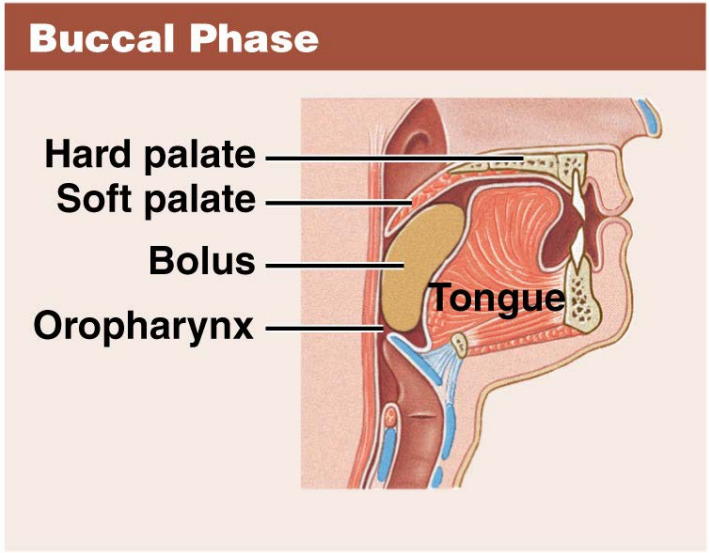
Module 22.8: The pharynx and esophagus

Swallowing, or deglutition

- Initiated voluntarily but proceeds automatically
- Three phases of swallowing
  1. **Buccal phase** (strictly voluntary)
     - Begins with compression of bolus against hard palate
     - Tongue forces bolus into the oropharynx
       - Also elevates soft palate (sealing off nasopharynx)
     - Entry into the oropharynx triggers reflex response



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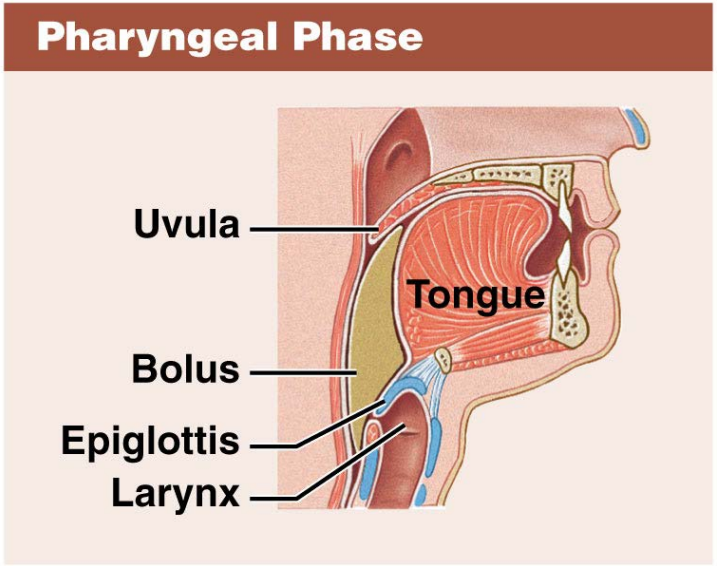
Module 22.8: The pharynx and esophagus

Three phases of swallowing (continued)

2. Pharyngeal phase



- Begins with stimulation of tactile receptors in uvula and palatine arches
- Motor commands from the swallowing center (in medulla oblongata) coordinate muscle contraction in pharyngeal muscles
  - Larynx is elevated; epiglottis is folded; uvula and soft palate are elevated
- Bolus is moved through the pharynx into the esophagus

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Module 22.8: The pharynx and esophagus

Three phases of swallowing (continued)

3. **Esophageal phase**
   - Begins as bolus is forced through the entrance to the esophagus
   - Bolus is pushed toward the stomach by peristalsis
   - Approach of bolus triggers the opening of the lower esophageal sphincter
     - Bolus enters the stomach
   - Typical travel time is 9 seconds
     - Liquids may travel faster
   - A dry (poorly lubricated) bolus may require **secondary peristaltic waves**

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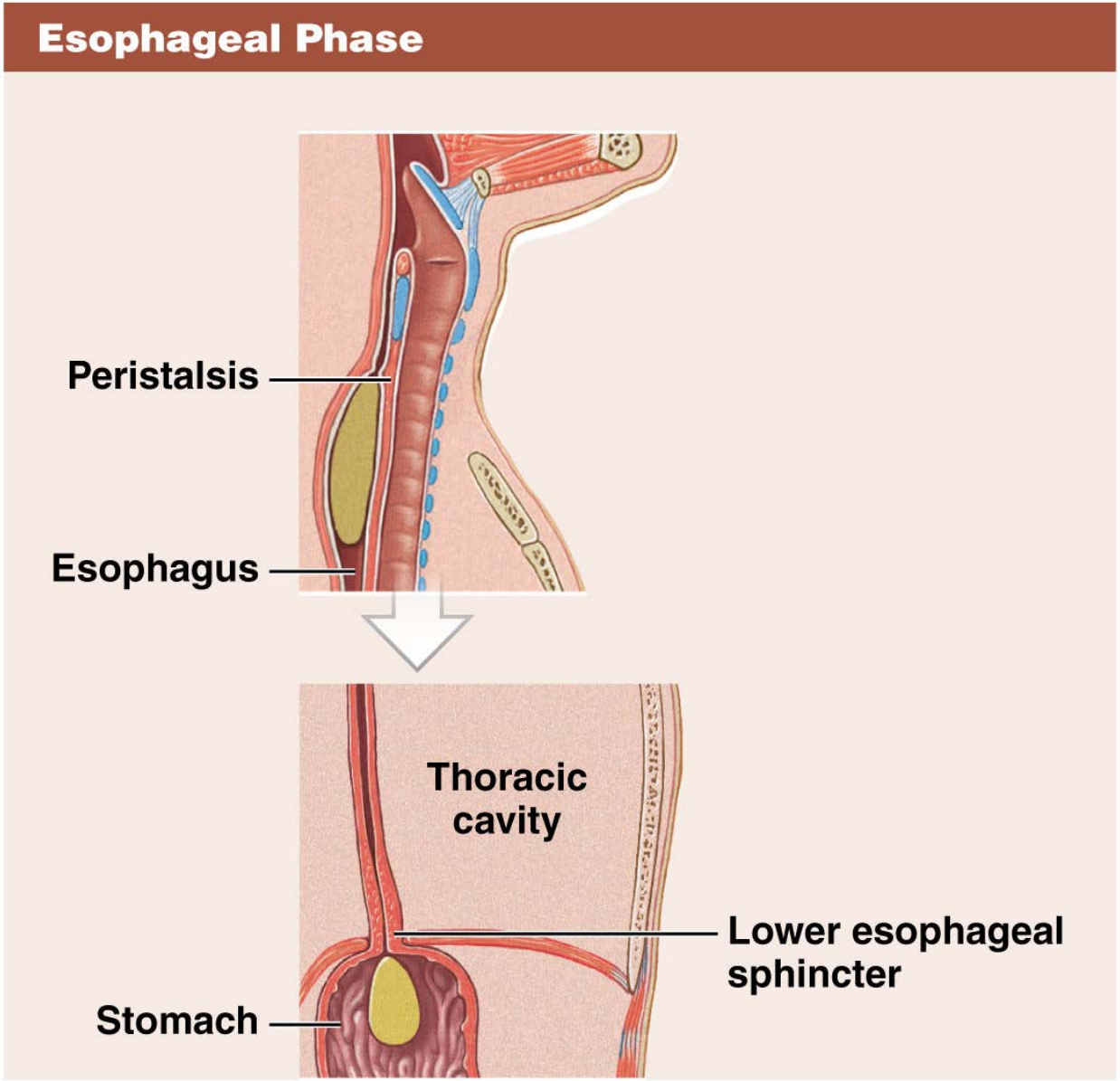
The esophageal phase



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Module 22.8: Review

A. Name the regions and functions of the pharynx.
B. Describe the muscular layer of the esophagus.
C. Describe the major event in each of the three phases of swallowing.

Learning Outcome: Describe the anatomy and functions of the pharynx and esophagus, and explain the swallowing process.

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Module 22.9: The stomach and most of the intestinal tract are suspended by mesenteries and covered by the peritoneum

Peritoneal cavity

- Encloses stomach and most of intestine
- Lined by a serous membrane called the peritoneum
  - Serous membrane divided into:
    - Serosa, or **visceral peritoneum**
      - Covers organs enclosed by the peritoneal cavity
    - **Parietal peritoneum**
      - Lines the inner surface of the peritoneal cavity

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Module 22.9: Mesenteries

Peritoneal cavity (continued)

- Serous membrane
  - Continuously secretes peritoneal fluid into peritoneal cavity
  - ~7 liters/day secreted and reabsorbed
  - Volume at any one time is about 50 mL
    - Thin layer separates parietal and visceral surfaces
    - Allows sliding movements without friction or irritation
  - Rate of fluid moving into the cavity is accelerated by liver disease, kidney disease, and heart failure
    - Accumulation of peritoneal fluid can create abdominal swelling (**ascites**)

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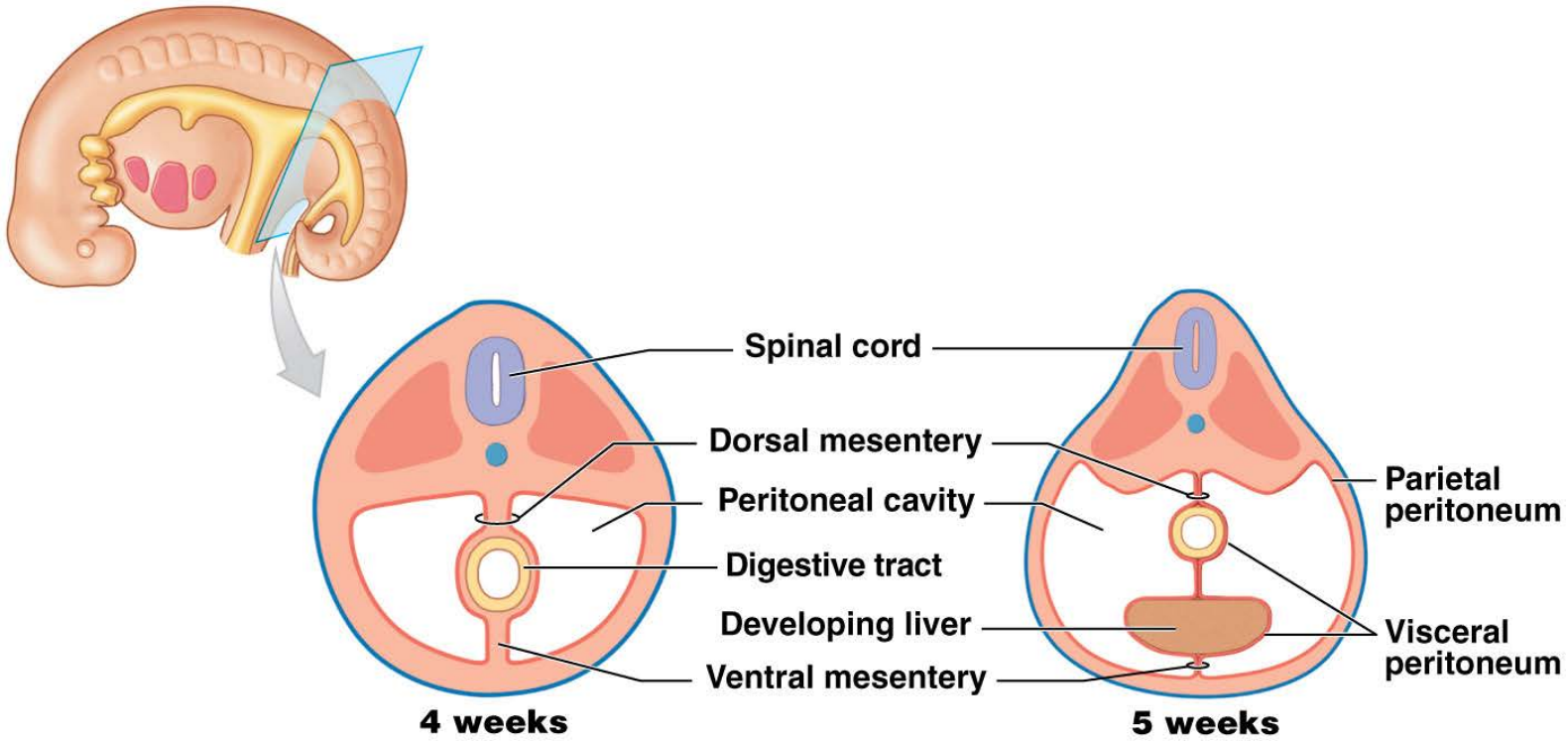
Module 22.9: Mesenteries

Dorsal and ventral mesenteries

- Formed during embryonic development
- Suspend the digestive tract and accessory organs
- Develop into other adult connections



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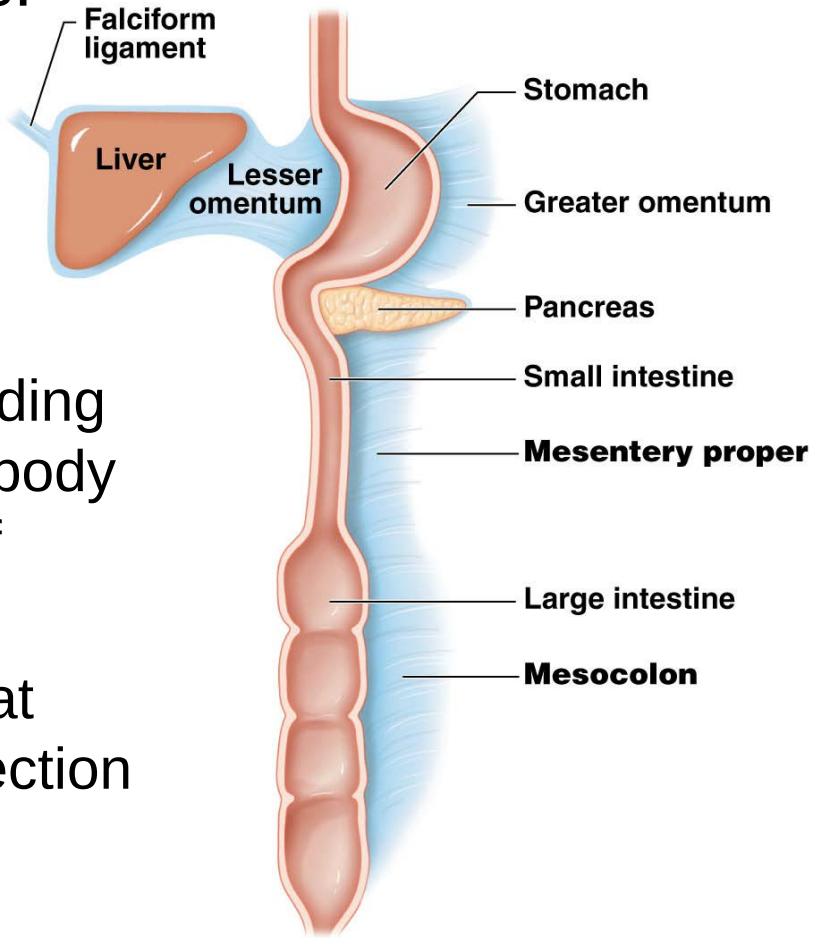
Module 22.9: Mesenteries

Dorsal and ventral mesenteries (continued)

- **Dorsal mesentery** becomes:
  - **Greater omentum** (*omentum*, fat)
    - Attached to stomach and transverse colon
    - Forms a large pouch extending inferiorly between anterior body wall and anterior surface of the small intestine
    - Contains adipose tissue that provides padding and protection



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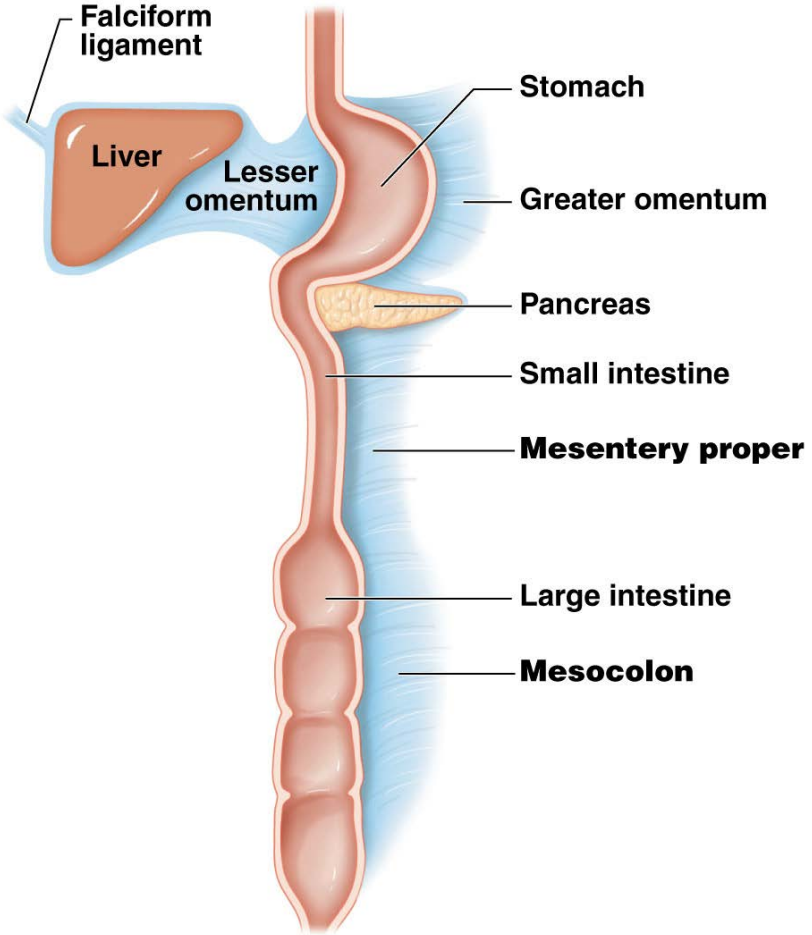
Module 22.9: Mesenteries

Dorsal and ventral mesenteries (continued)

- **Mesentery proper**
  - Connects small intestine to posterior body wall
- **Mesocolon**
  - Connects large intestine to posterior body wall



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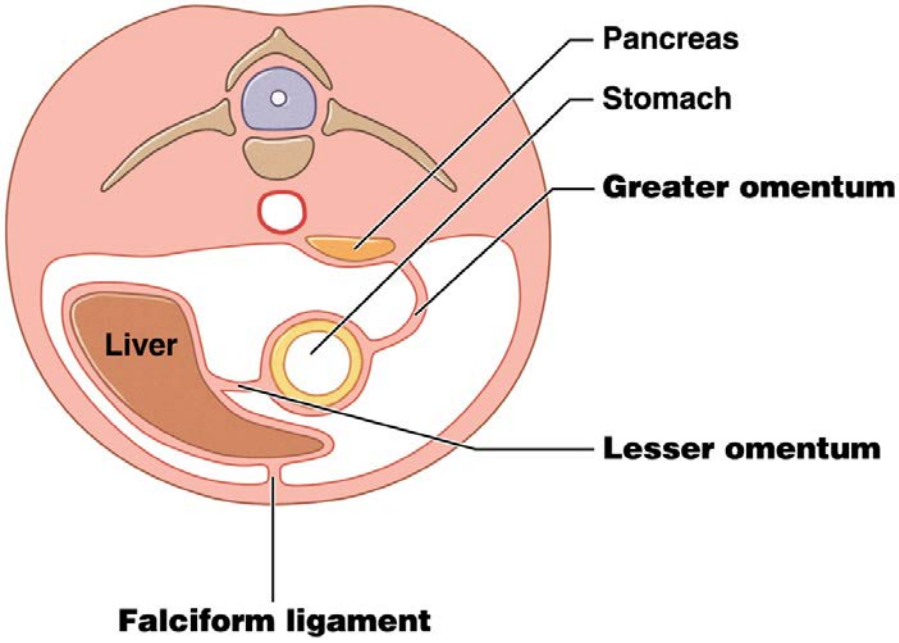
Module 22.9: Mesenteries

Dorsal and ventral mesenteries (continued)

- **Ventral mesentery** becomes:
  - **Lesser omentum**
    - Connects the stomach to the liver
    - Provides an access route for blood vessels and other structures entering/leaving the liver
  - **Falciform ligament**
    - Connects the liver to the anterior body wall



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Module 22.9: Mesenteries

Changing position of the mesenteries

- With elongation of the digestive tract, position of the mesenteries changes
  - Some segments of the tract become fixed in position
  - Segments of the mesentery proper come into contact and fuse together
  - Much of the mesocolon fuses to the dorsal body wall

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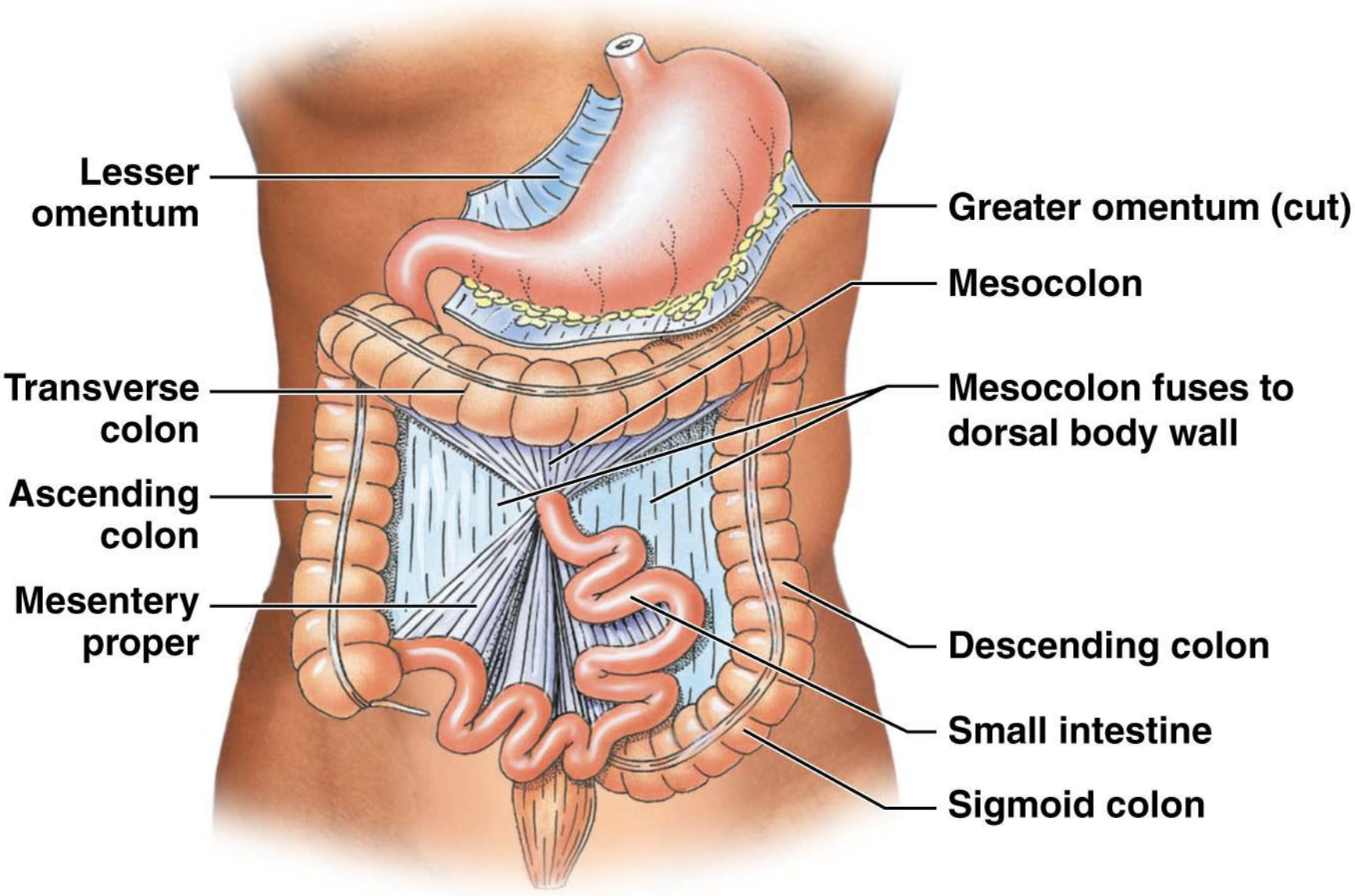
Mesenteries



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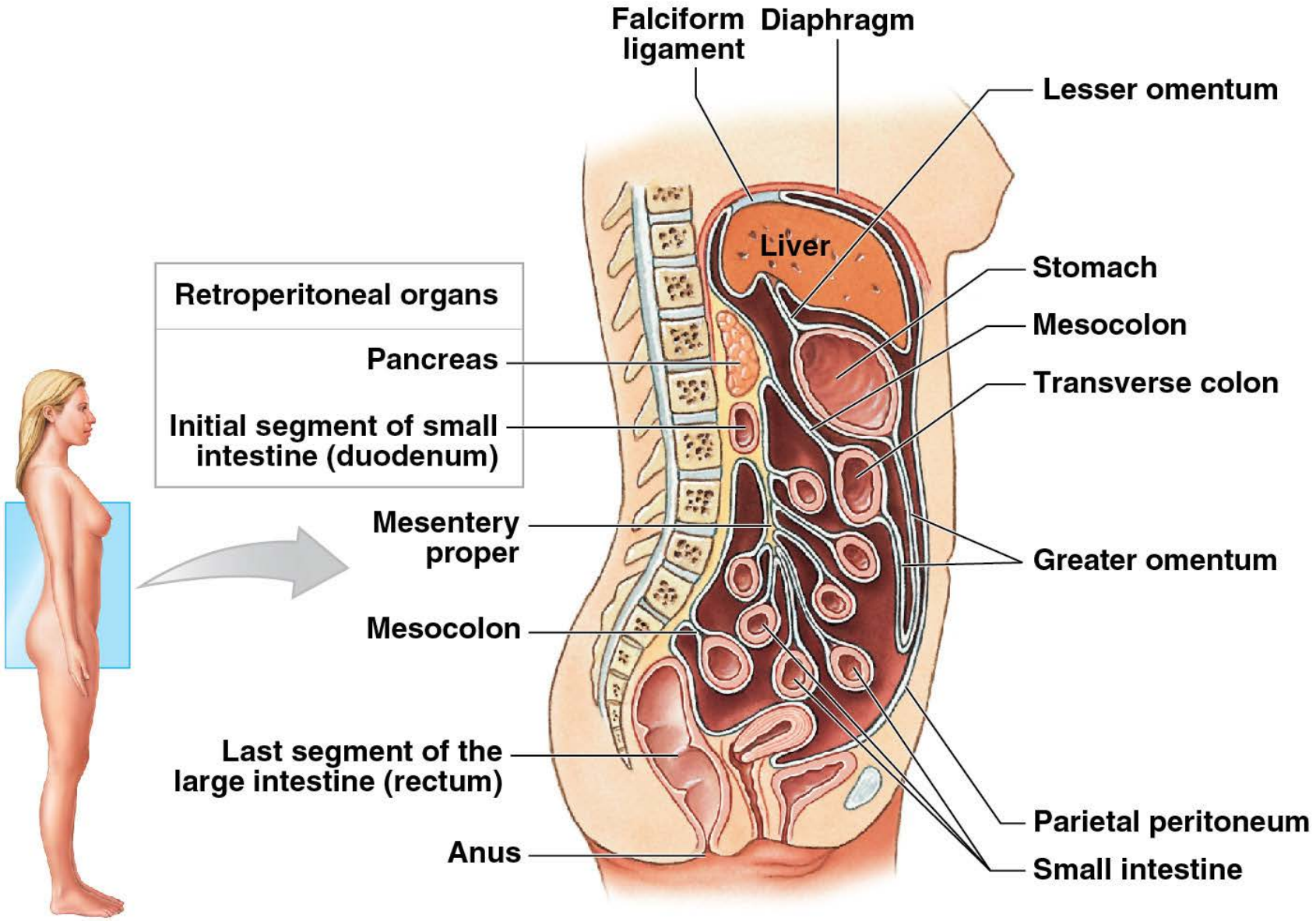
Orientation of the mesenteries



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Module 22.9: Review

A. What is the falciform ligament?
B. What is the function of the lesser omentum?
C. Explain the significance of peritoneal fluid.

Learning Outcome: Explain the embryonic development of the mesenteries, and describe the mesenteries that remain in adulthood.

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Module 22.10: The stomach is a muscular, expandable, J-shaped organ with three layers in the muscular layer

Stomach

- Highly variable shape depending on contents
  - Empty: muscular tube with constricted lumen
  - Full: can expand to contain 1–1.5 liters of material (**chyme**)
    - Viscous, highly acidic, soupy mixture formed from the combination of food, saliva, and gastric gland secretions

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Module 22.10: The stomach

Stomach (continued)

- Lesser curvature forms the medial surface
  - Attached to the mesentery of the lesser omentum
- Greater curvature forms the lateral and inferior surfaces
  - Attached to the mesentery of the greater omentum

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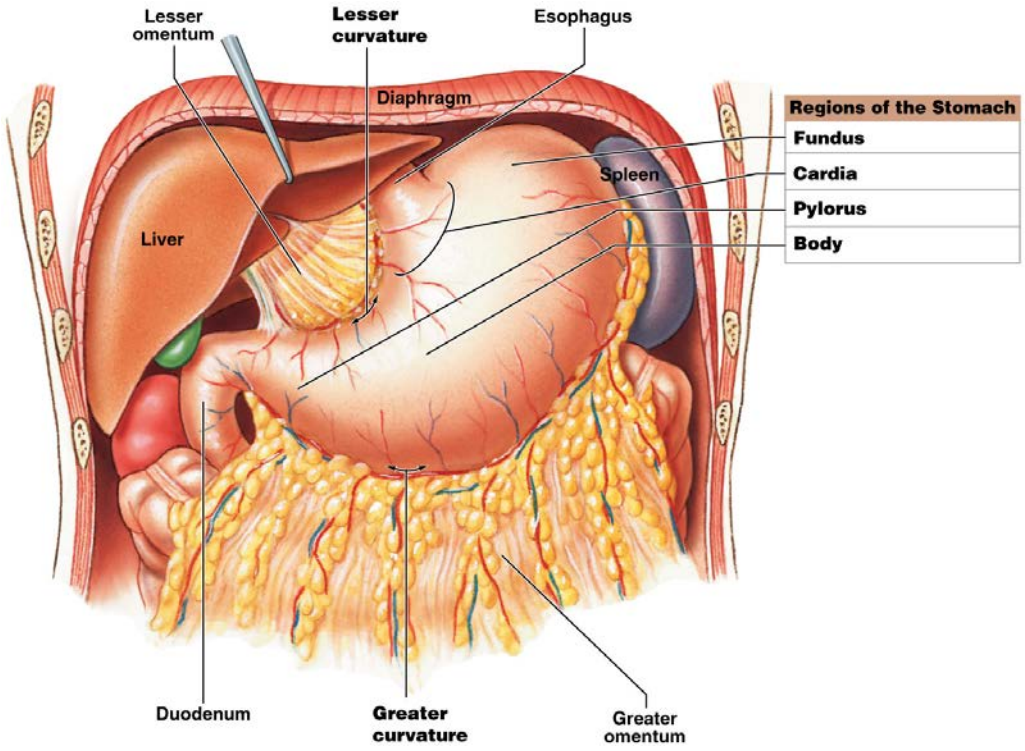
Module 22.10: The stomach

Stomach regions

1. **Fundus**
   - Superior to the junction between the stomach and esophagus



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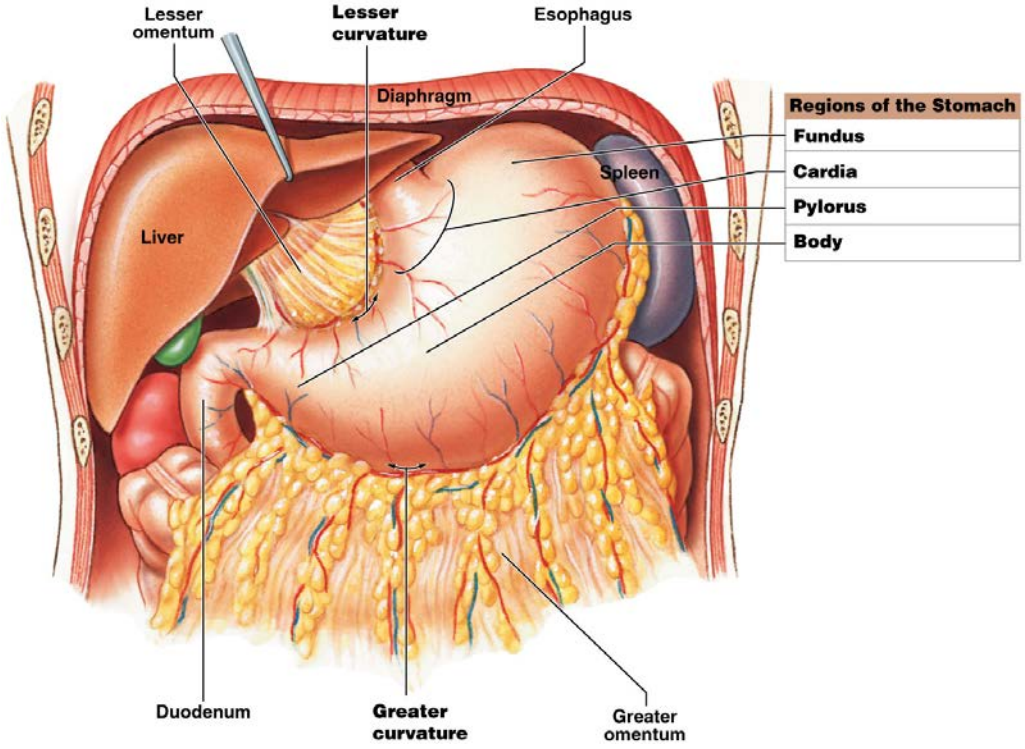
Module 22.10: The stomach

Stomach regions (continued)

2. **Cardia**
   - Superior, medial portion within 3 cm of gastroesophageal junction
   - Secretes mucus to protect esophagus from stomach acid/enzymes



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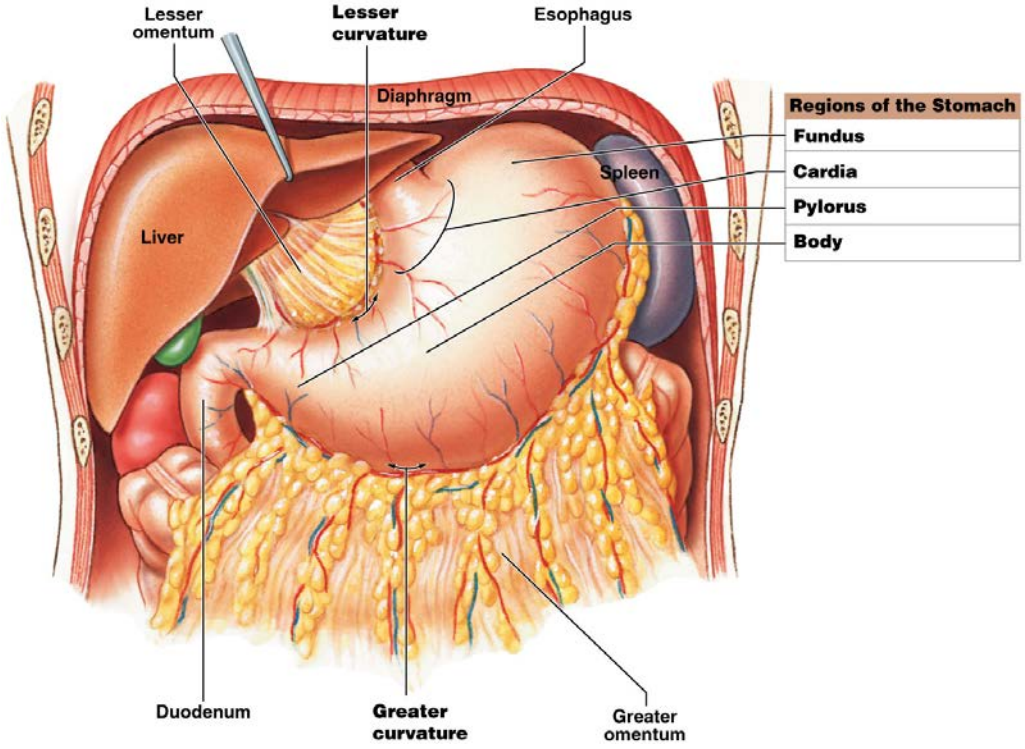
Module 22.10: The stomach

Stomach regions (continued)

3. **Body**
   - Largest region
   - Between the fundus and pylorus
   - Functions as a mixing bowl



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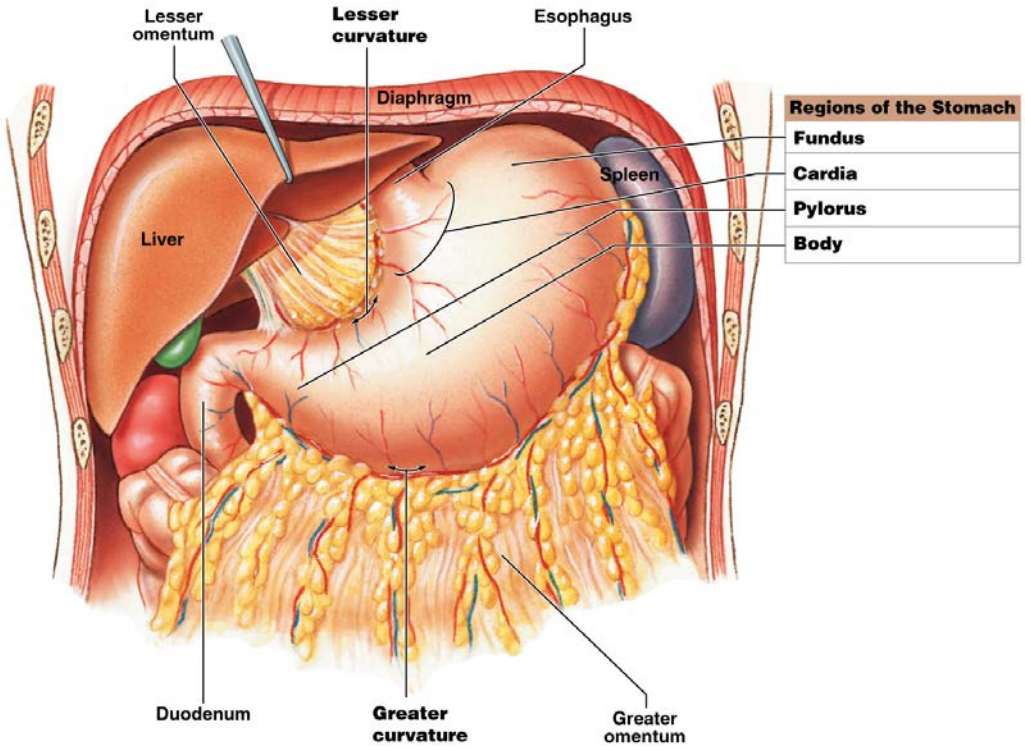
Module 22.10: The stomach

Stomach regions (continued)

4. **Pylorus**
   - Sharp curve of “J” of the stomach
   - Frequently changes shape with mixing movements



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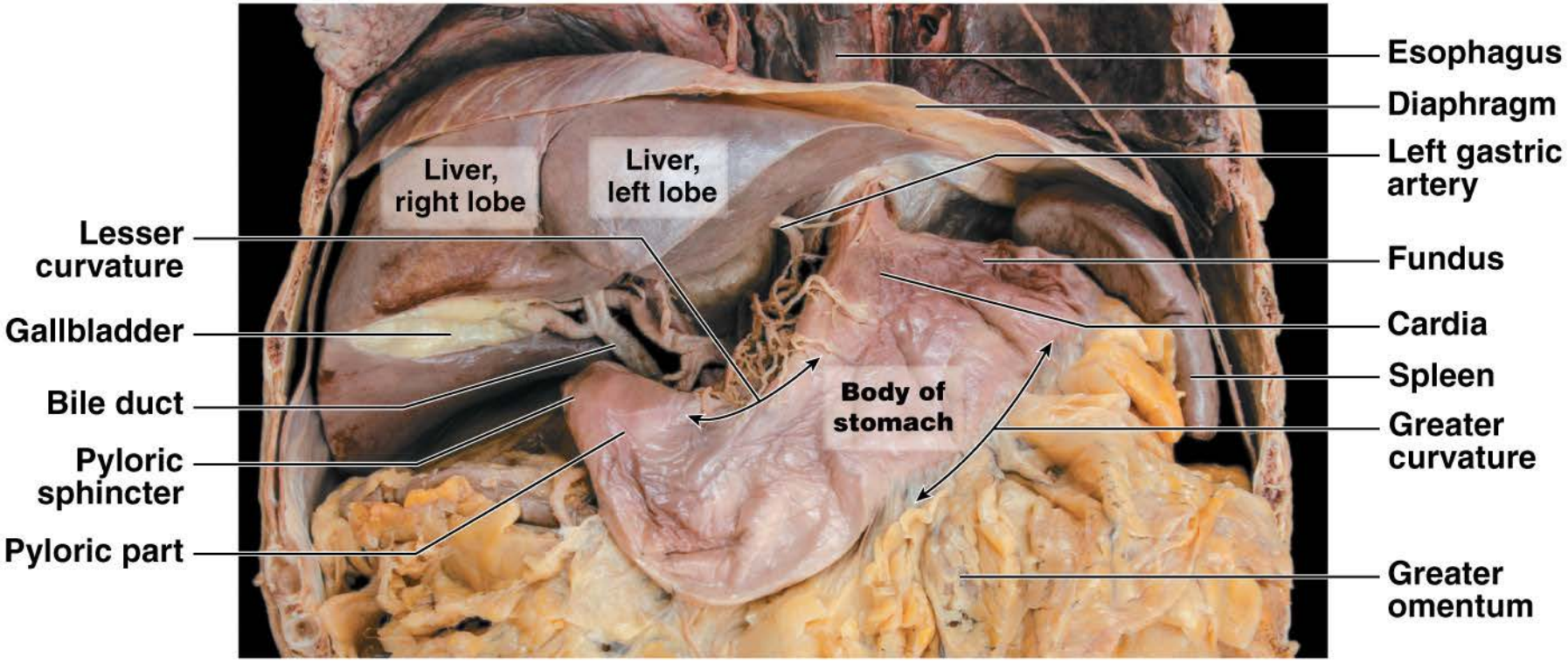
Cadaver dissection with stomach



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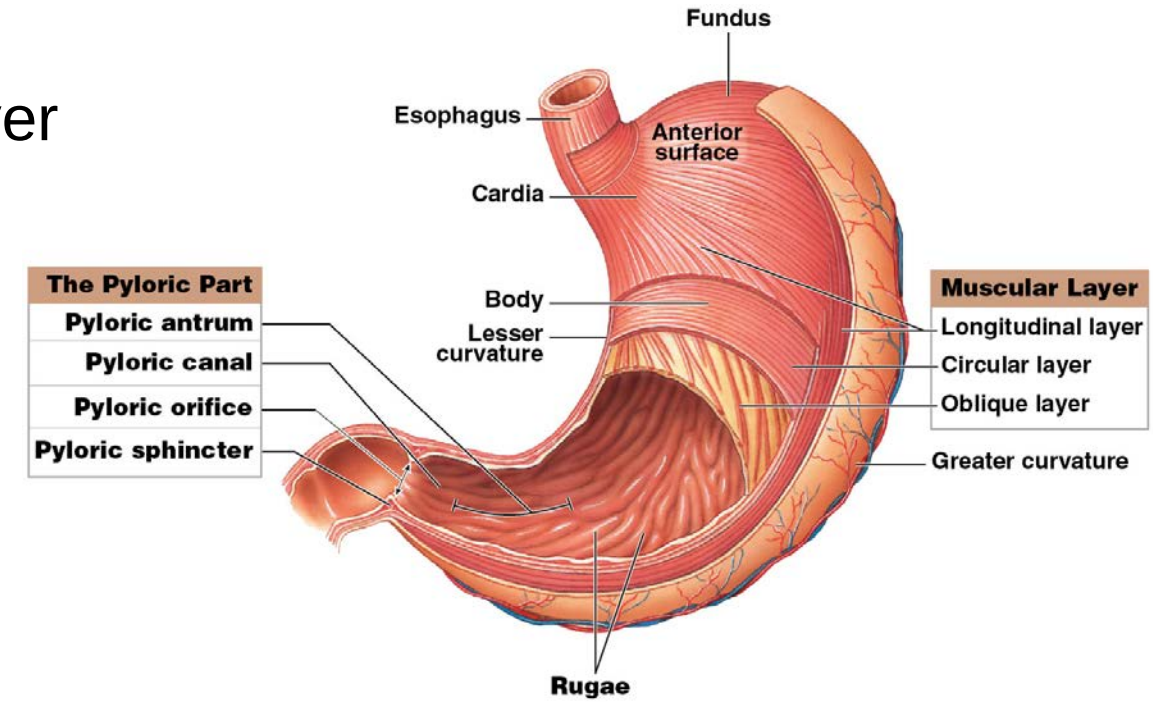
Module 22.10: The stomach

Muscle layers and rugae

- **Layers of the muscularis externa**
  - Oblique layer
    - Strengthens the stomach wall
    - Assists in mixing and churning to form chyme
  - Circular layer
  - Longitudinal layer



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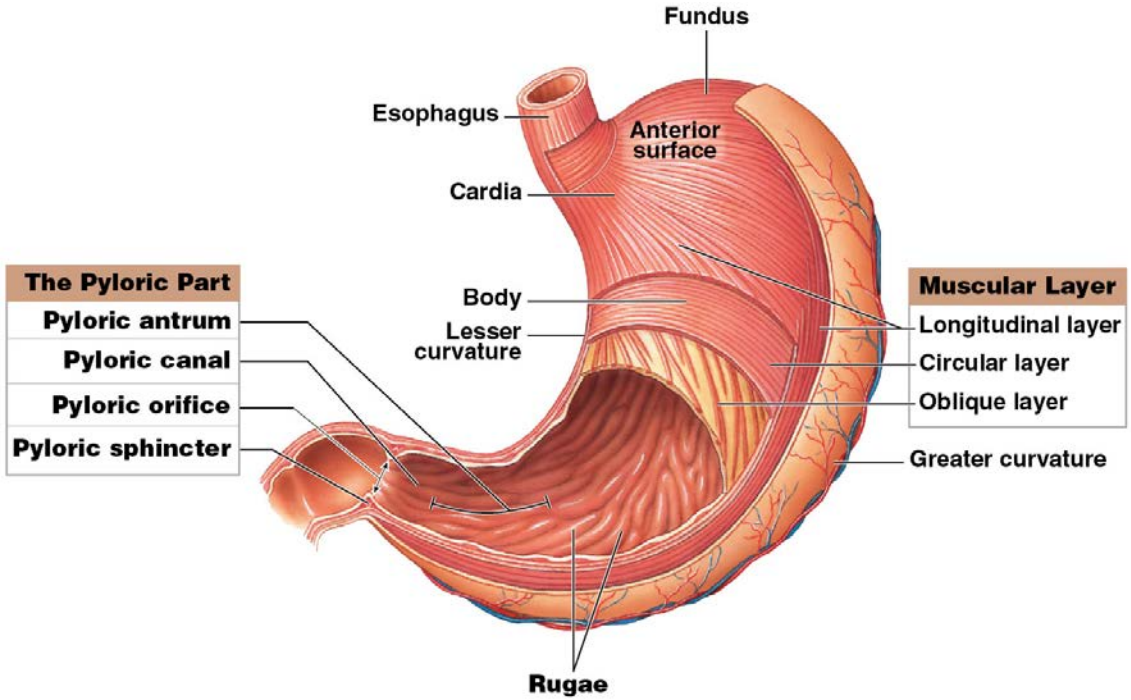
Module 22.10: The stomach

Muscle layers and rugae (continued)

- **Rugae** (**wrinkles**)
  - Prominent, temporary mucosal folds
  - Allow gastric expansion by flattening out with stomach expansion



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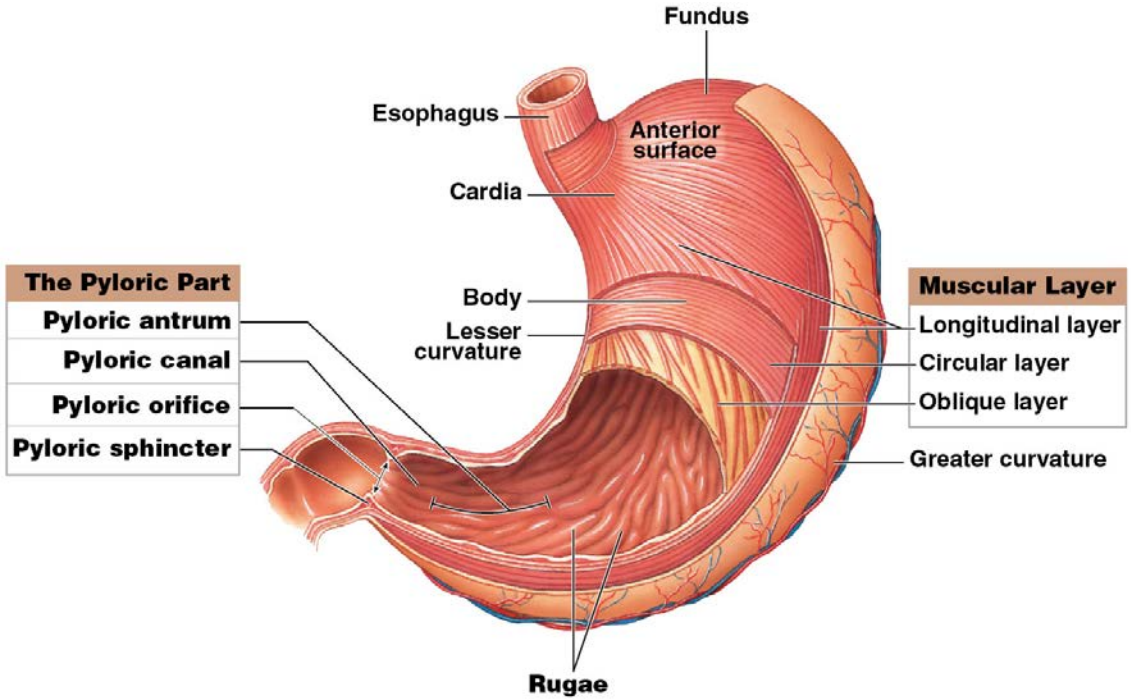
Module 22.10: The stomach

The pyloric part

- **Pyloric antrum** (*antron*, cavity)
  - Portion connected to stomach body
- **Pyloric canal**
  - Empties into the *duodenum* (proximal segment of small intestine)



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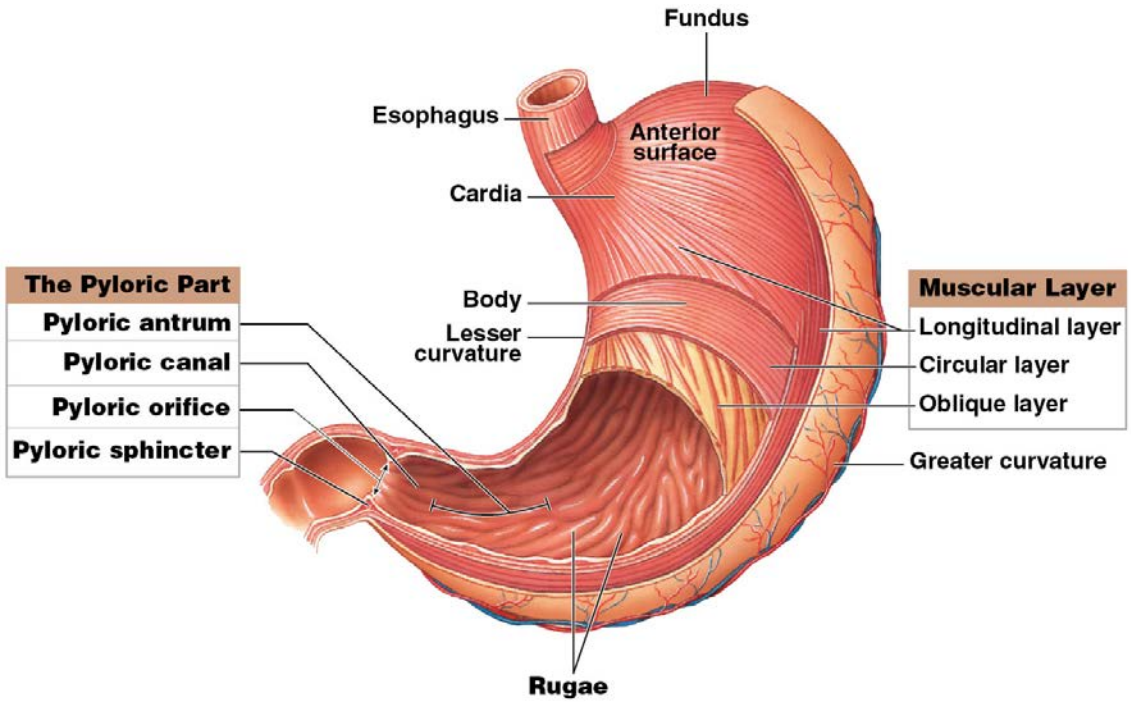
Module 22.10: The stomach

The pyloric part (continued)

- **Pyloric sphincter**
  - Smooth muscle band regulating release of **chyme** into the duodenum
- **Pyloric orifice**
  - Stomach outlet



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Module 22.10: Review

A. Name the four major regions of the stomach in order from its junction with the esophagus to the small intestine.
B. What anatomical feature of the stomach allows the organ to form chyme?
C. Describe the lining of the stomach.

Learning Outcome: Describe the anatomy of the stomach and its histological features.

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Module 22.11: The stomach receives food and liquids from the esophagus and aids in mechanical and chemical digestion

Functions of the stomach

1. Temporary storage of ingested food
2. Mechanical digestion of ingested food
3. Chemical digestion of food through the action of acid and enzymes
4. Production of intrinsic factor

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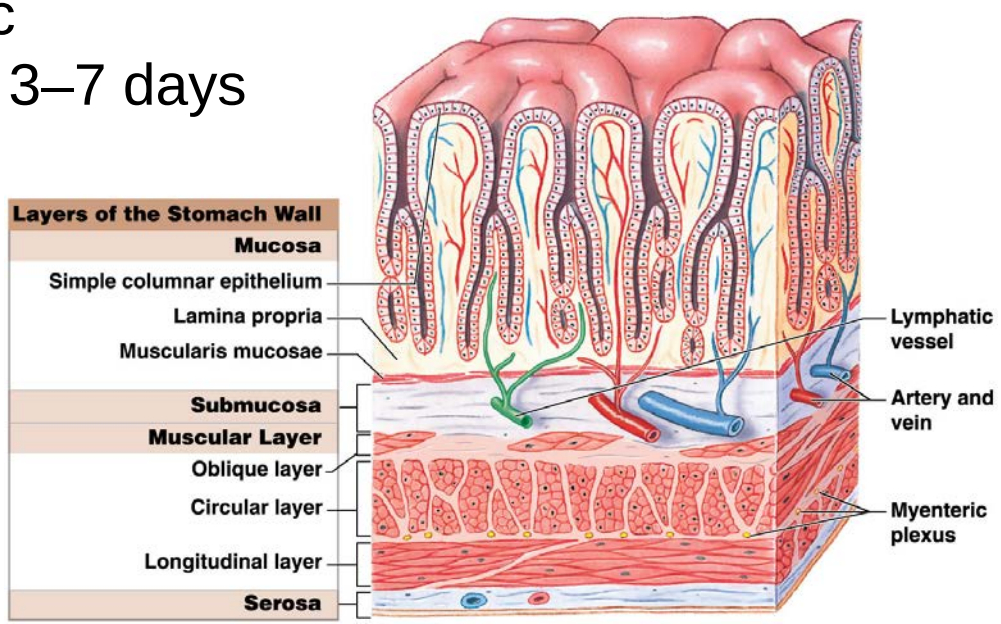
Module 22.11: The stomach wall and functions

Layers of the stomach wall

- **Mucosa**
  - Composed of simple columnar epithelium
    - Produces layer of alkaline mucus
      - Protects epithelial cells against acid and enzymes in gastric lumen
    - Life span of a gastric epithelial cell is only 3–7 days



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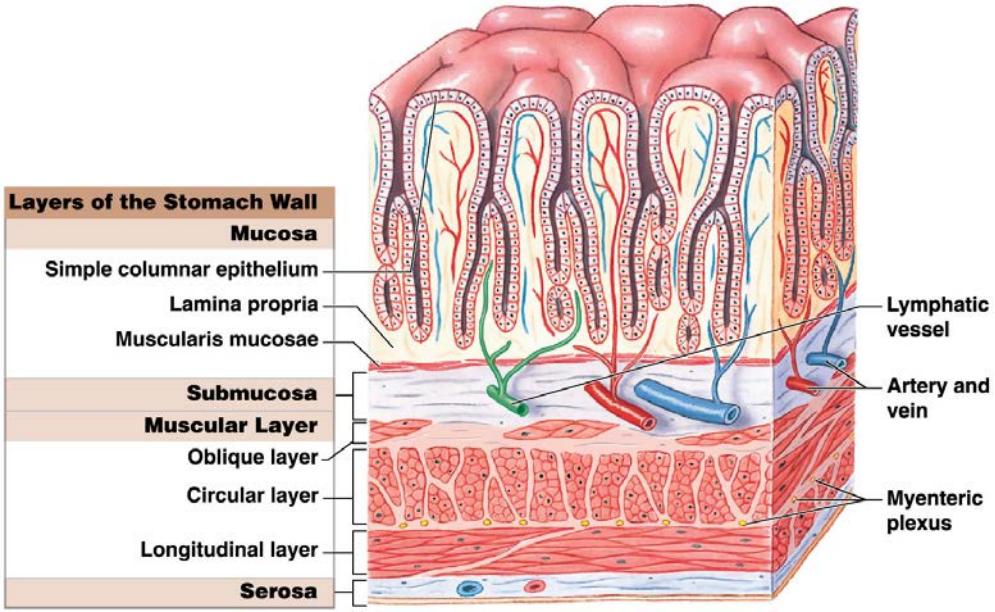
Module 22.11: The stomach wall and functions

Layers of the stomach wall (continued)

- **Submucosa**
- **Muscular layer**
  - Oblique, circular, and longitudinal layers
- **Serosa**



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Module 22.11: The stomach wall and functions

Gastric glands

- Glands in the fundus and body
  - Secrete most of the acid and enzymes enabling gastric digestion
  - Dominated by **parietal cells** and **chief cells**
  - Secrete ~1.5 L of gastric juice each day
- Glands in the pylorus
  - Secrete mucus and hormones that coordinate and control digestive activity

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Module 22.11: The stomach wall and functions

Gastric pits

- Shallow depressions opening onto the gastric surface
- Active stem cells at the base of each pit replace superficial cells shed into the chyme
- Each pit communicates with several gastric glands

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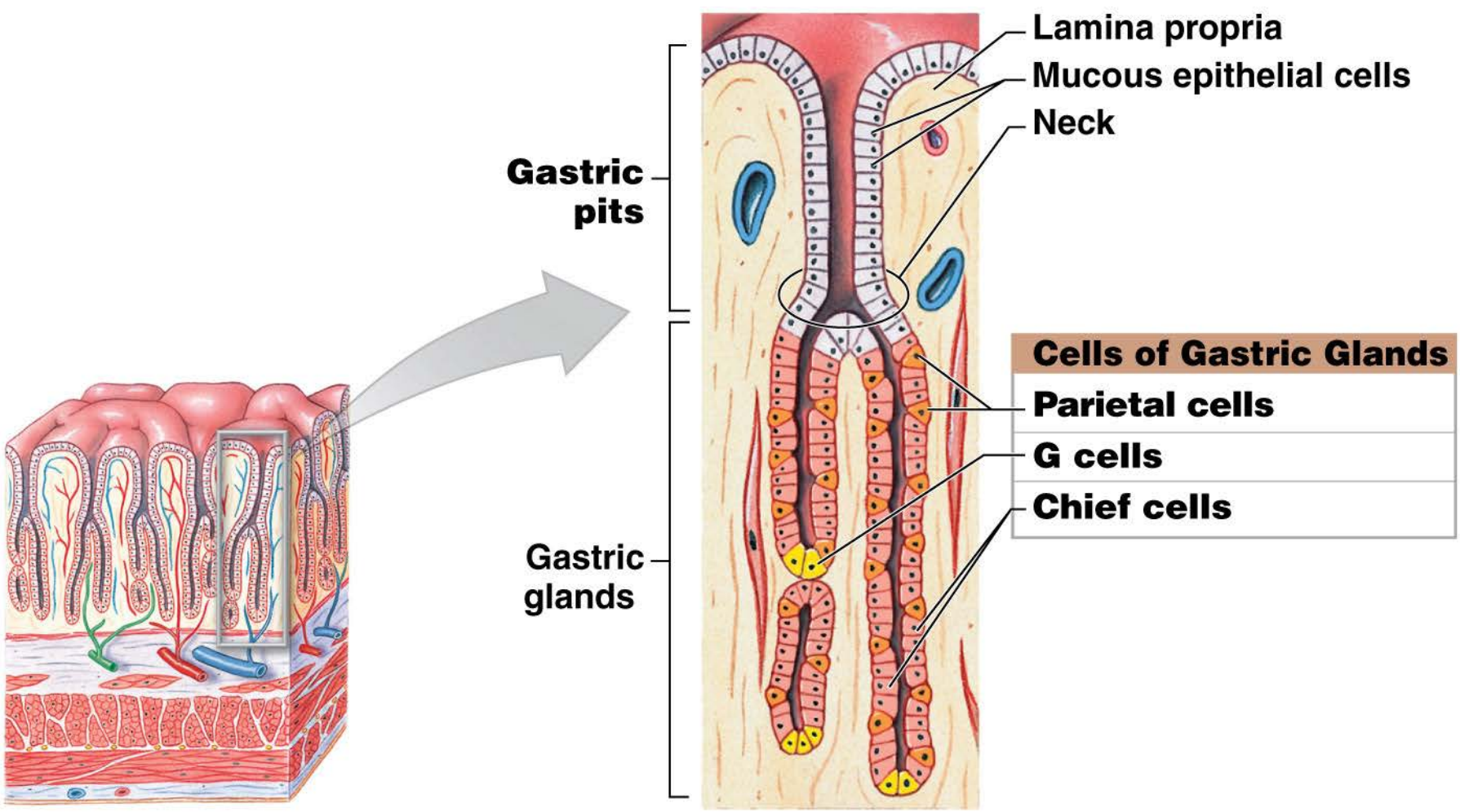
Gastric pits and glands



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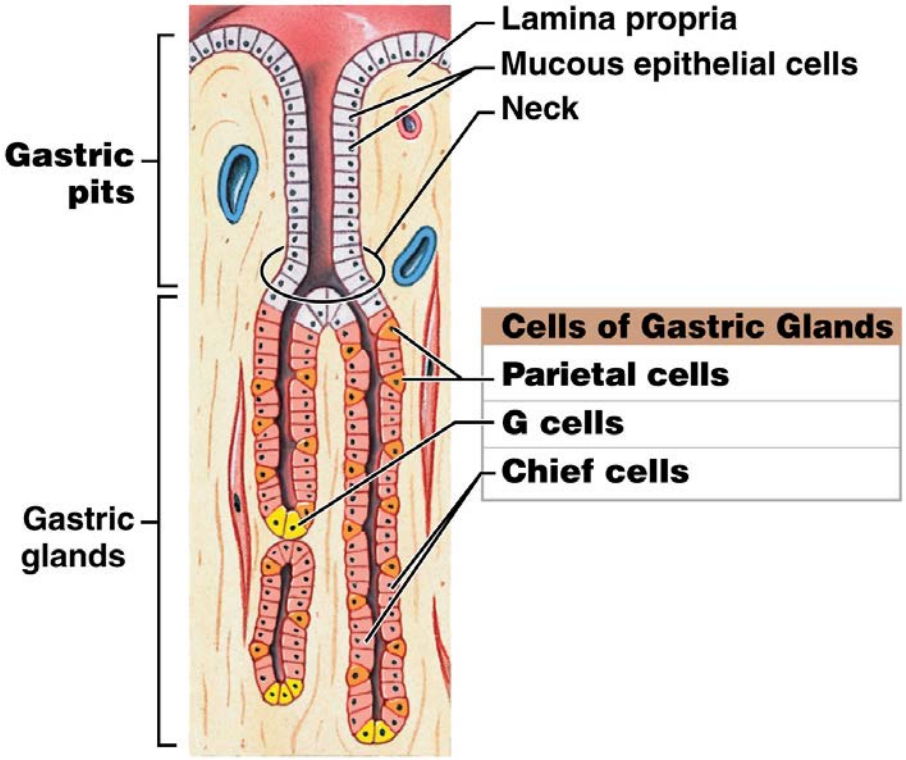
Module 22.11: The stomach wall and functions

Cells of gastric glands

- **Parietal cells** secrete:
  - **Intrinsic factor**
    - Glycoprotein that aids in vitamin B_{12} absorption
  - Hydrochloric acid (HCl)
    - Activates pepsinogen
    - Keeps stomach at pH 1.5–2



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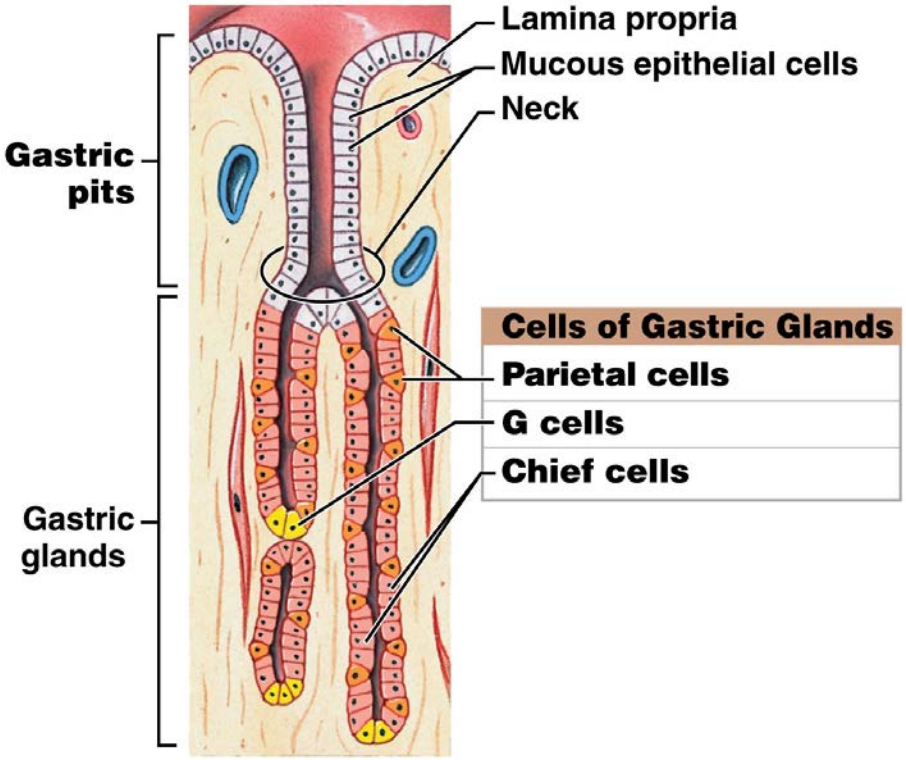
Module 22.11: The stomach wall and functions

Cells of gastric glands (continued)

- **G cells** (enteroendocrine cells)
  - Produce variety of hormones



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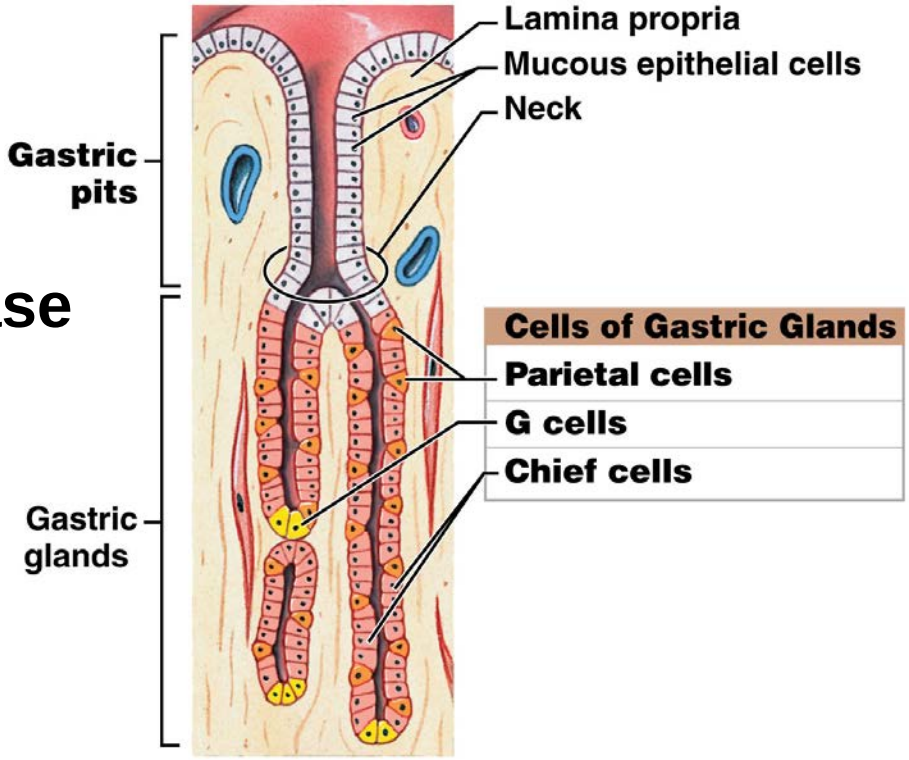
Module 22.11: The stomach wall and functions

Cells of gastric glands (continued)

- **Chief cells** secrete:
  - **Pepsinogen**
    - Activated by HCl to become **pepsin**
      - Active proteolytic (protein-digesting) enzyme
  - Newborns also produce **rennin** and **gastric lipase**
    - Enzymes important for the digestion of milk



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Module 22.11: The stomach wall and functions

HCl production

- Parietal cells do not create HCl in their cytoplasm (it would destroy the cell)
  - H^+ and Cl^- are transported and secreted separately
  - H^+ is generated as carbonic anhydrase converts CO_2 and H_2O to carbonic acid
    - Carbonic acid dissociates into bicarbonate ions and hydrogen ions
    - $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow HCO_3^- + H^+$

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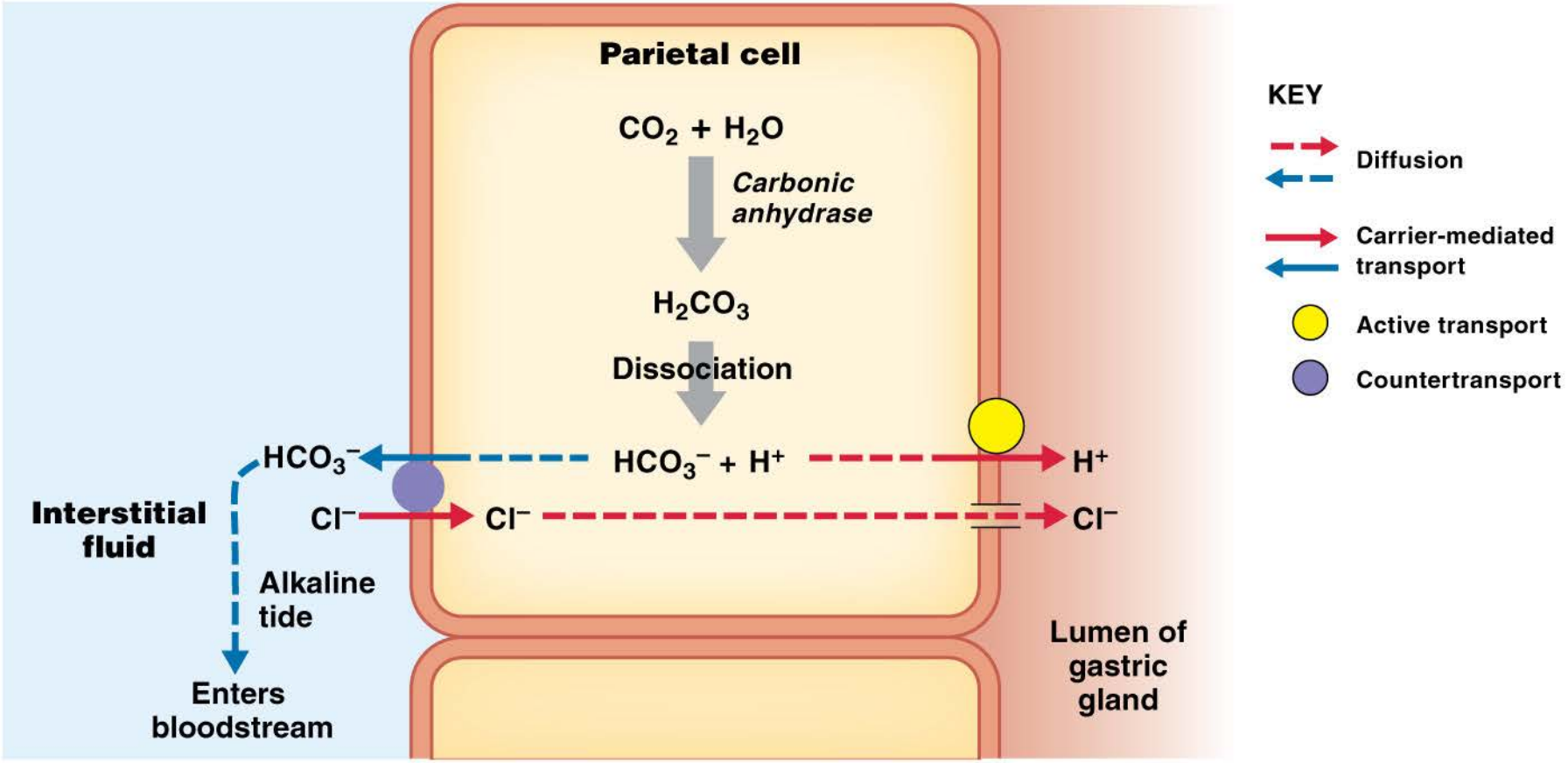
HCl production



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Module 22.11: The stomach wall and functions

HCl production (continued)

- Bicarbonate ejected into the interstitial fluid in exchange for a chloride ion
  - From the interstitial fluid, bicarbonate enters the bloodstream
    - If gastric glands very active, amount of bicarbonate released is enough to increase the pH of the blood
    - Sudden influx of bicarbonate ions is called the **alkaline tide**
- Chloride ions diffuse across cell and exit into the lumen of the gastric gland
- Hydrogen ions are also actively transported into the gastric gland lumen

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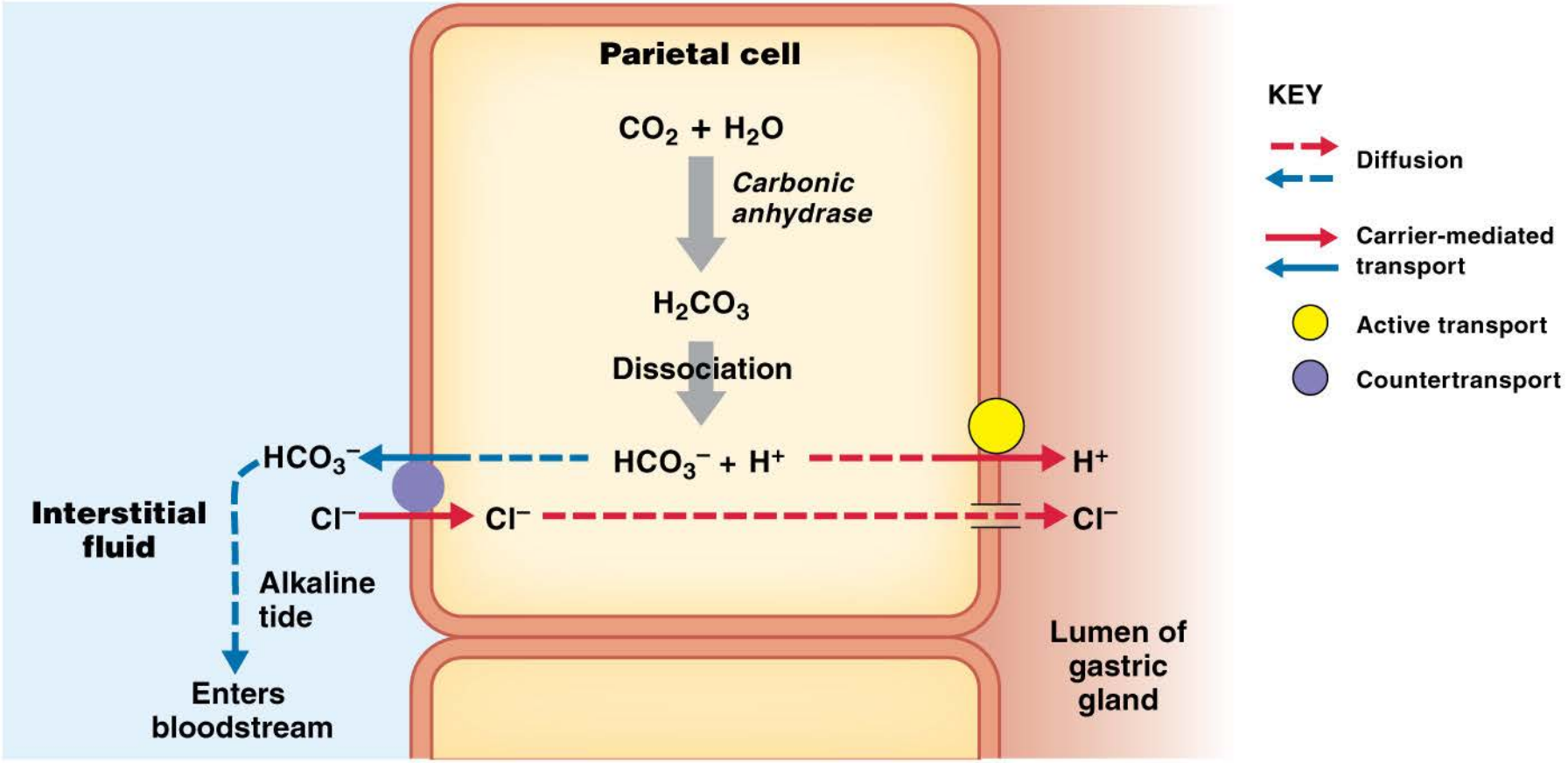
HCl production



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Module 22.11: Review

A. Explain the significance of the alkaline mucous layer lining the interior surface of the stomach.
B. What is the function of parietal cells?
C. Describe the alkaline tide.

Learning Outcome: Describe the anatomy of the stomach relating to its role in digestion and absorption.

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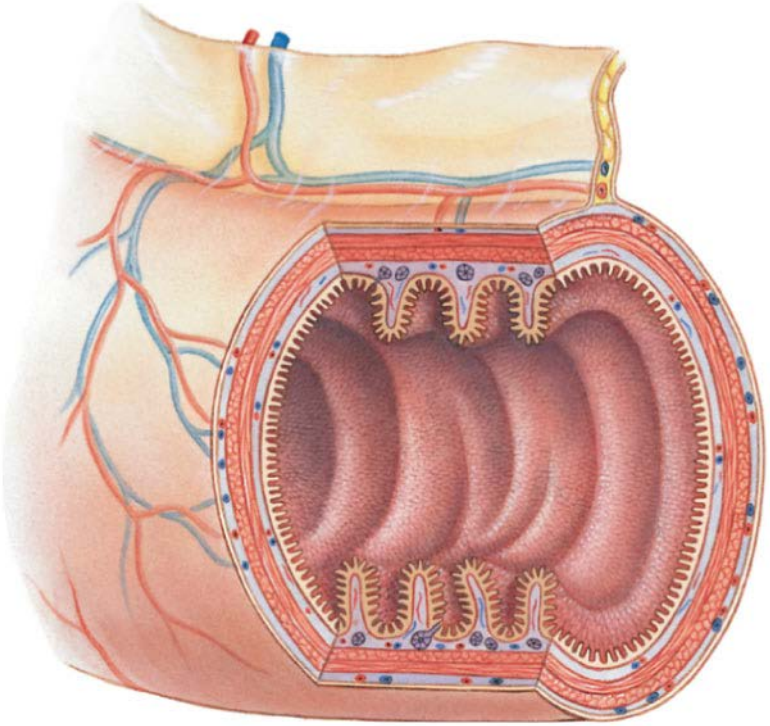
Module 22.12: The intestinal tract is specialized to absorb nutrients

Specialized structures

- Many intestinal structures add surface area to increase absorption
  - **Circular folds** (*plicae circulares*)
    - Series of transverse folds along the intestinal lining
    - Permanent features
    - Roughly 800 folds in the small intestine
    - Mostly in the jejunum



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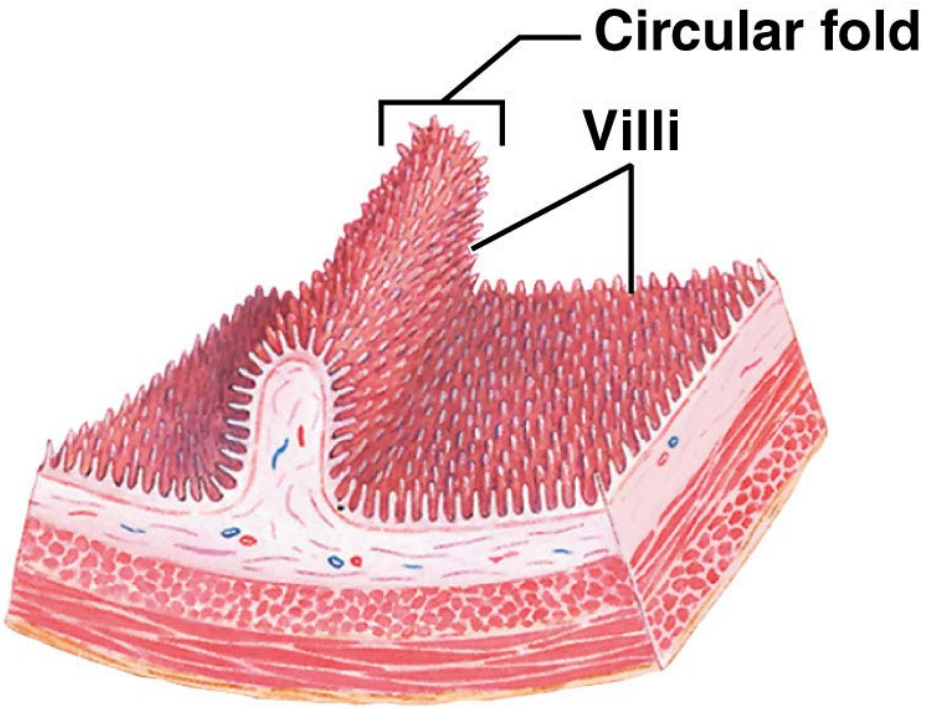
Module 22.12: Intestinal tract structures

Specialized structures (continued)

- **Intestinal villi** (singular, *villus*)
  - Fingerlike projections of mucosa
  - Covered by epithelial cells
    - Surfaces covered with microvilli



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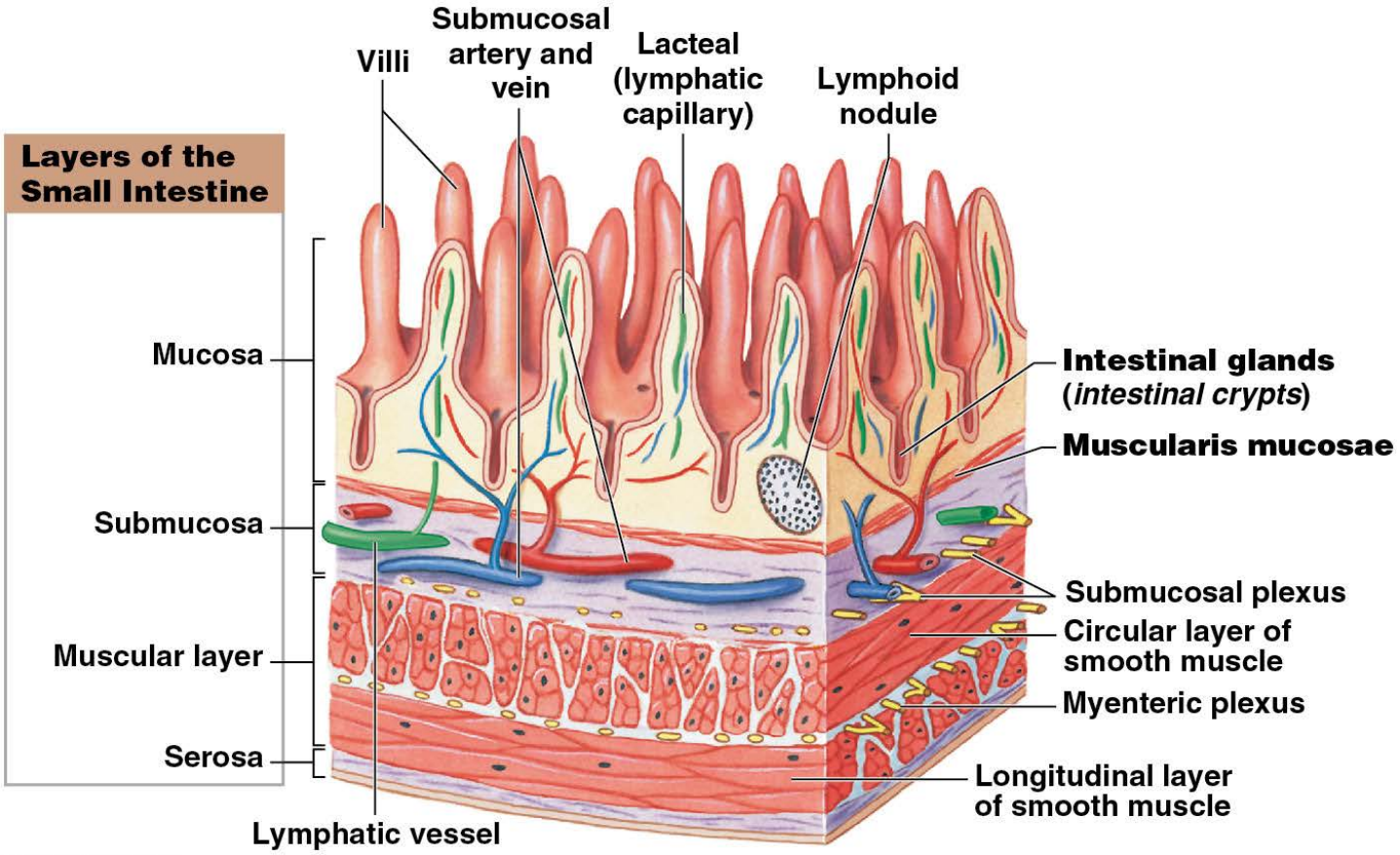
Module 22.12: Intestinal tract structures

Intestinal glands

- Located at the bases of villi



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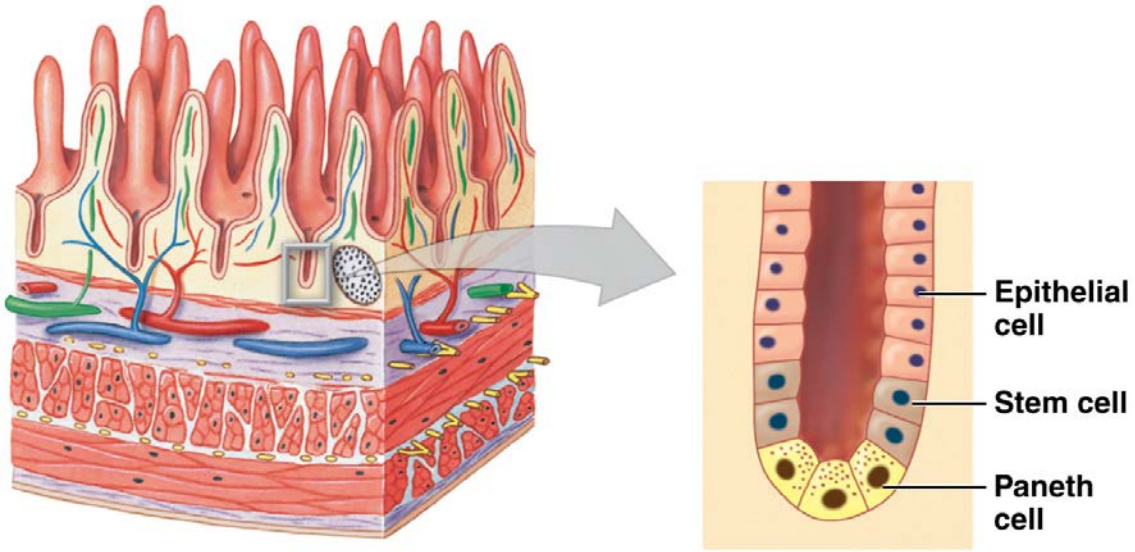
Module 22.12: Intestinal tract structures

Intestinal glands (continued)

- Near base, *stem cells* divide and produce *epithelial cells*
- **Paneth cells** at the base have a role in innate immunity
  - Release defensins and lysozyme



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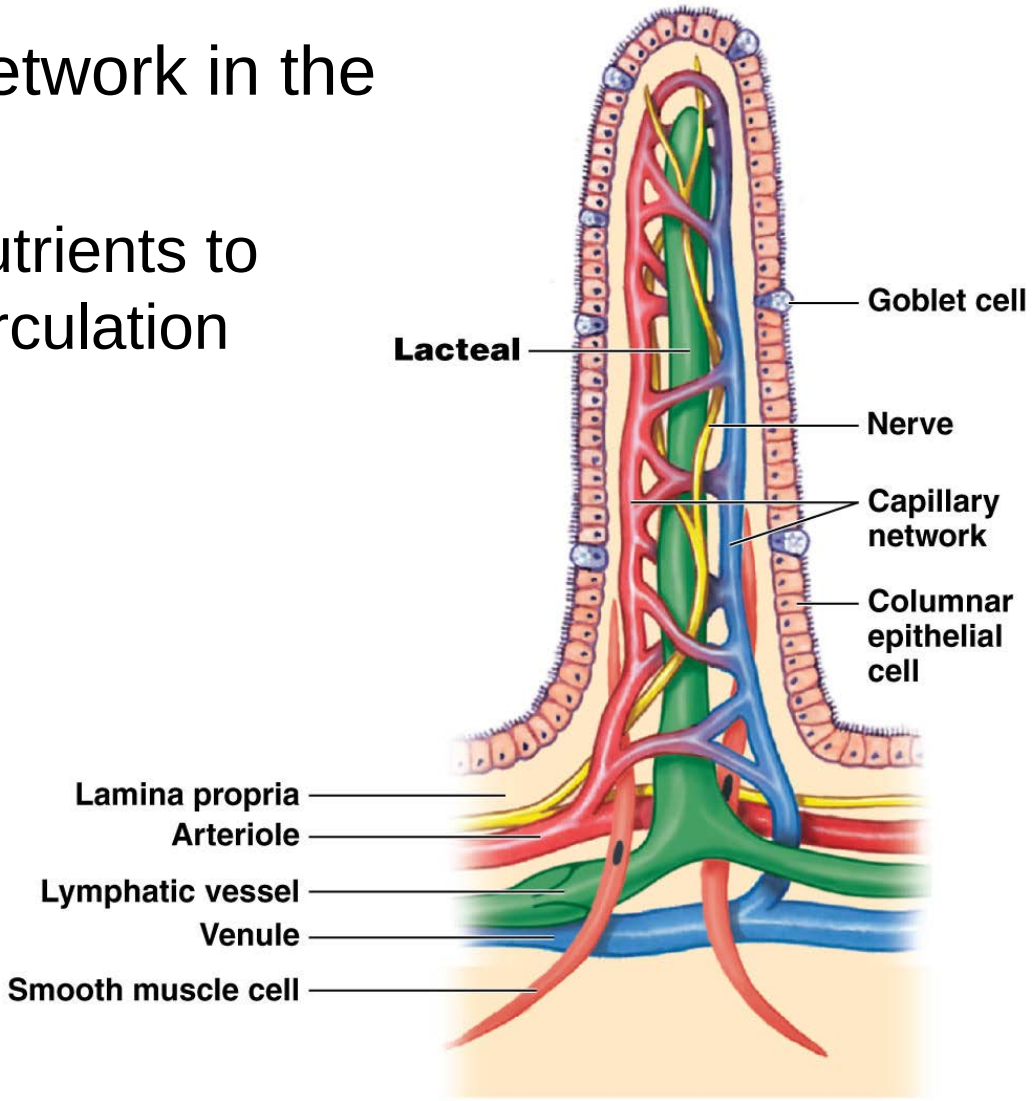
Module 22.12: Intestinal tract structures

Internal structure of a villus

- Extensive capillary network in the lamina propria
  - Carries absorbed nutrients to the hepatic portal circulation



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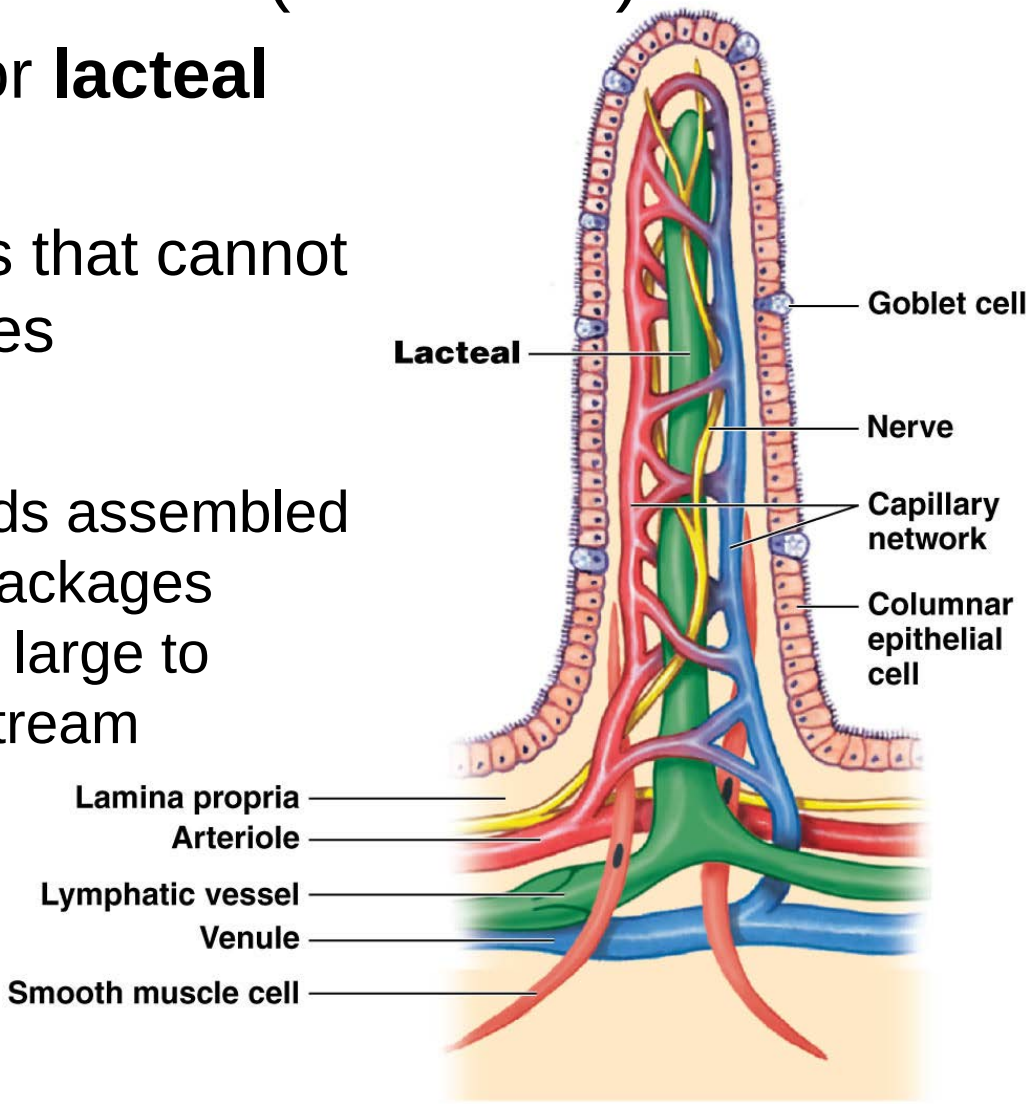
Module 22.12: Intestinal tract structures

Internal structure of a villus (continued)

- Lymphatic capillary, or **lacteal** (*lacteus*, milky)
  - Transports materials that cannot enter blood capillaries
  - Example:
    - Absorbed fatty acids assembled into protein–lipid packages (*chylomicrons*) too large to diffuse into bloodstream
    - Transported by lymphatic system to venous circulation



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Module 22.12: Intestinal tract structures

Internal structure of a villus (continued)

- Smooth muscle in **muscularis mucosae** and within the villi
  - Moves villi back and forth, exposing surfaces to intestinal contents
  - Squeezes lacteal, assisting in lymph movement

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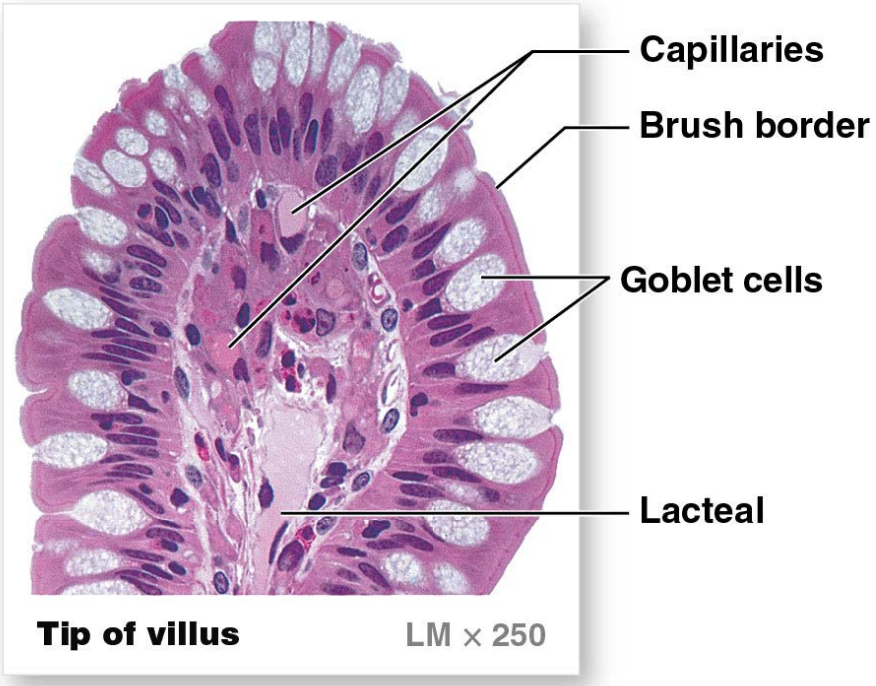
Module 22.12: Intestinal tract structures

Internal structure of a villus (continued)

- **Brush border**
  - Carpet of microvilli on the surface of the epithelial cells
  - Increases surface area for absorption
  - Contains enzymes that digest materials
    - Epithelial cells can then absorb breakdown products



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Module 22.12: Review

A. Name the layers of the small intestine from superficial to deep.
B. Describe the anatomy of the intestinal mucosa.
C. Explain the function of lacteals.

Learning Outcome: Describe the anatomy of the intestinal tract and its histological features.

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Module 22.13: The small intestine is divided into the duodenum, jejunum, and ileum

The small intestine

- Plays key role in nutrient digestion and absorption
  - 90 percent of nutrient absorption occurs in small intestine
  - Most of remaining 10 percent occurs in large intestine
- Average overall length = 6 m (19.7 ft)
- Diameter ranges from 4 cm (1.6 in.) near stomach to 2.5 cm (1 in.) near large intestine
- Three segments
  1. **Duodenum**
  2. **Jejunum**
  3. **Ileum**

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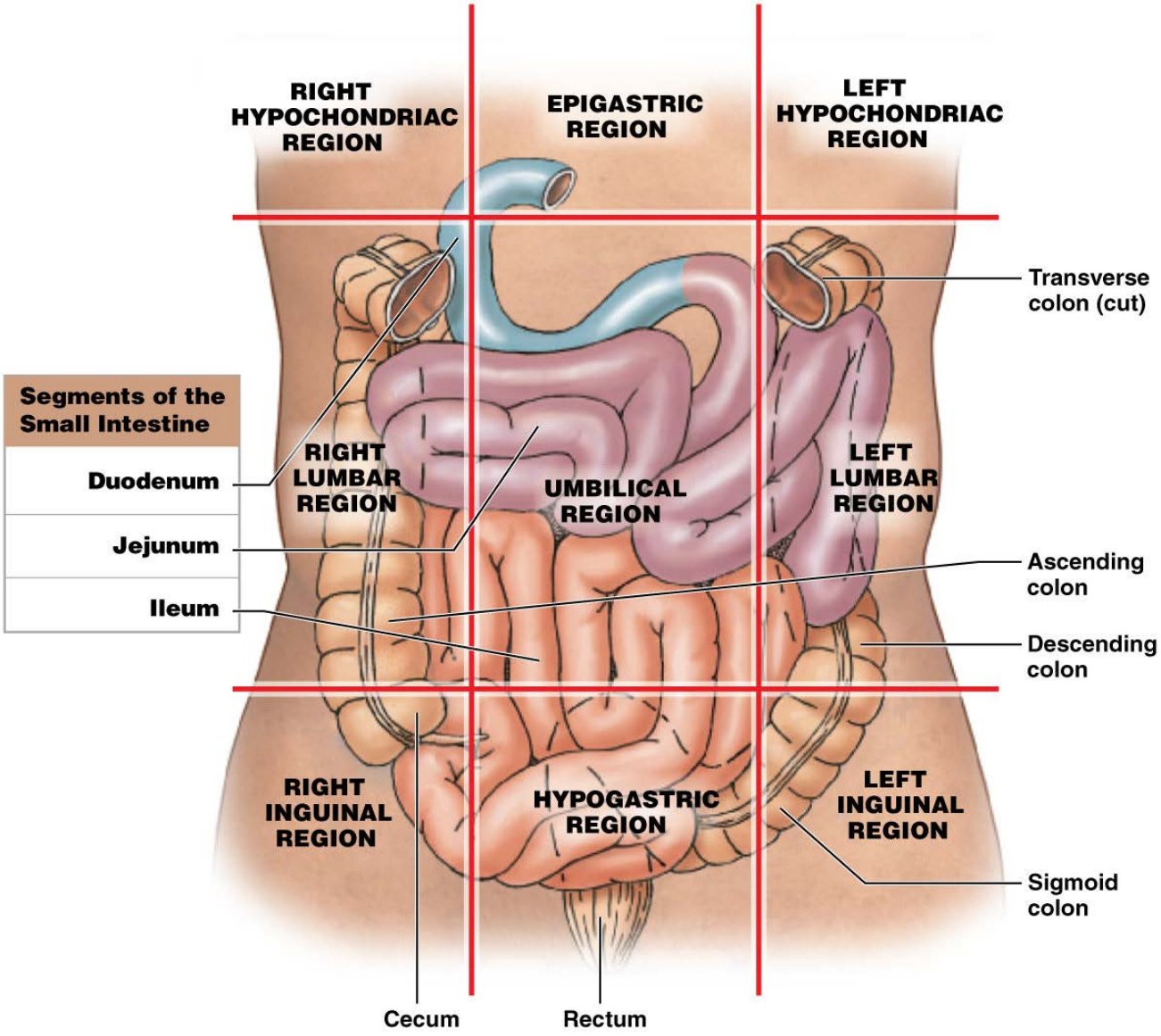
The small intestine



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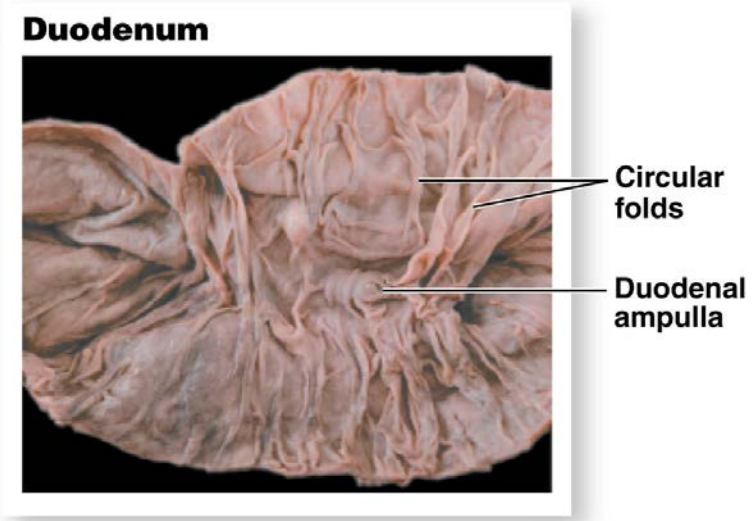
Module 22.13: Segments of the small intestine

Segments of the small intestine

1. **Duodenum**
   - 25 cm (10 in.) in length
   - Segment closest to the stomach
   - Acts as a “mixing bowl”
     - Receives chyme from stomach and digestive secretions from liver, gallbladder, and pancreas
   - Mostly retroperitoneal
   - **Duodenal glands** produce mucous secretions
   - Has few circular folds and small villi
   - Main function is to neutralize acidic chyme



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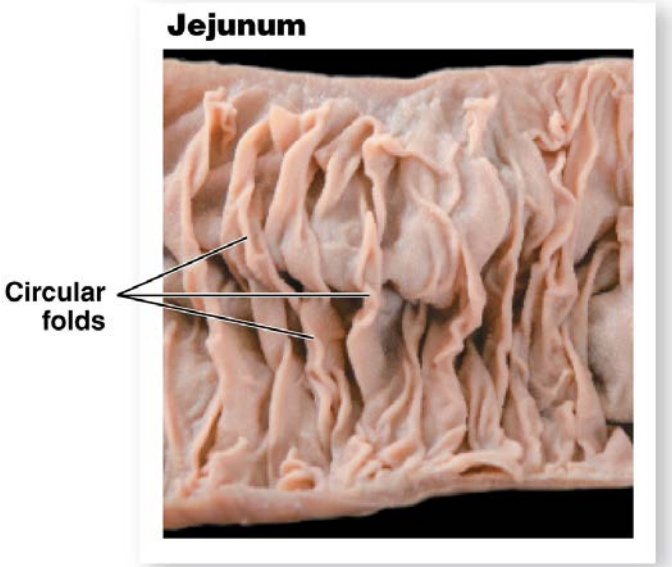
Module 22.13: Segments of the small intestine

Segments of the small intestine (continued)

2. **Jejunum**
   - Between the duodenum and ileum
   - Marked by a sharp bend at its beginning
   - ~2.5 m (8.2 ft) in length
   - In the peritoneal cavity
   - Has numerous circular folds and abundant, long villi
   - Majority of chemical digestion and nutrient absorption occurs in jejunum



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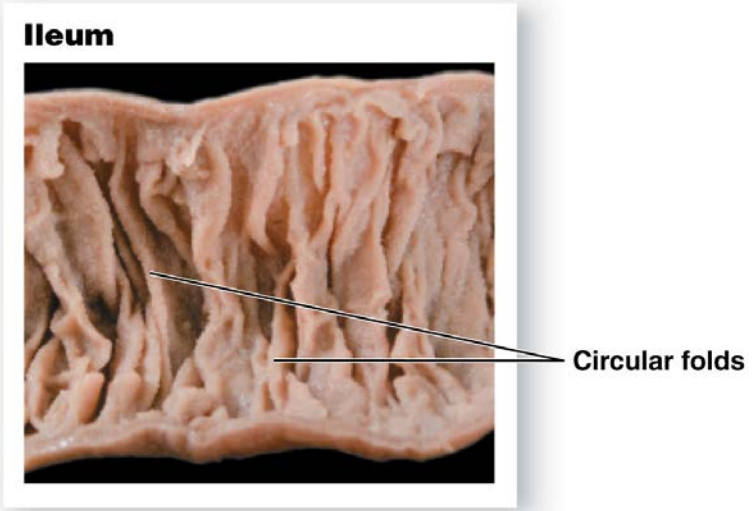
Module 22.13: Segments of the small intestine

Segments of the small intestine (continued)

3. **Ileum**
   - Final segment of small intestine
   - ~3.5 m (11.5 ft) in length
   - Ends at the **ileocecal valve**
     - Sphincter controlling flow from the ileum into the cecum of the large intestine
   - Has few circular folds (none in the distal portion)
   - Villi are relatively stumpy
   - Submucosa contains aggregated lymphoid nodules



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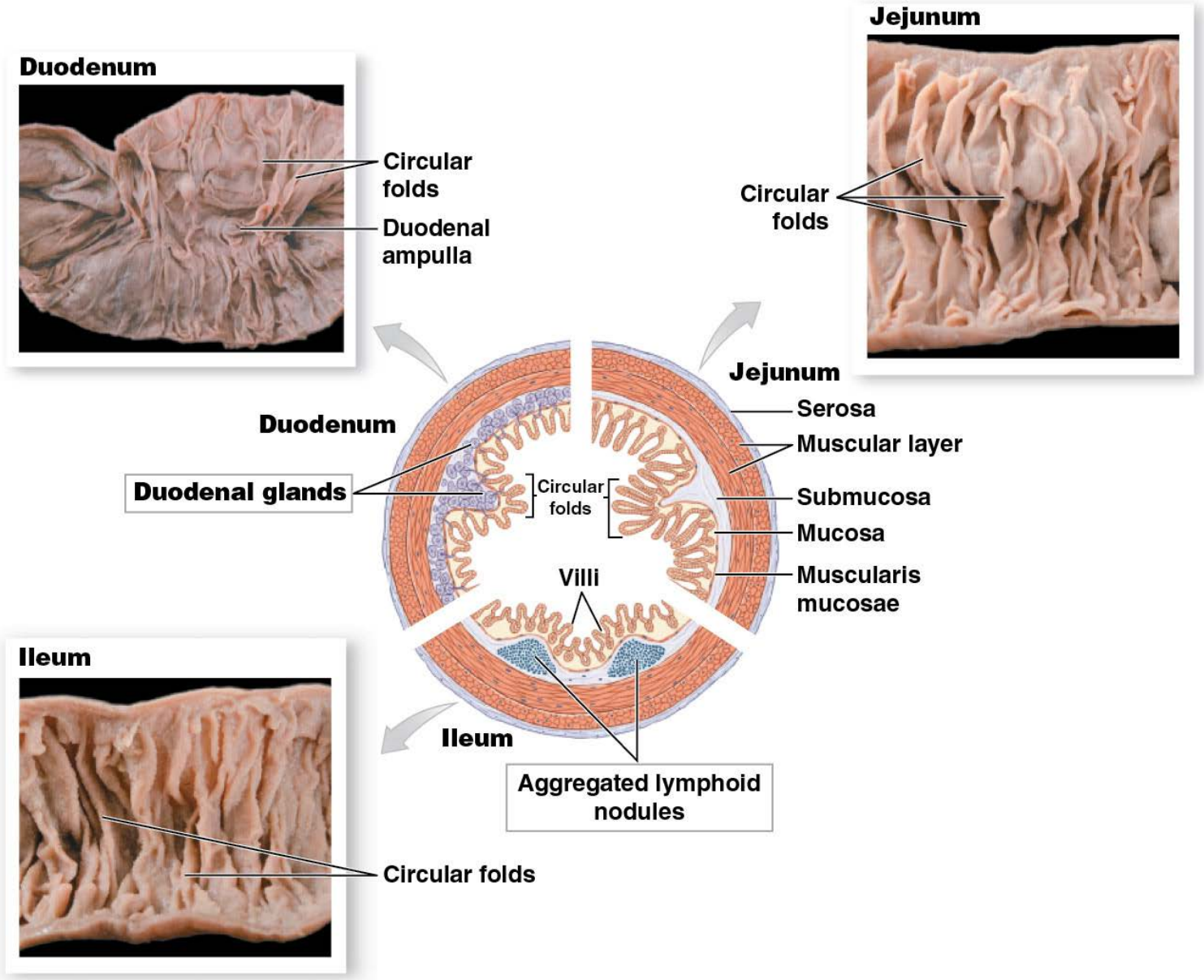
Segments of the small intestine



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Module 22.13: Review

A. Name the three segments of the small intestine from proximal to distal.
B. Identify the segment of the small intestine found within the epigastric region.
C. What is the primary function of the duodenum?
D. A traumatic injury to the umbilical region could affect which segments of the small intestine?

Learning Outcome: Describe the anatomy and physiology of the small intestine.

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Module 22.14: Several hormones regulate digestion

Multiple major hormones regulate digestive activities

- Several of them are produced by the duodenum
  - Duodenum coordinates gastric activity and digestive secretion according to characteristics of the arriving chyme

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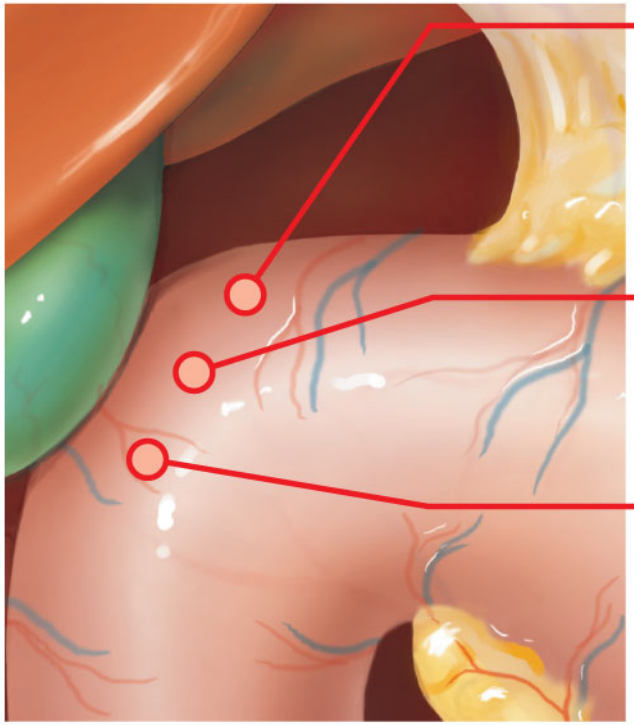
Hormones of the duodenum, part 1



Major Hormones of the Duodenum
Gastrin
Gastrin is secreted by G cells in the pyloric antrum and enteroendocrine cells in the duodenum. The pyloric antrum secretes gastrin when stimulated by the vagus nerves or when food arrives in the stomach. Duodenal cells release gastrin when they are exposed to large quantities of incompletely digested proteins. The functions of gastrin include increasing stomach motility and stimulating gastric acid and enzyme production.
Secretin
Secretin is released when chyme arrives in the duodenum. Secretin's primary effect is an increase in the secretion of buffers by the pancreas, which increase the pH of the chyme. Among its secondary effects, secretin also stimulates secretion of bile by the liver and reduces gastric motility and gastric secretory rates.
Gastric Inhibitory Peptide (GIP)
Gastric inhibitory peptide (GIP) is secreted when fats and carbohydrates—especially glucose—enter the small intestine. The inhibition of gastric activity is accompanied by the stimulation of insulin release at the pancreatic islets. GIP has several secondary effects, including stimulating submucosal duodenal gland activity, stimulating lipid synthesis in adipose tissue, and increasing glucose use by skeletal muscles.

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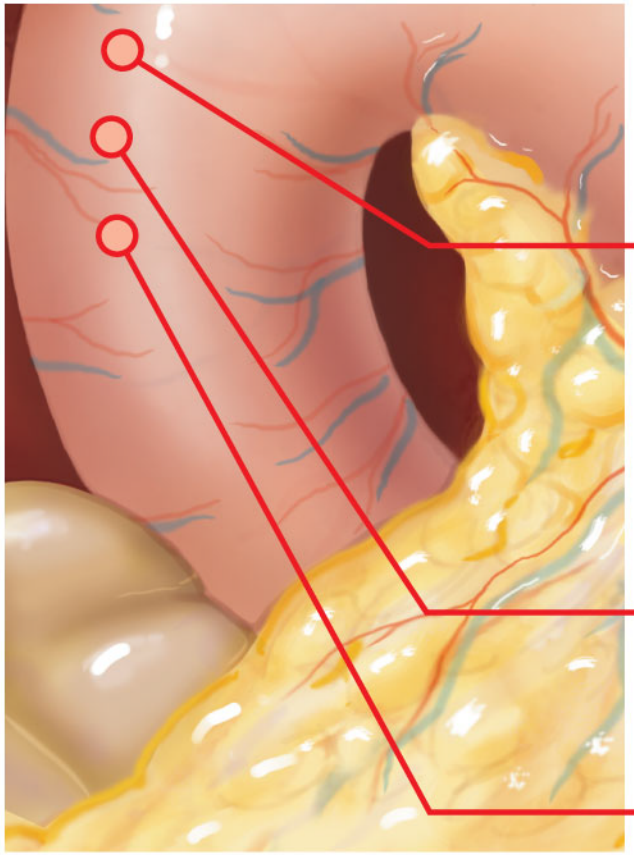
Hormones of the duodenum, part 2



Major Hormones of the Duodenum

Cholecystokinin (CCK)

Cholecystokinin (CCK) is secreted when chyme arrives in the duodenum, especially when the chyme contains lipids and partially digested proteins. In the pancreas, CCK accelerates the production and secretion of all types of digestive enzymes. It also causes a relaxation of the hepatopancreatic sphincter and contraction of the gallbladder, resulting in the ejection of bile and pancreatic juice into the duodenum. Thus, the net effects of CCK are to increase the secretion of pancreatic enzymes and to push pancreatic secretions and bile into the duodenum. The presence of CCK in high concentrations has two additional effects: It inhibits gastric activity, and it appears to have CNS effects that reduce the sensation of hunger.

Vasoactive Intestinal Peptide (VIP)

Vasoactive intestinal peptide (VIP) stimulates the secretion of intestinal glands, dilates regional capillaries, and inhibits acid production in the stomach. By dilating capillaries in active areas of the intestinal tract, VIP provides an efficient mechanism for removing absorbed nutrients.

Enterocrinin

Enterocrinin is released by enteroendorine cells of the duodenum in response to stimulation by the vagus nerves before chyme reaches the pyloric sphincter and also when chyme enters the duodenum. It stimulates production of alkaline mucus by the duodenal submucosal glands, which protects the intestine from acidic chyme.

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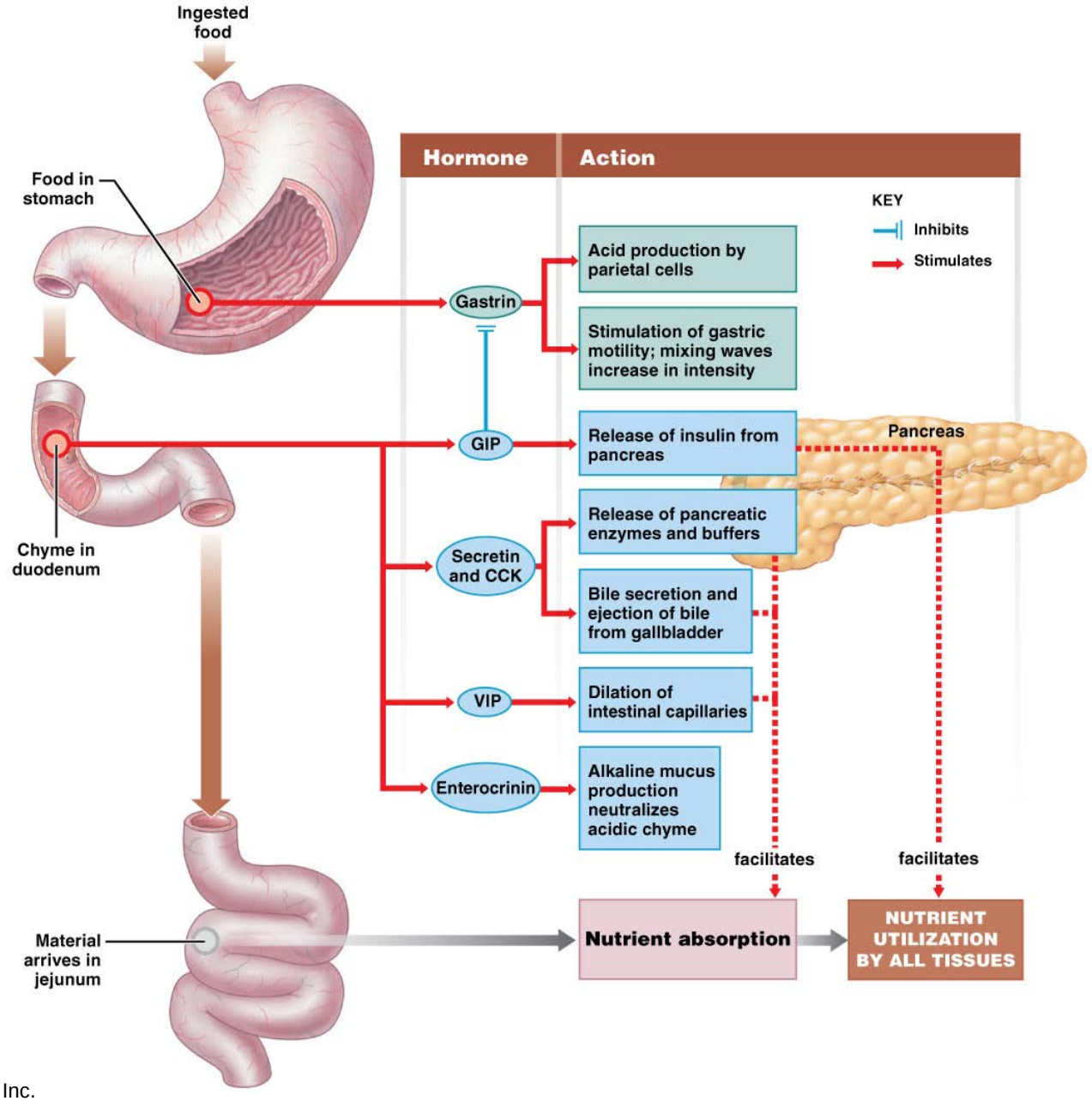
Hormone action of the digestive system



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Module 22.14: Review

A. Name the major hormones that regulate digestive activities.
B. How would the pH of the intestinal contents be affected if the small intestine did not produce secretin?
C. Does a high-fat meal raise or lower the level of cholecystokinin (CCK) in the blood?

Learning Outcome: Discuss the major digestive hormones and their primary effects.

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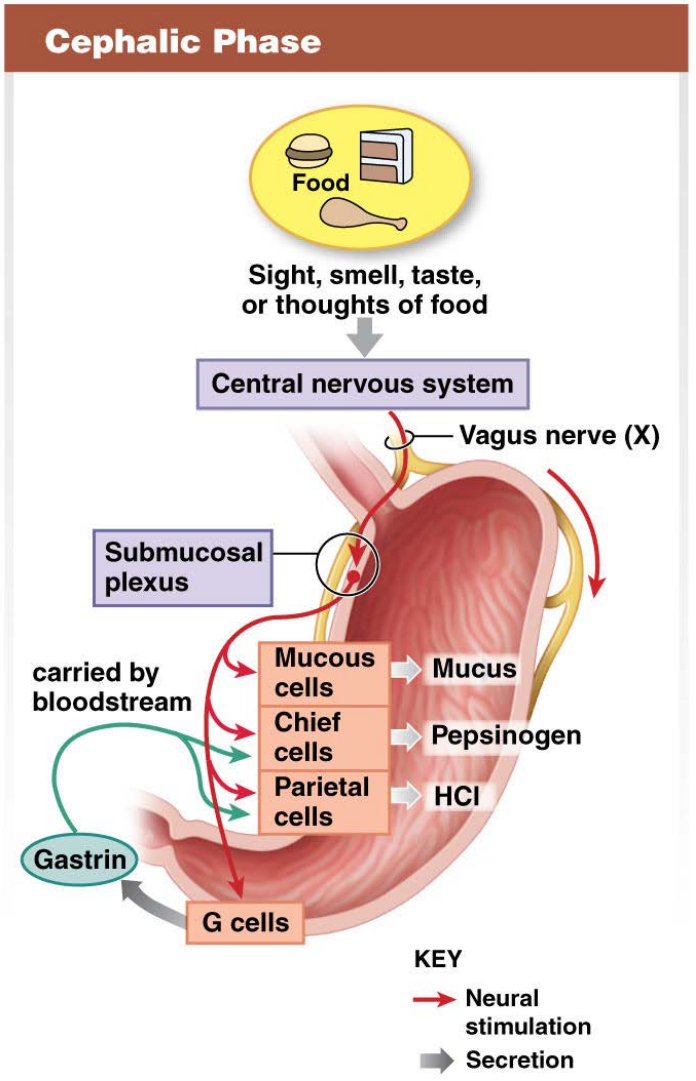
Module 22.15: Central and local mechanisms coordinate gastric…

Phases of gastric secretion

1. **Cephalic phase**
   - Begins when you see, smell, taste, or think of food
   - Directed by the CNS to prepare stomach to receive food
   - Parasympathetic impulse down the vagus nerve stimulates the submucosal plexus
     - Postganglionic fibers innervate gastric gland cells



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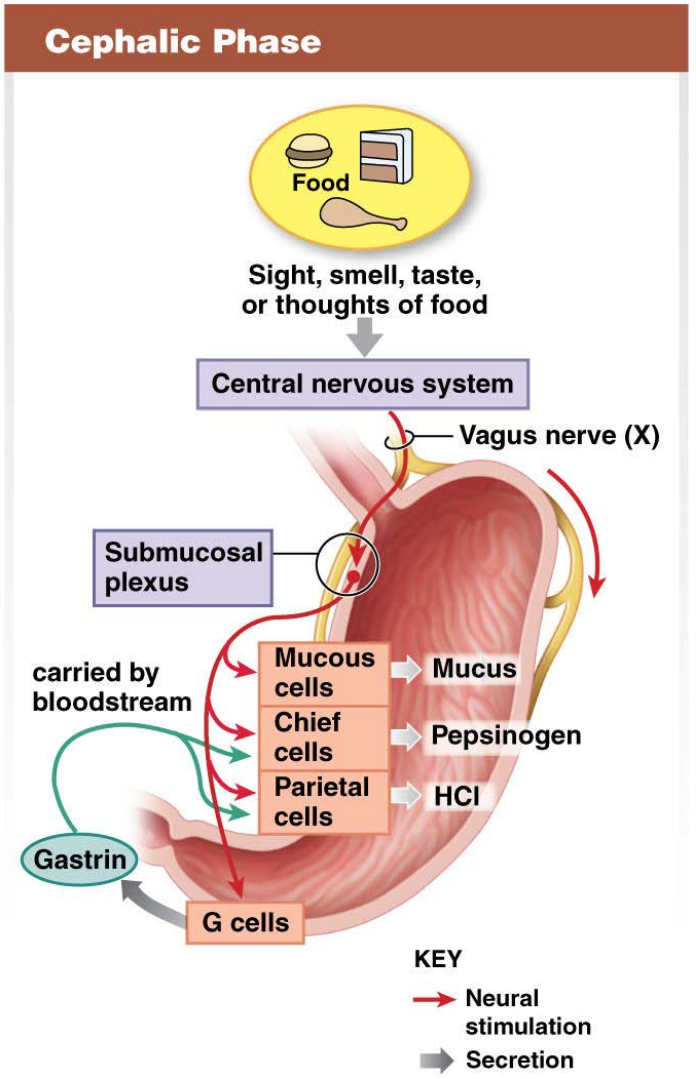
Module 22.15: Central and local mechanisms coordinate gastric…

Phases of gastric secretion (continued)

1. **Cephalic phase** (continued)
   - Gastric juice production increases (~500 mL/h)
   - Phase generally lasts only minutes



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Module 22.15: Central and local coordination of digestive activities

Phases of gastric secretion (continued)

2. **Gastric phase**
   - Begins with stimuli as food arrives in the stomach
   - Stimuli include:
     1. Distention of stomach
     2. Increase in gastric content pH
     3. Presence of undigested materials (especially proteins and peptides) in stomach
   - Gastrin secretion
     - Increases **mixing waves** of stomach muscle contraction
     - Increases secretion by parietal and chief cells
   - Phase may last 3–4 hours

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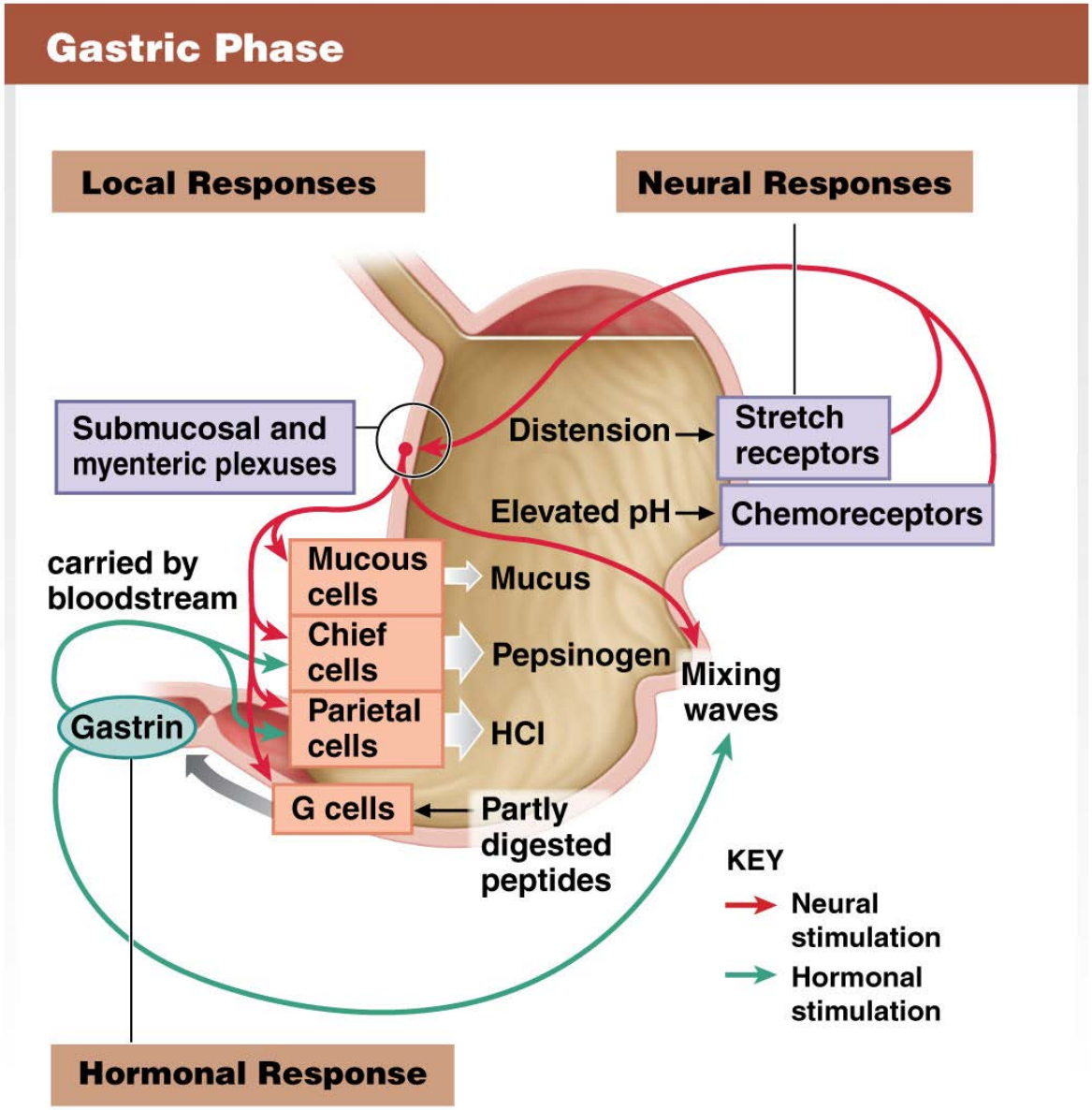
Gastric phase



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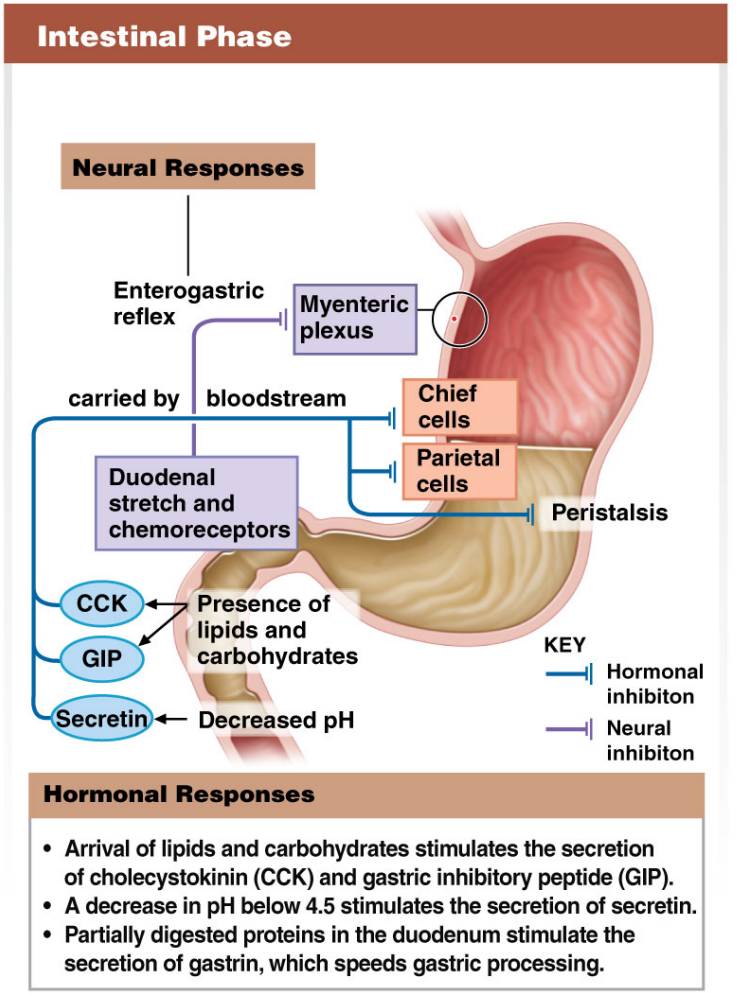
Module 22.15: …and intestinal activities

Phases of gastric secretion (continued)

3. **Intestinal phase**
   - Begins when chyme enters duodenum (usually after several hours of mixing)
   - Distention of the duodenum initiates the **enterogastric reflex**



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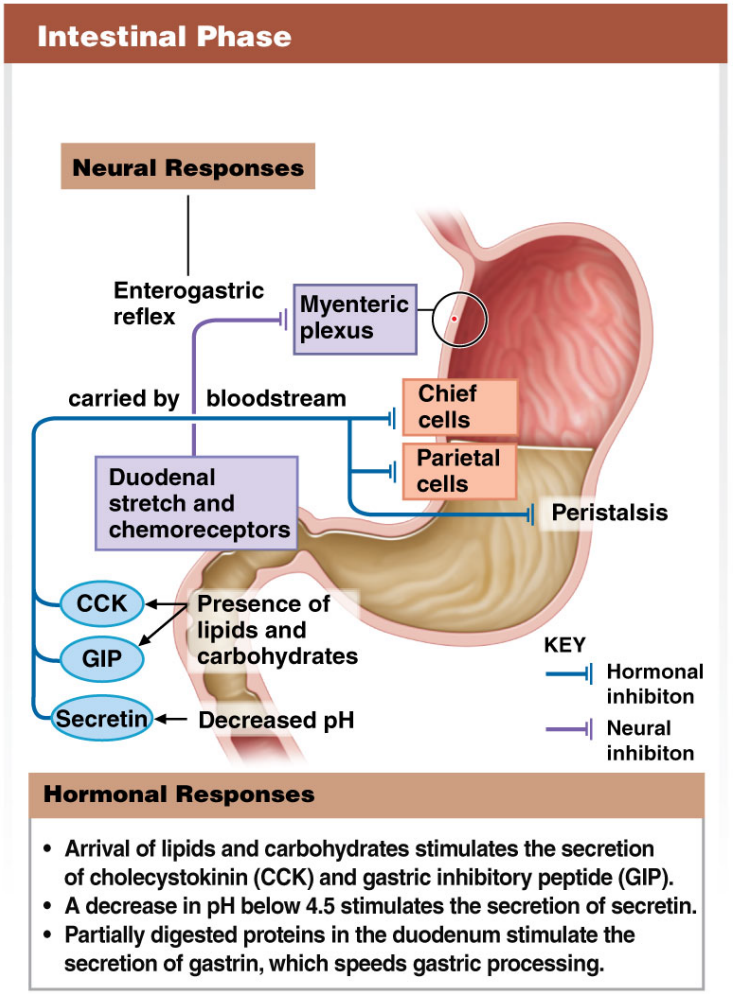
Module 22.15: …and intestinal activities

Phases of gastric secretion (continued)

3. **Intestinal phase** (continued)
   - Inhibits gastrin production
   - Decreases gastric motility and secretion
   - Stimulates contraction of pyloric sphincter, decreasing chyme release into duodenum
   - Mucus production is increased in the duodenum



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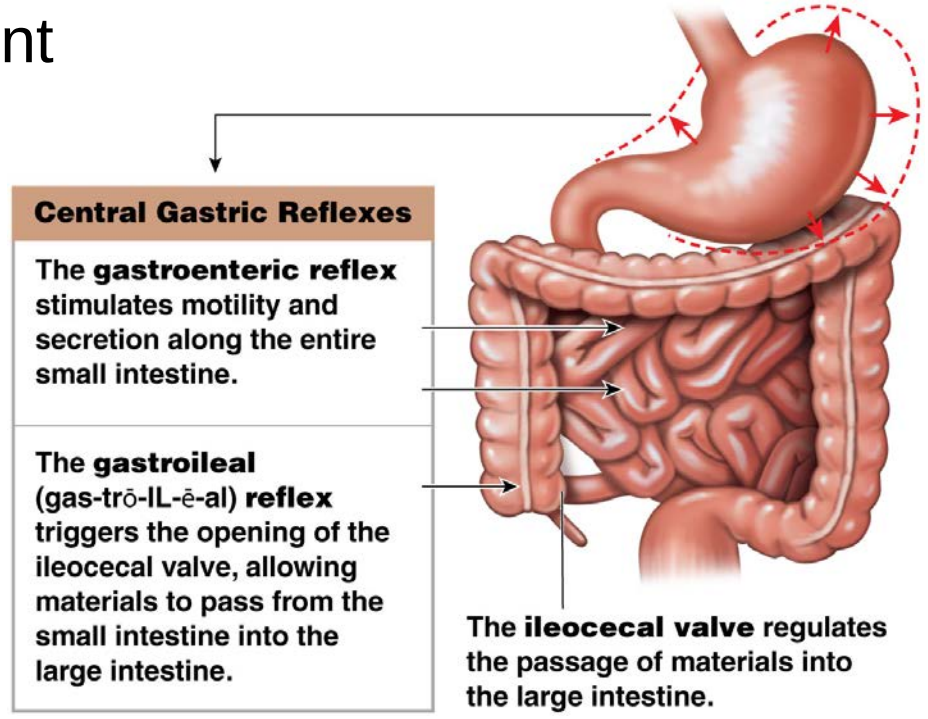
Module 22.15: Central and local coordination of digestive activities

Gastric central reflexes

- Triggered by the stimulation of stretch receptors in the stomach wall as it fills
- Accelerate movements along the small intestine
  - Rate of chyme movement into small intestine is fastest when the stomach is greatly distended



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Module 22.15: Review

A. Name and briefly describe an important characteristic of each of the three phases of gastric secretion.
B. Describe two central reflexes triggered by stimulation of the stretch receptors in the stomach wall.
C. Why might severing the branches of the vagus nerves that supply the stomach provide relief for a person who suffers from chronic gastric ulcers (sores on the stomach lining)?

Learning Outcome: Explain the regulation of gastric activity by central and local mechanisms.

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Module 22.16: The large intestine stores and concentrates fecal material

The large intestine

- Also known as large bowel
- Average length is ~1.5 m (4.9 ft), and diameter is 7.5 cm (3 in.)
- Major functions
  1. Reabsorbing water and compacting intestinal contents into feces
  2. Absorbing important vitamins generated by bacterial action
  3. Storing fecal material prior to defecation
- Three segments: *cecum*, *colon*, *rectum*

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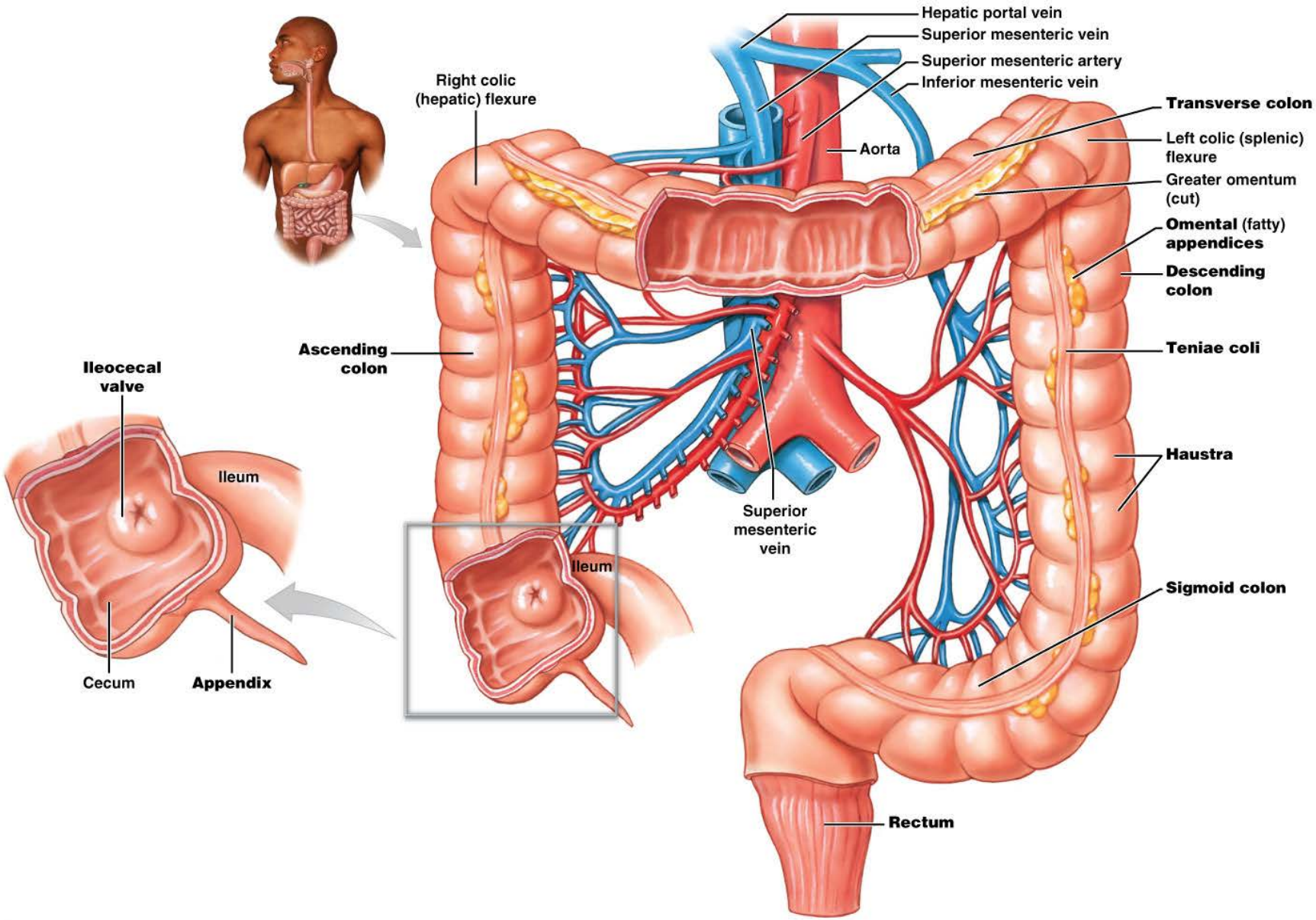
The Large Intestine



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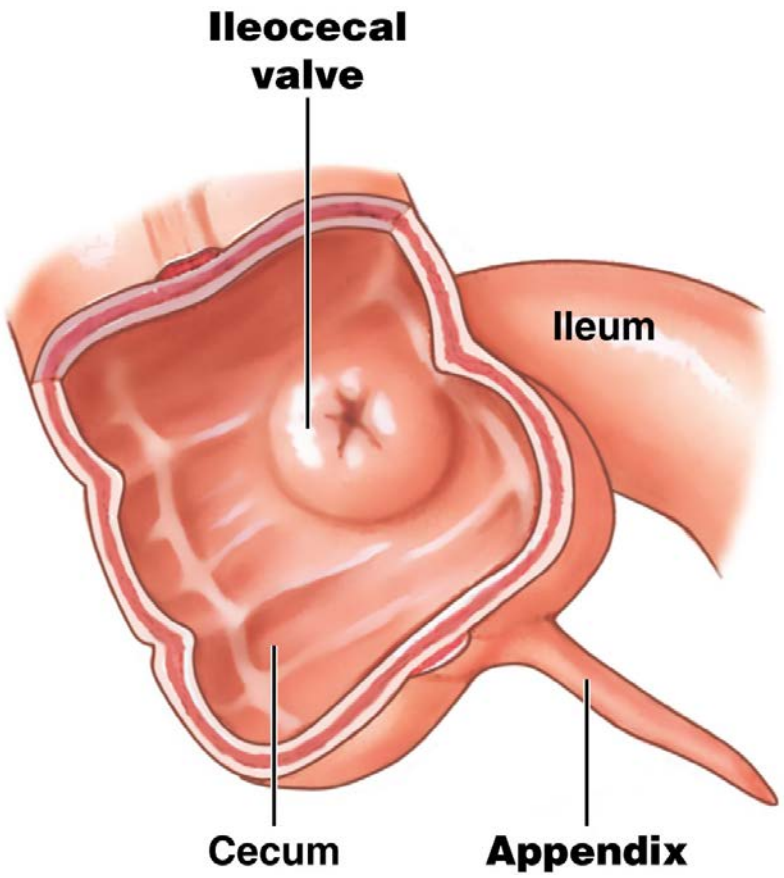
Module 22.16: The large intestine

Large intestine segments

- **Cecum**
  - Expanded pouch distal to the ileum
  - Collects and stores material
  - Begins the process of **compaction**
    - Compression into feces
  - Opening between the cecum and ileum is the **ileocecal valve**



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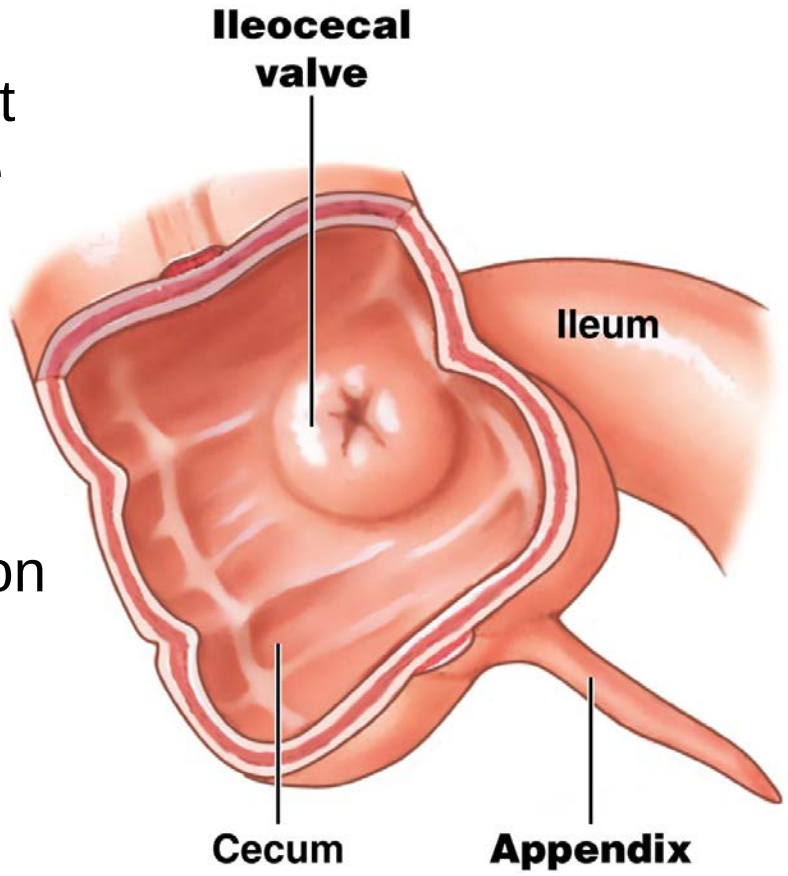
Module 22.16: The large intestine

Large intestine segments (continued)

- **Cecum** (continued)
  - Attached to the **appendix** (also called the *vermiform appendix*)
    - ~9 cm (3.6 in.) in length, but size and shape are variable
    - Contains numerous lymphoid nodules
      - Functions as a lymphoid organ
    - **Appendicitis** is inflammation of the appendix



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Module 22.16: The large intestine

Large intestine segments (continued)

- **Colon**
  - Larger diameter and thinner wall than the small intestine
  - Subdivided into four regions
    1. Ascending colon
    2. Transverse colon
    3. Descending colon
    4. Sigmoid colon
  - Ascending and descending colon are retroperitoneal and attached to the abdominal wall
  - Transverse and sigmoid colon are suspended by remnants of the embryonic mesocolon

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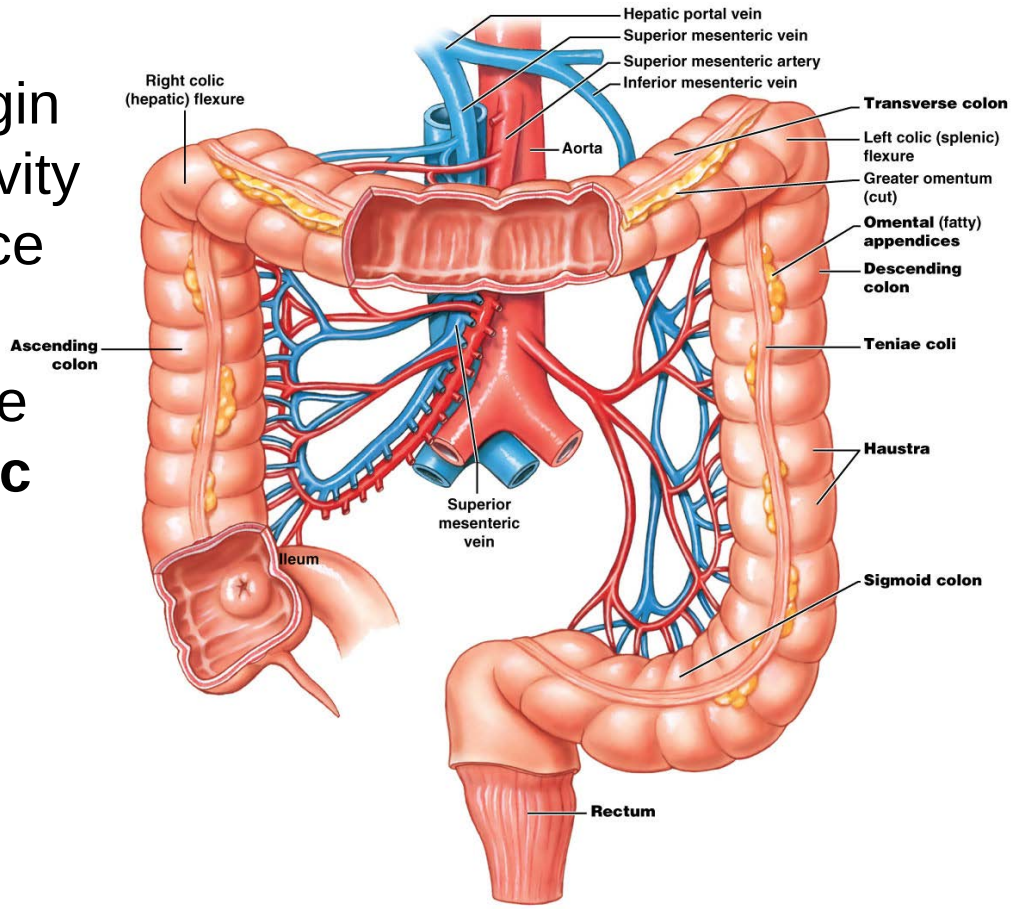
Module 22.16: The large intestine

Large intestine segments (continued)

- **Colon** (continued)
  1. **Ascending colon**
     - From the cecum along the right margin of the peritoneal cavity to the inferior surface of the liver
     - Bends sharply to the left at the **right colic** (hepatic) **flexure**



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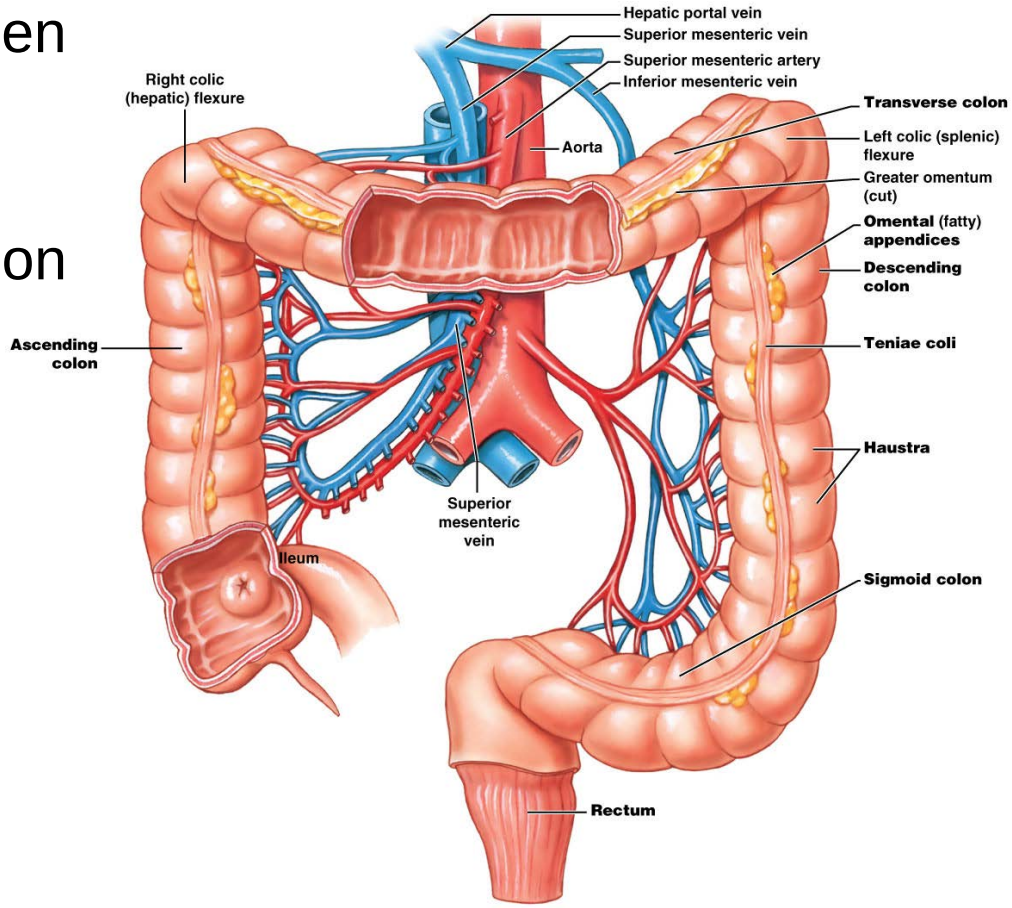
Module 22.16: The large intestine

Large intestine segments (continued)

- **Colon** (continued)
  2. **Transverse colon**
     - Crosses the abdomen from right to left
     - Supported by the transverse mesocolon
     - Makes a 90° turn at the **left colic** (splenic) **flexure**



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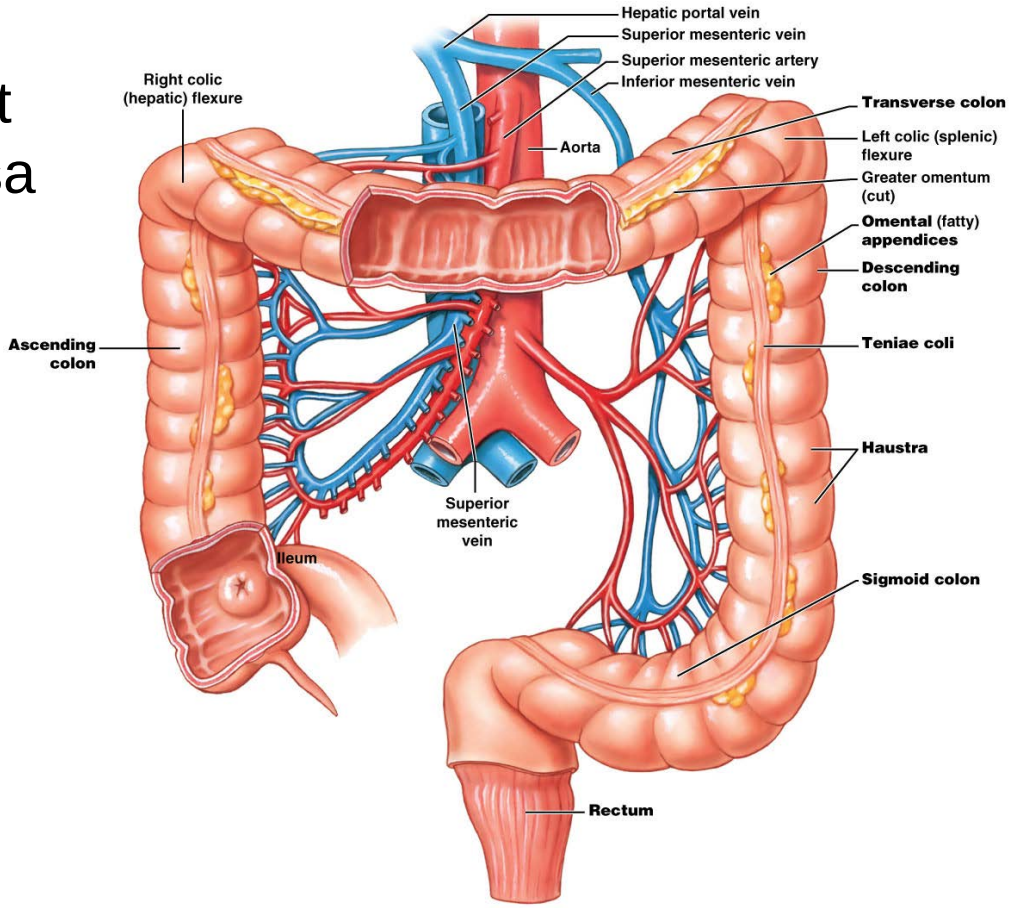
Module 22.16: The large intestine

Large intestine segments (continued)

- **Colon** (continued)
  3. **Descending colon**
     - Moves inferiorly along the body's left side to the iliac fossa
     - Ends at the **sigmoid flexure**



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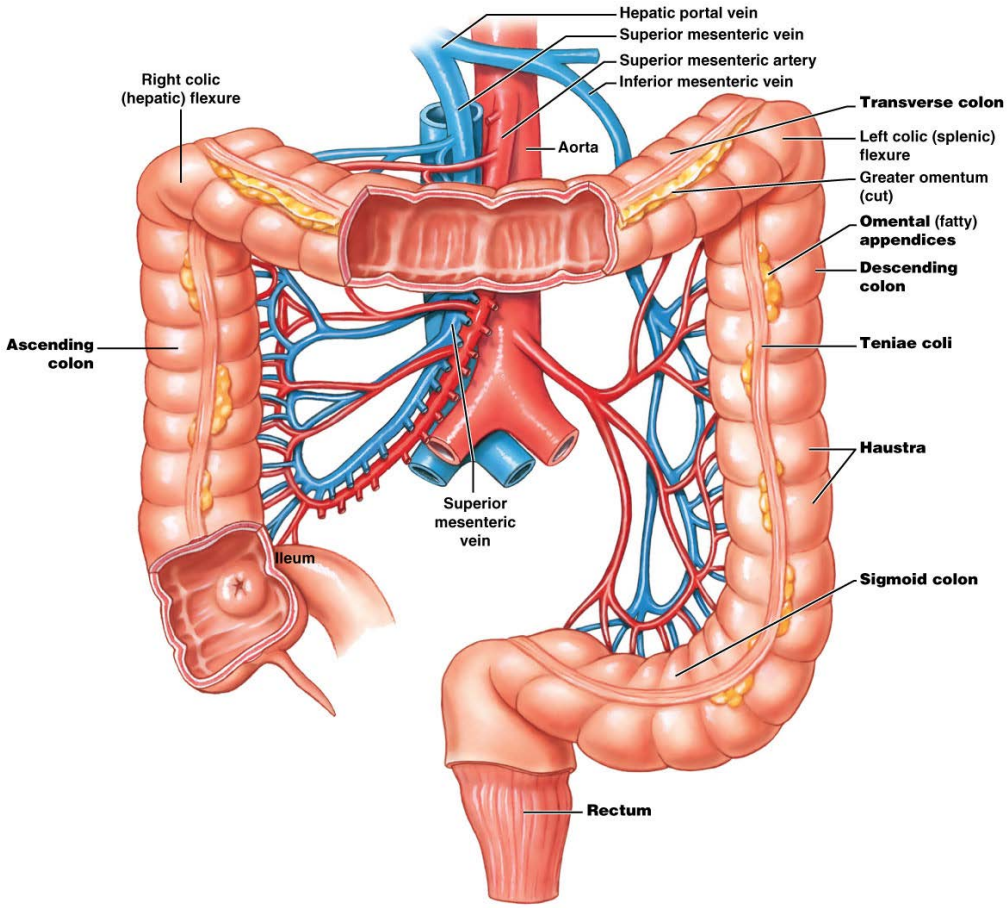
Module 22.16: The large intestine

Large intestine segments (continued)

- **Colon** (continued)
  4. **Sigmoid colon** (*sigmeidos*, Greek letter S)
     - S-shaped segment
     - About 15 cm (6 in.) long
     - Empties into the rectum



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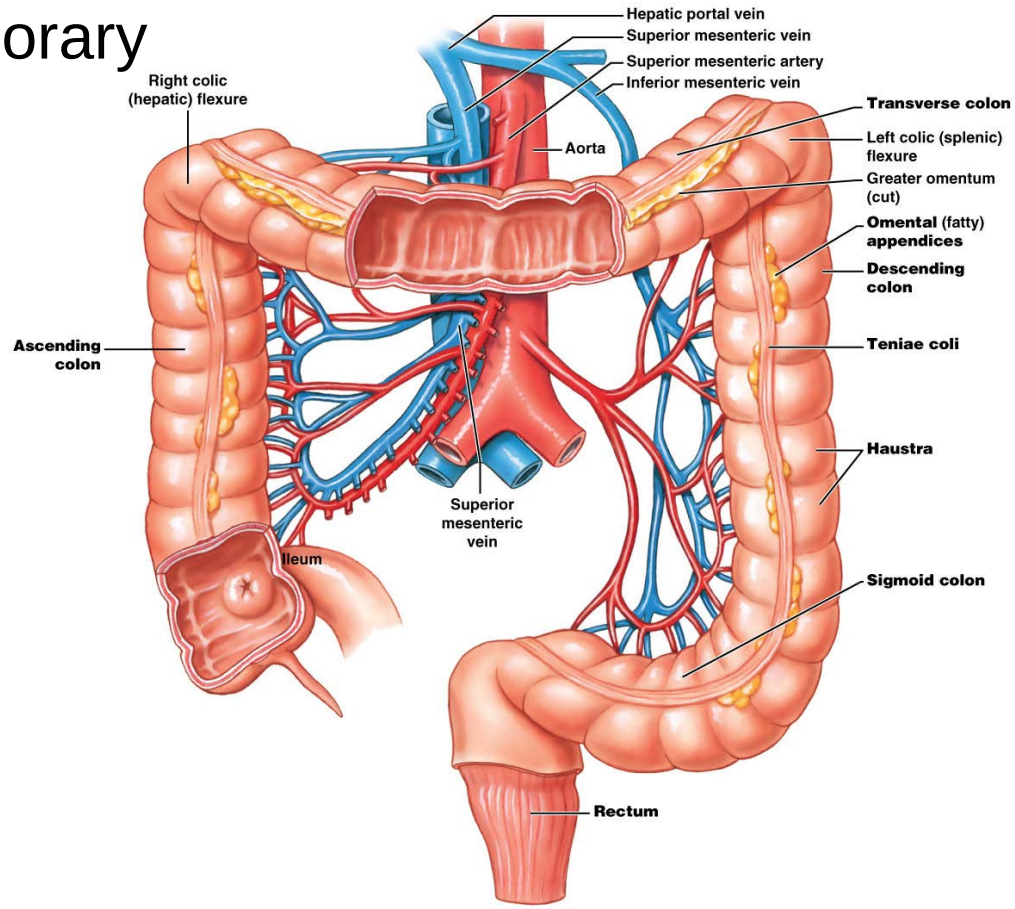
Module 22.16: The large intestine

Large intestine segments (continued)

- **Rectum**
  - Forms last 15 cm (6 in.) of digestive tract
  - Expandable for temporary feces storage
  - Movement of fecal material into the rectum triggers the urge to defecate



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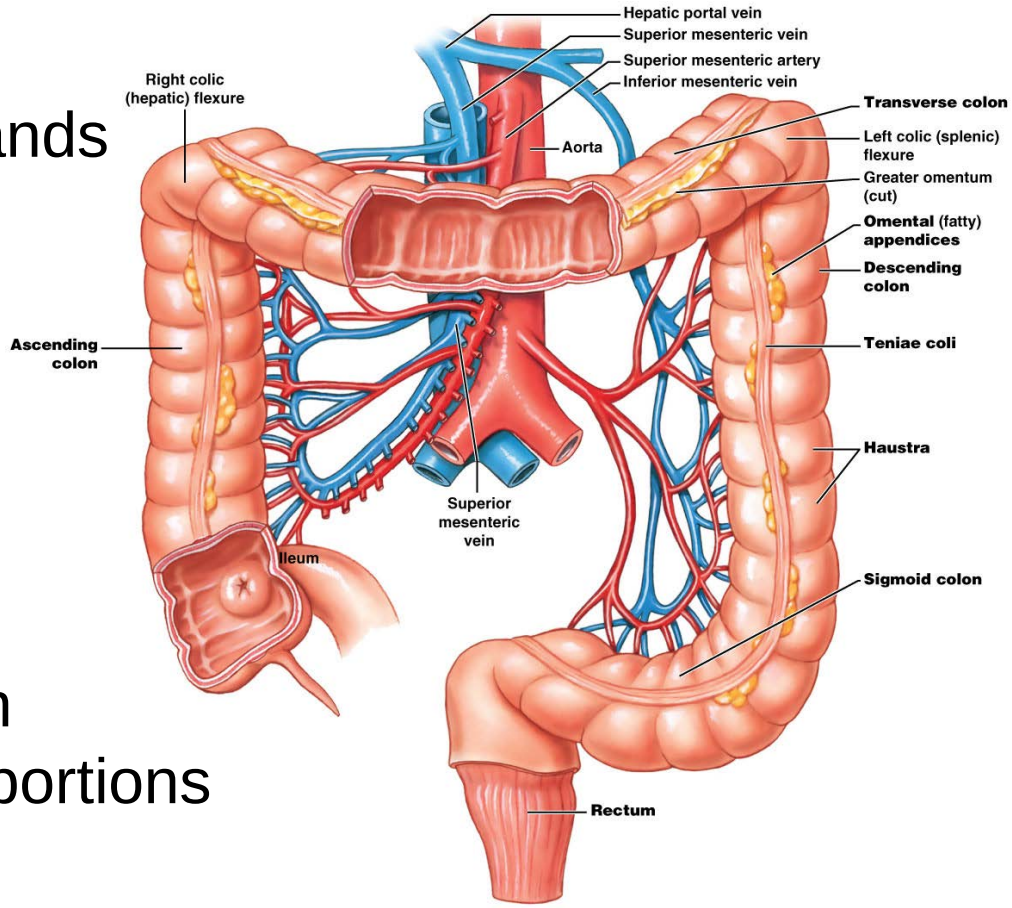
Module 22.16: The large intestine

Other large intestine structures

- **Omental (fatty) appendices**
  - Teardrop-shaped sacs of fat in the serosa of the colon
- **Tenia coli**
  - Three longitudinal bands of smooth muscle
  - Run along outer colon surface deep to the serosa
  - Correspond to the outer layer of the muscularis externa in other digestive tract portions



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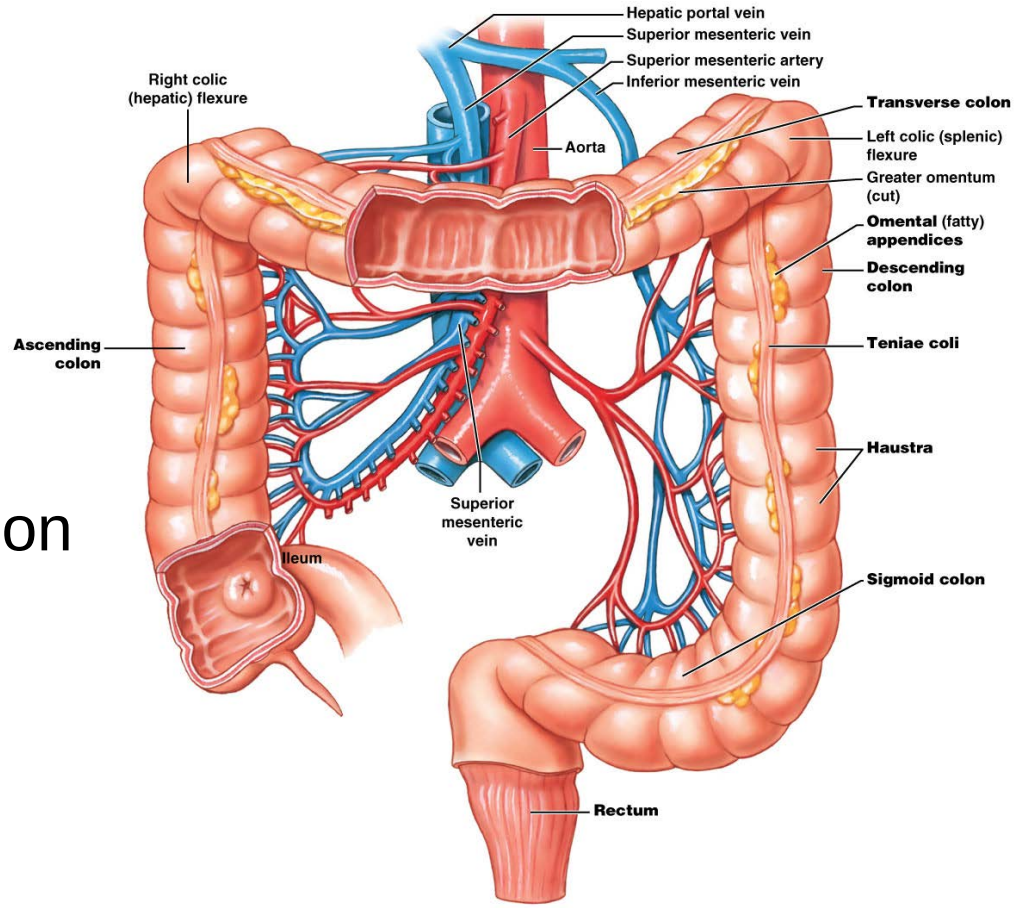
Module 22.16: The large intestine

Other large intestine structures (continued)

- **Haustra**
  - Series of pouches in the colon wall
  - Also produce internal folding in the intestinal lumen
  - Created by muscle tone of the tenia coli
  - Allow for expansion and elongation of colon



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Module 22.16: The large intestine

Mass movements

- Powerful peristaltic contractions
- Occur a few times each day in response to distention of the stomach and duodenum
- Begin at the transverse colon and push materials along the distal portion of the large intestine

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Module 22.16: Review

A. Name the major functions of the large intestine.
B. Identify the four regions of the colon.
C. Describe mass movements.

Learning Outcome: Describe the gross anatomy of the three segments of the large intestine.

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Module 22.17: The large intestine compacts fecal material; the defecation reflex coordinates the elimination of feces

Major characteristics of the large intestine wall

- Lacks villi
- Contains distinctive intestinal glands
  - Dominated by mucin-secreting goblet cells
  - Mucus lubricates feces as it becomes drier and more compact
- Mucosa does not produce enzymes

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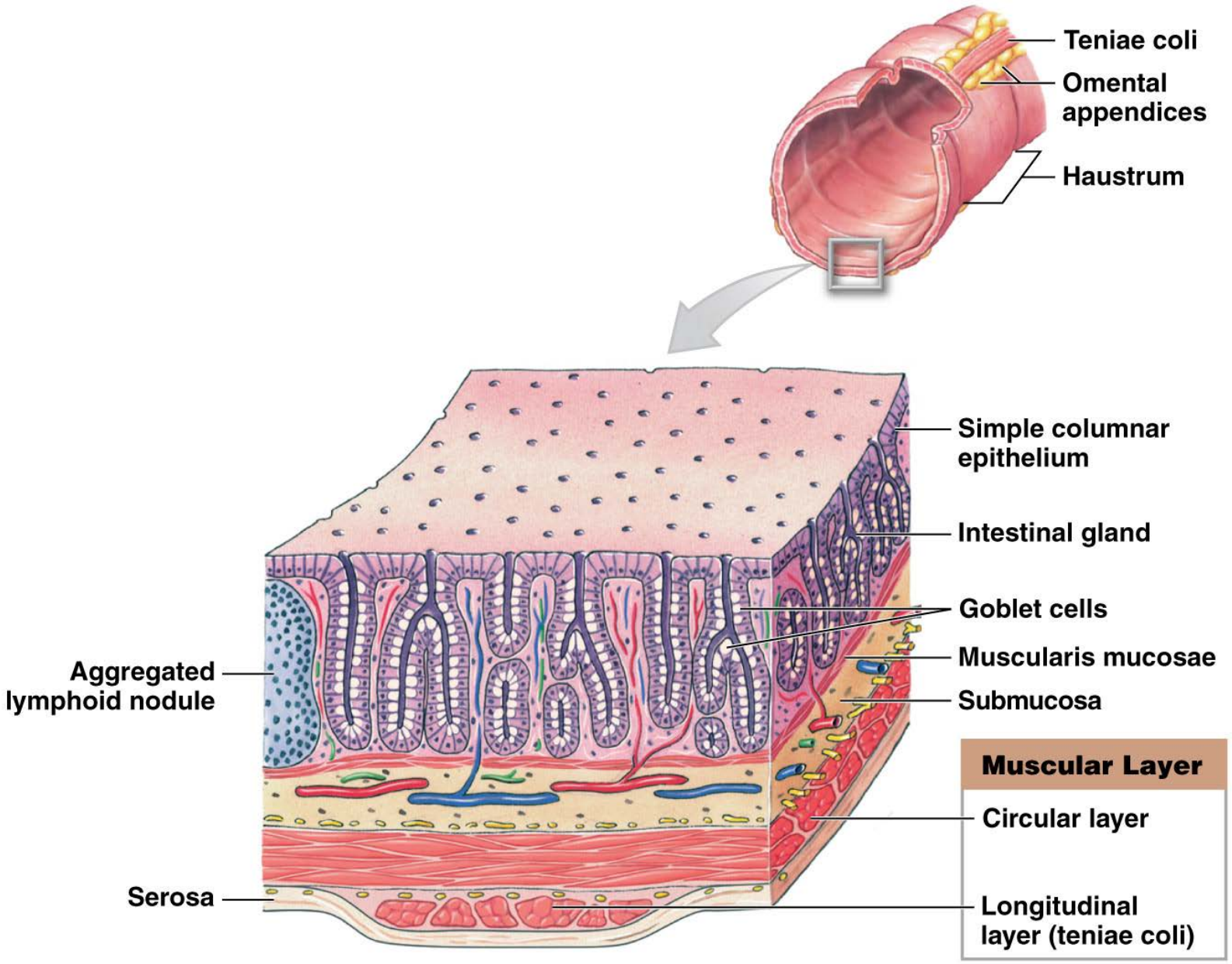
Large intestine wall



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Module 22.17: Compaction and elimination of feces

Characteristic features of the rectum

- **Anal canal** (distal portion of rectum)
  - Contains small longitudinal folds called **anal columns**
  - Epithelium transitions from columnar to stratified squamous epithelium
  - Network of veins in the lamina propria and submucosa
    - Increased venous pressure can distend the veins, producing **hemorrhoids**
      - Increased pressure caused by pregnancy or straining during defecation

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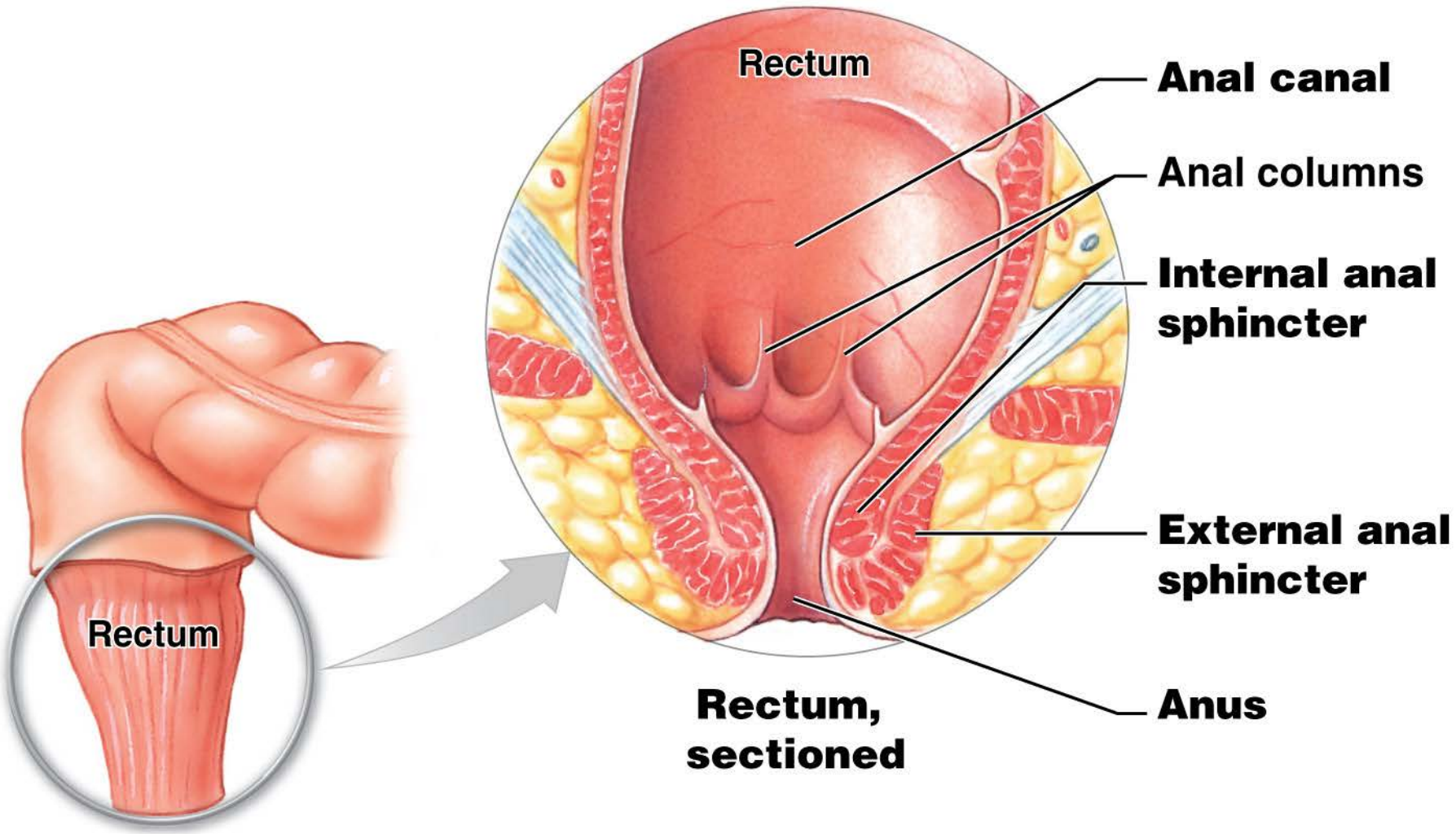
The rectum



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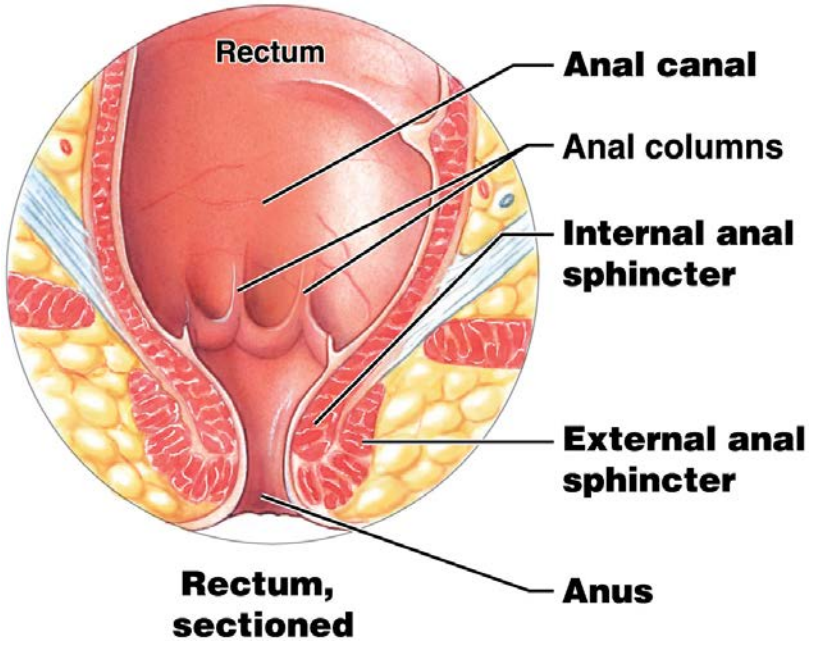
Module 22.17: Compaction and elimination of feces

Characteristic features of the rectum (continued)

- **Internal anal sphincter**
  - Inner circular smooth muscle layer
  - Not under voluntary control
- **External anal sphincter**
  - Outer skeletal muscle layer
  - Under voluntary control



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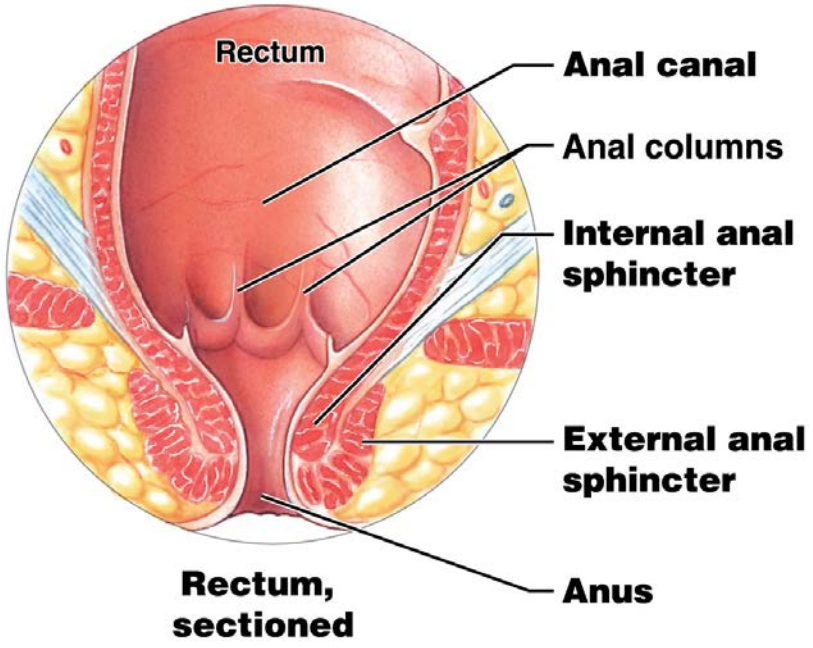
Module 22.17: Compaction and elimination of feces

Characteristic features of the rectum (continued)

- **Anus (exit of the anal canal)**
  - Epidermis here becomes keratinized



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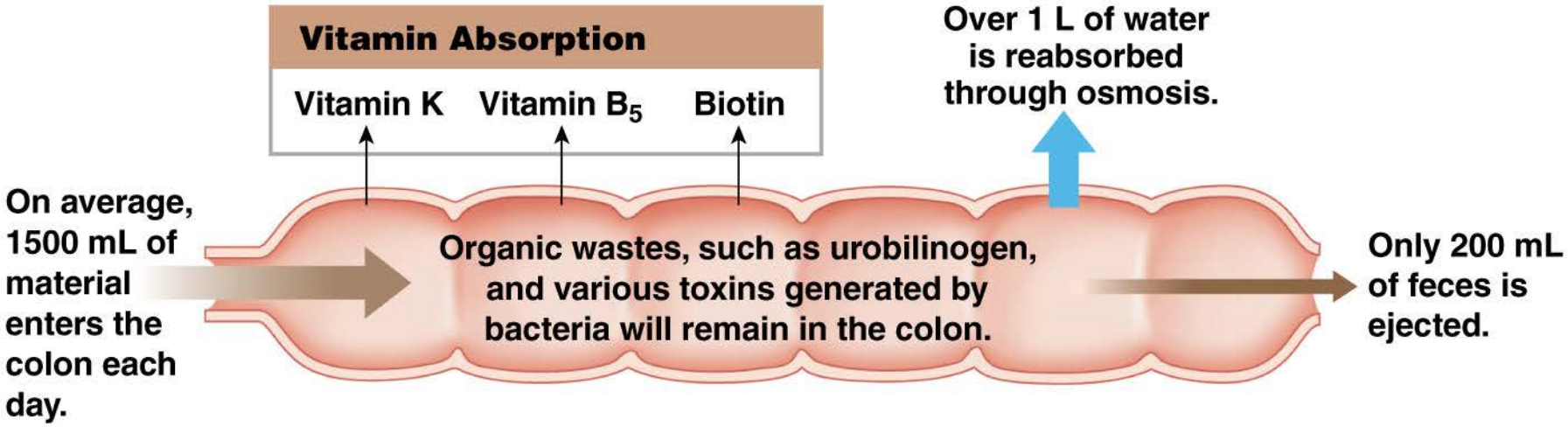
Module 22.17: Compaction and elimination of feces

Absorption in the large intestine

- Accounts for <10 percent of all nutrient absorption in the digestive tract
- Vitamin absorption
  - Biotin, vitamin K, vitamin B_5
    - Produced by normal bacteria in the colon



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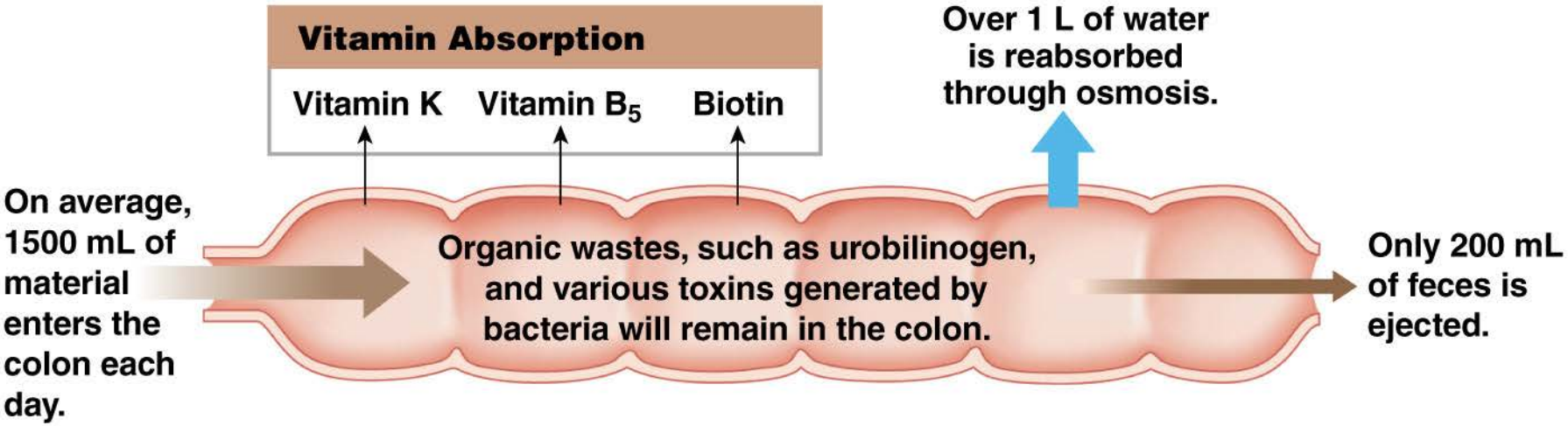
Module 22.17: Compaction and elimination of feces

Absorption in the large intestine (continued)

- Water reabsorption
  - Prevents dehydration
  - ~1500 mL of material enters colon
    - Over 1 L of water is reabsorbed through osmosis
    - ~200 mL of feces are



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Module 22.17: Compaction and elimination of feces

Feces

- About 200 mL of feces are ejected each day
  - 75 percent water
  - ~20 percent mixture of indigestible material, inorganic matter, remains of epithelial cells
  - 5 percent bacteria
    - Bacterial compounds contribute to odor of feces
      - Ammonia
      - *Indole* and *skatole*
        - Nitrogen-containing compounds
      - *Hydrogen sulfide*
        - Produces a “rotten-egg” odor

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Module 22.17: Compaction and elimination of feces

Defecation reflex

- Begins with distension of rectal wall after arrival of feces
- Triggered by stretch receptors in the rectal wall
- Involves two positive feedback loops
  1. **Long reflex**
     - Coordinated by sacral parasympathetic system
     - Stimulates mass movements that push feces toward the rectum from the descending colon and sigmoid colon
  2. **Short reflex**
     - Stimulates the myenteric plexus in the sigmoid colon and rectum

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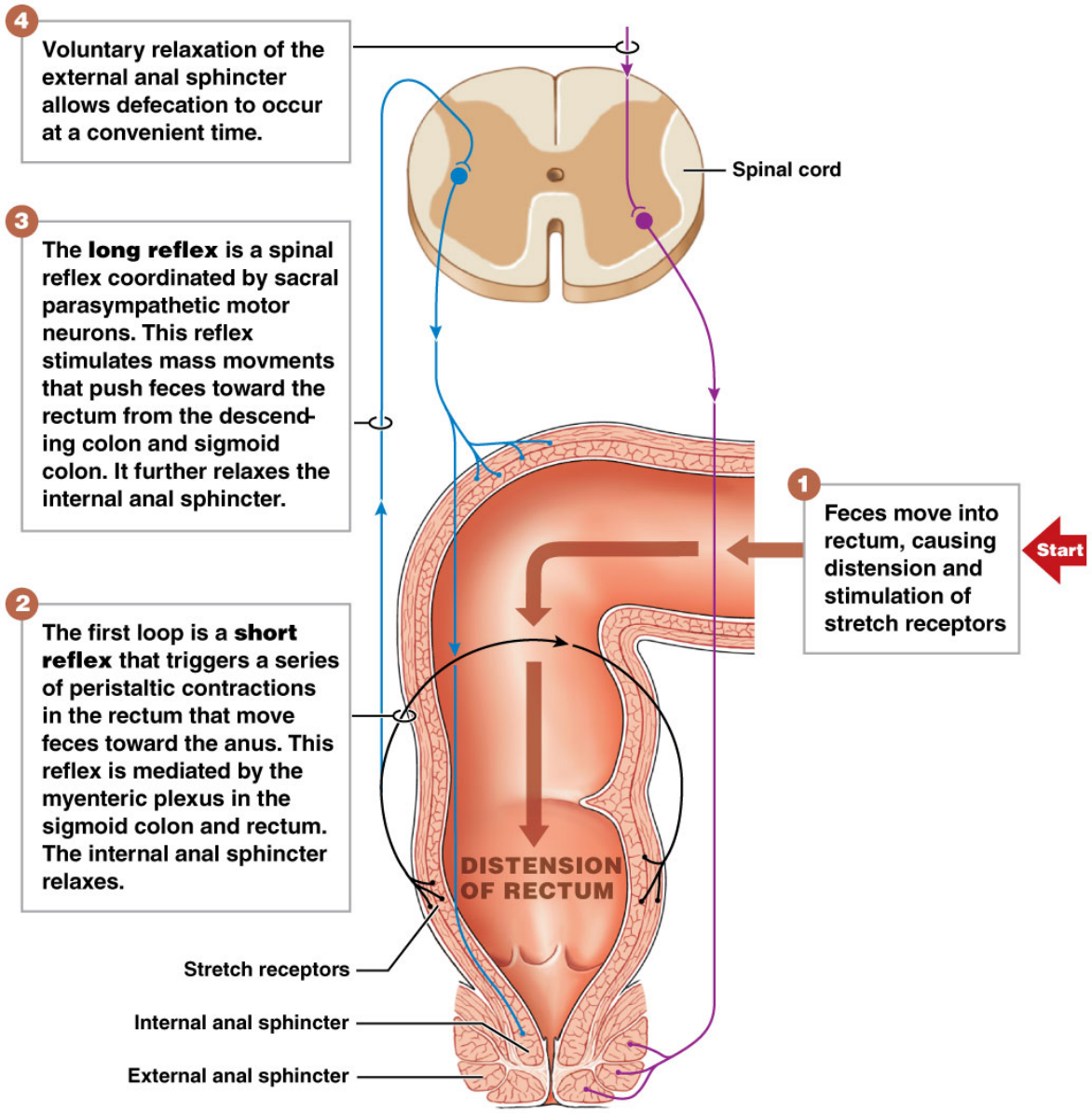
Defecation reflex



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Module 22.17: Review

A. How does digestion occur in the large intestine?
B. Define *hemorrhoids.*
C. Describe the two positive feedback loops involved in the defecation reflex.

Learning Outcome: Describe the large intestine's histology and role in fecal compaction, and explain the defecation reflex.

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Section 3: Accessory Digestive Organs

Learning Outcomes

22.18 Describe the functions of the accessory organs of the digestive system.

22.19 Discuss the structure and functions of the salivary glands.

22.20 Describe the anatomy and location of the liver and gallbladder.

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Section 3: Accessory Digestive Organs

Learning Outcomes (continued)

22.21 Describe the histological features of liver tissue.

22.22 Describe the structure, functions, and regulatory activities of the gallbladder.

22.23 Describe the structure, functions, and regulatory activities of the pancreas.

22.24 **Clinical Module:** Briefly describe several digestive system disorders.

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Module 22.18: Some accessory digestive organs have secretory functions

Accessory digestive organs

- **Salivary glands**
  - Produce saliva containing mucins and enzymes
- **Gallbladder**
  - Stores and concentrates bile secreted by the liver
- **Pancreas**
  - Exocrine cells secrete buffers and digestive enzymes
  - Endocrine cells secrete several hormones
- **Liver**
  - Almost 200 known functions

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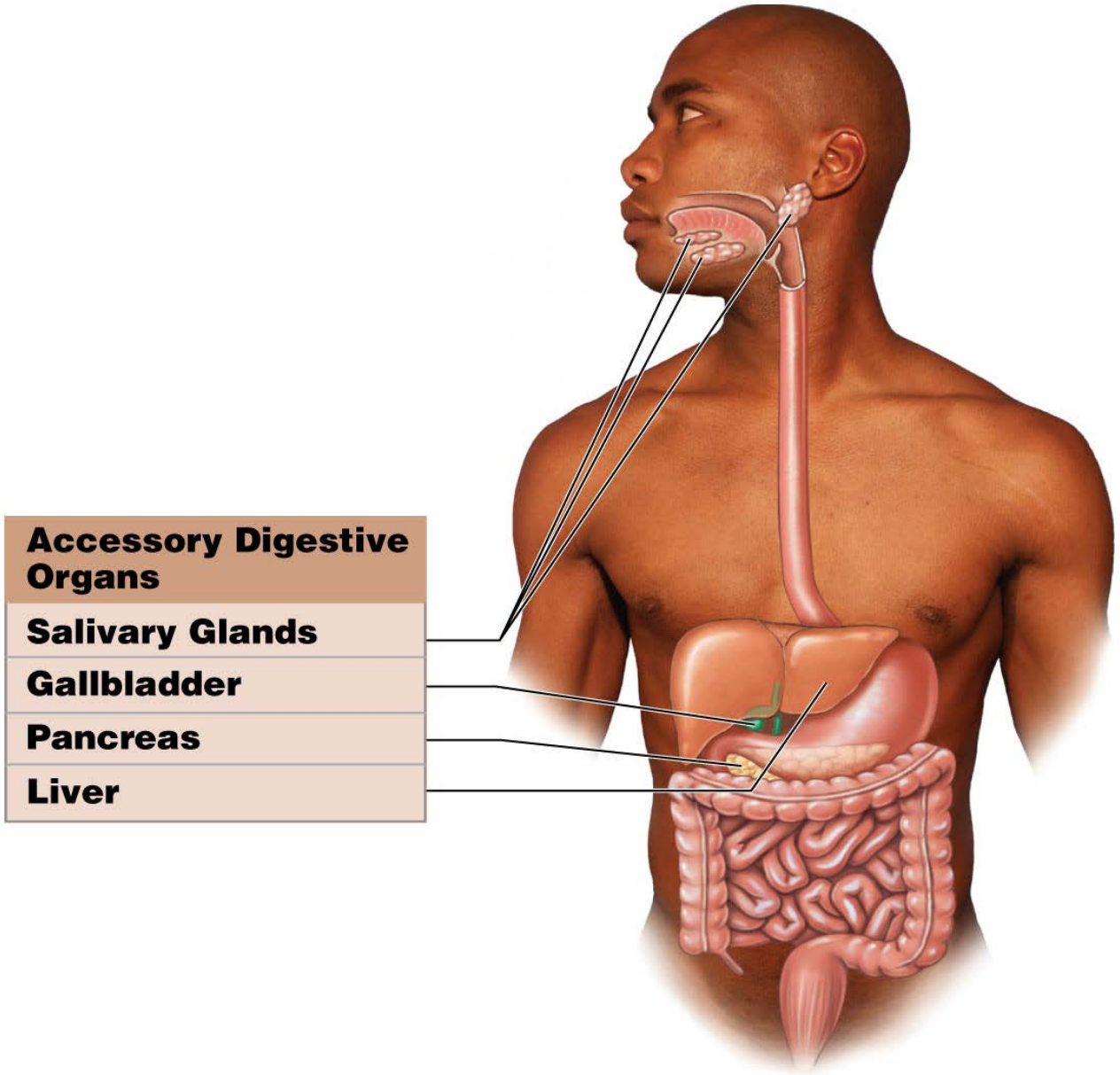
Accessory digestive organs



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Module 22.18: Accessory digestive organs

Accessory digestive organs (continued)

- Salivary glands, pancreas, and liver also have vital metabolic and endocrine functions

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Digestive and Metabolic Functions of the Liver

- Synthesizing and secreting bile
- Storing glycogen and lipids
- Maintaining normal concentrations of glucose, amino acids, and fatty acids in the bloodstream
- Synthesizing and interconverting nutrient types (such as the conversion of carbohydrates to lipids)
- Synthesizing and releasing cholesterol bound to transport proteins
- Inactivating toxins
- Storing iron
- Storing fat-soluble vitamins

Other Major Functions

- Synthesizing plasma proteins
- Synthesizing clotting factors
- Phagocytizing damaged red blood cells (by stellate macrophages)
- Storing blood
- Absorbing and breaking down circulating hormones and immunoglobulins
- Absorbing and inactivating lipid-soluble drugs

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Module 22.18: Review

A. What is the function of the salivary glands?
B. Distinguish between the exocrine and endocrine secretions of the pancreas.
C. Which accessory organ of the digestive system is responsible for almost 200 known functions?

Learning Outcome: Describe the functions of the accessory organs of the digestive system.

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Module 22.19: Saliva lubricates, moistens, and protects the mouth and begins carbohydrate digestion

Salivary glands

- Three pairs of glands
- Secrete saliva into the oral cavity through ducts
  - Saliva from each pair has slightly different properties
- Salivary reflex stimulates:
  - Receptors monitored by trigeminal nerve (V)
  - Taste buds innervated by cranial nerves VII, IX, or X
- Parasympathetic stimulation increases salivary secretion

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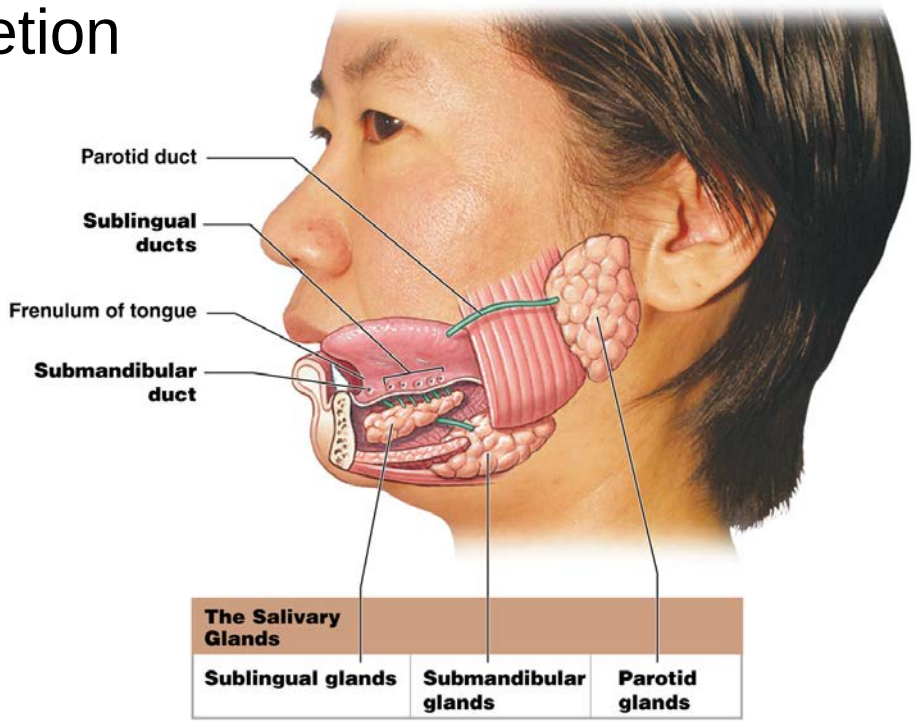
Module 22.19: Salivary glands

Three pairs of salivary glands

1. **Sublingual salivary glands**
   - Lie under either side of the tongue
   - Secrete into numerous **sublingual ducts**
     - Open along either side of the lingual frenulum
   - Produce a mucous secretion that acts as a buffer and lubricant
   - Provide ~5 percent of total saliva secretion



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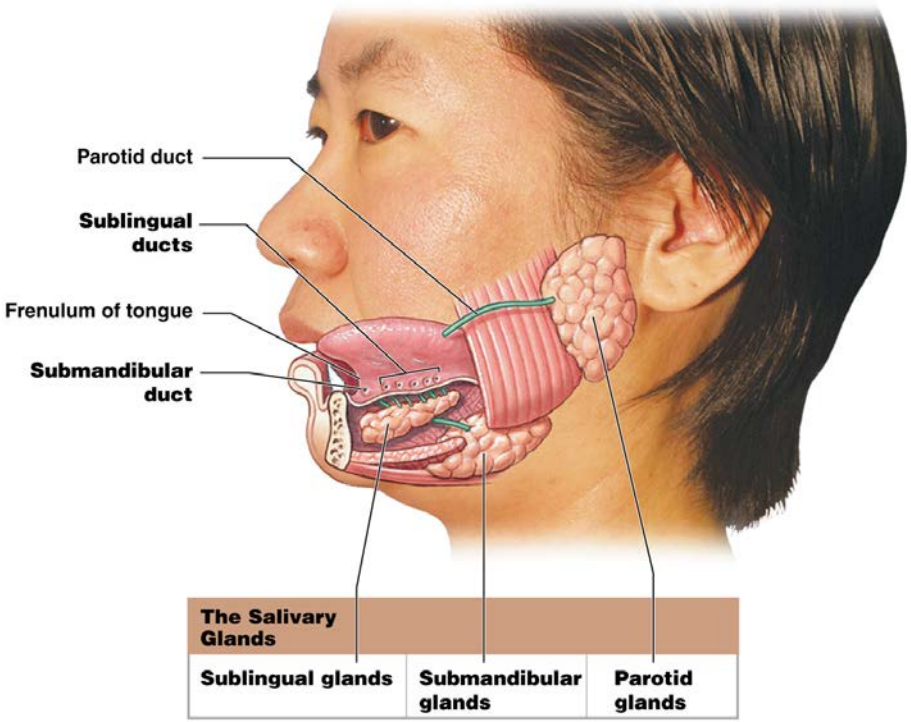
Module 22.19: Salivary glands

Three pairs of salivary glands (continued)

2. **Submandibular salivary glands**
   - Along the inner surface of the mandible (in the mandibular groove)
   - Each secretes into a **submandibular duct**
     - Opens on each side of the anterior margin of the lingual frenulum



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Module 22.19: Salivary glands

Three pairs of salivary glands (continued)

2. **Submandibular salivary glands** (continued)
   - Secrete a mixture of buffers, mucins, **salivary amylase**
     - Amylase is an enzyme that breaks down starches
   - Cells transport IgA antibodies into the saliva
     - Provides protection against pathogens
   - Provide ~70 percent of total saliva secretion

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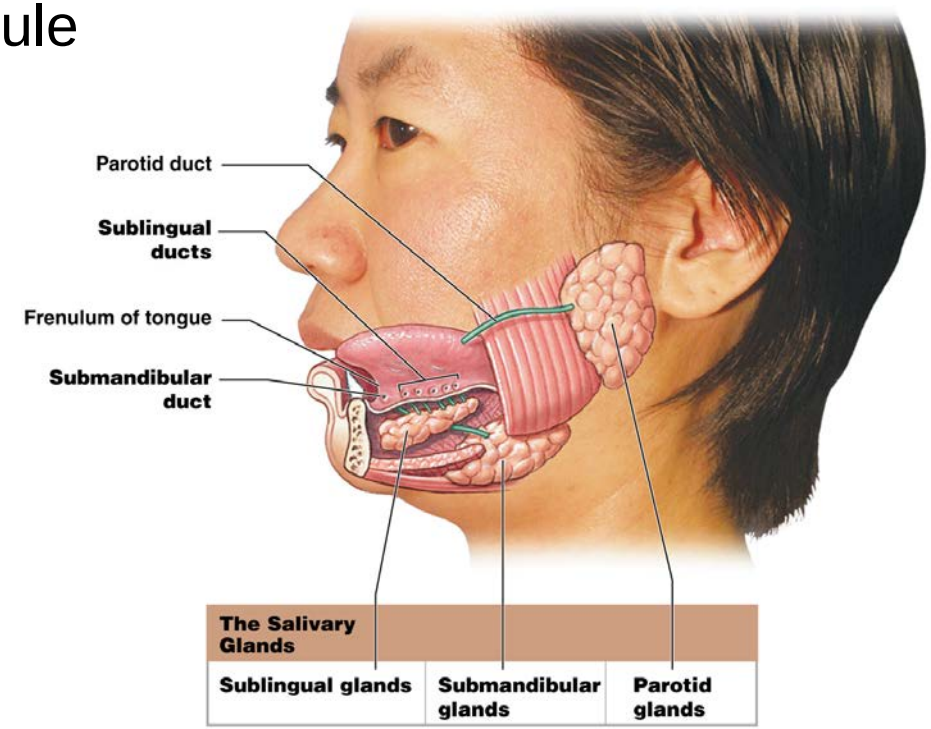
Module 22.19: Salivary glands

Three pairs of salivary glands (continued)

3. Parotid salivary glands

- Lie inferior to the zygomatic arch, deep to the skin, covering the mandible
- Each secretes into a **parotid duct**
  - Empties into the vestibule of the mouth near the second upper molar



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Module 22.19: Salivary glands

Three pairs of salivary glands (continued)

3. **Parotid salivary glands** (continued)
   - Produce serous secretion containing large amounts of salivary amylase
   - Provide ~25 percent of total saliva secretion

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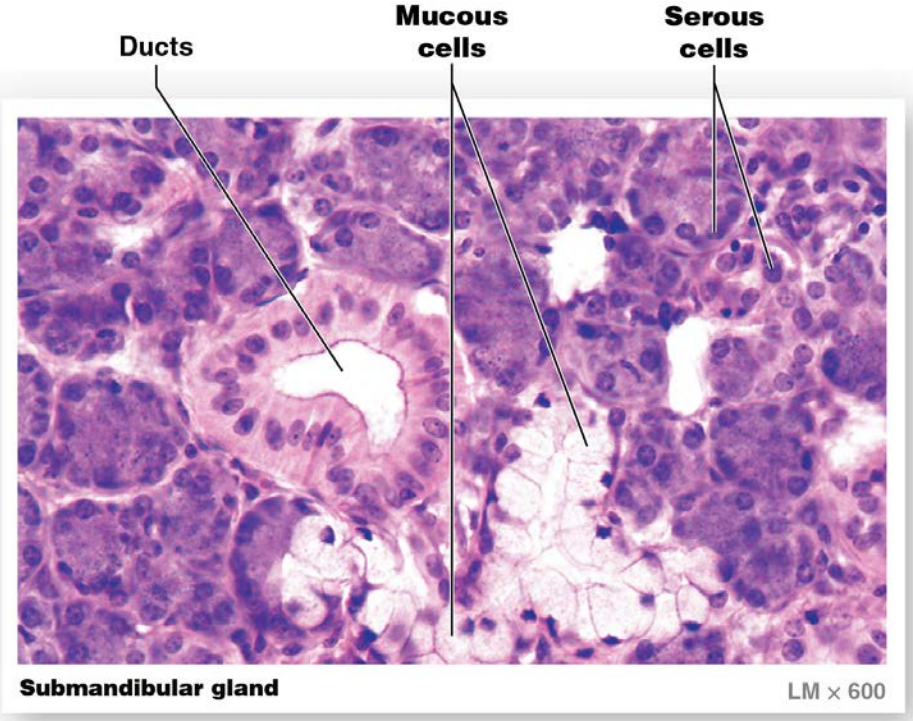
Module 22.19: Salivary glands

Cells of the salivary glands and ducts

- Duct cells
  - Assist in the secretion of buffers and antibodies
- **Mucous cells**
  - Secrete mucins, water, and buffers



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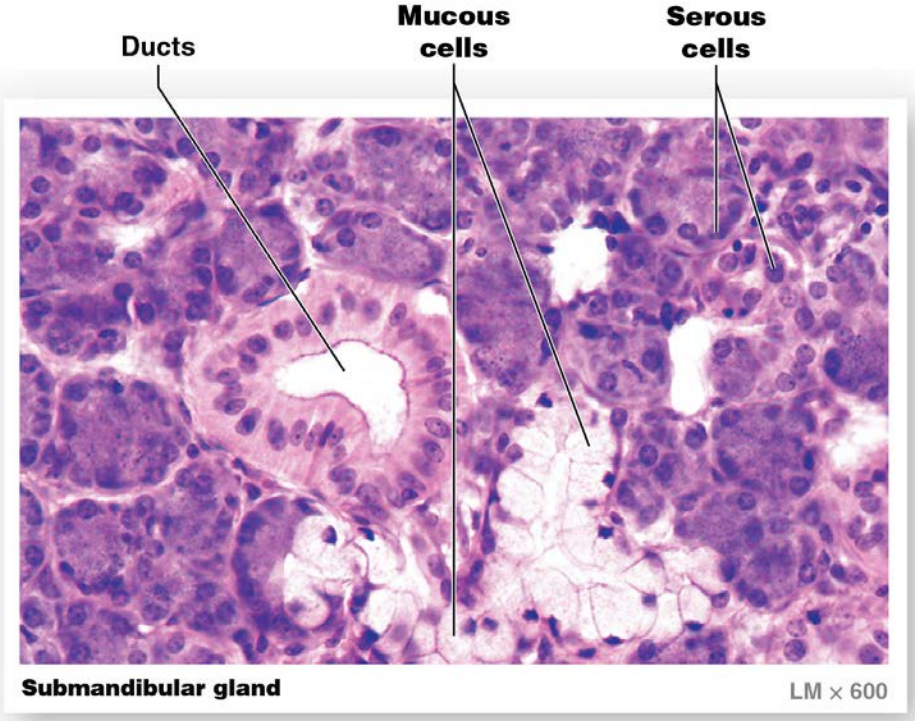
Module 22.19: Salivary glands

Cells of the salivary glands and ducts (continued)

- **Serous cells**
  - Secrete salivary amylase and **lysozyme** (an antibacterial enzyme)
  - Transport antibodies from the interstitial fluid into the saliva



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Module 22.19: Salivary glands

Saliva

- Mixture of glandular secretions
- Salivary glands produce 1.0–1.5 L of saliva each day (99.4 percent of that volume is water)
- Functions
  - Constantly flushes oral surfaces
  - Buffers keep pH of mouth near 7.0 and prevent buildup of acids produced by bacteria
  - Contains antibodies (IgA) and lysozyme to help control oral bacteria populations
  - Mixes with food to form a bolus to be easily swallowed

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Saliva

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Module 22.19: Review

A. Name the three pairs of salivary glands.
B. Damage to the parotid glands would affect the digestion of which nutrient?
C. Which pair of salivary glands contributes most to saliva production?
D. Which pair of salivary glands secretes substances that reduce oral bacteria populations?

Learning Outcome: Discuss the structure and functions of the salivary glands.

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Module 22.20: The liver, the largest visceral organ, is divided into left, right, caudate, and quadrate lobes

Liver

- Largest visceral organ
  - Weighs 1.5 kg (3.3 lb)
- Wrapped in tough fibrous capsule
- Covered by layer of visceral peritoneum
- Composed of four lobes
  - Right, left, caudate, quadrate

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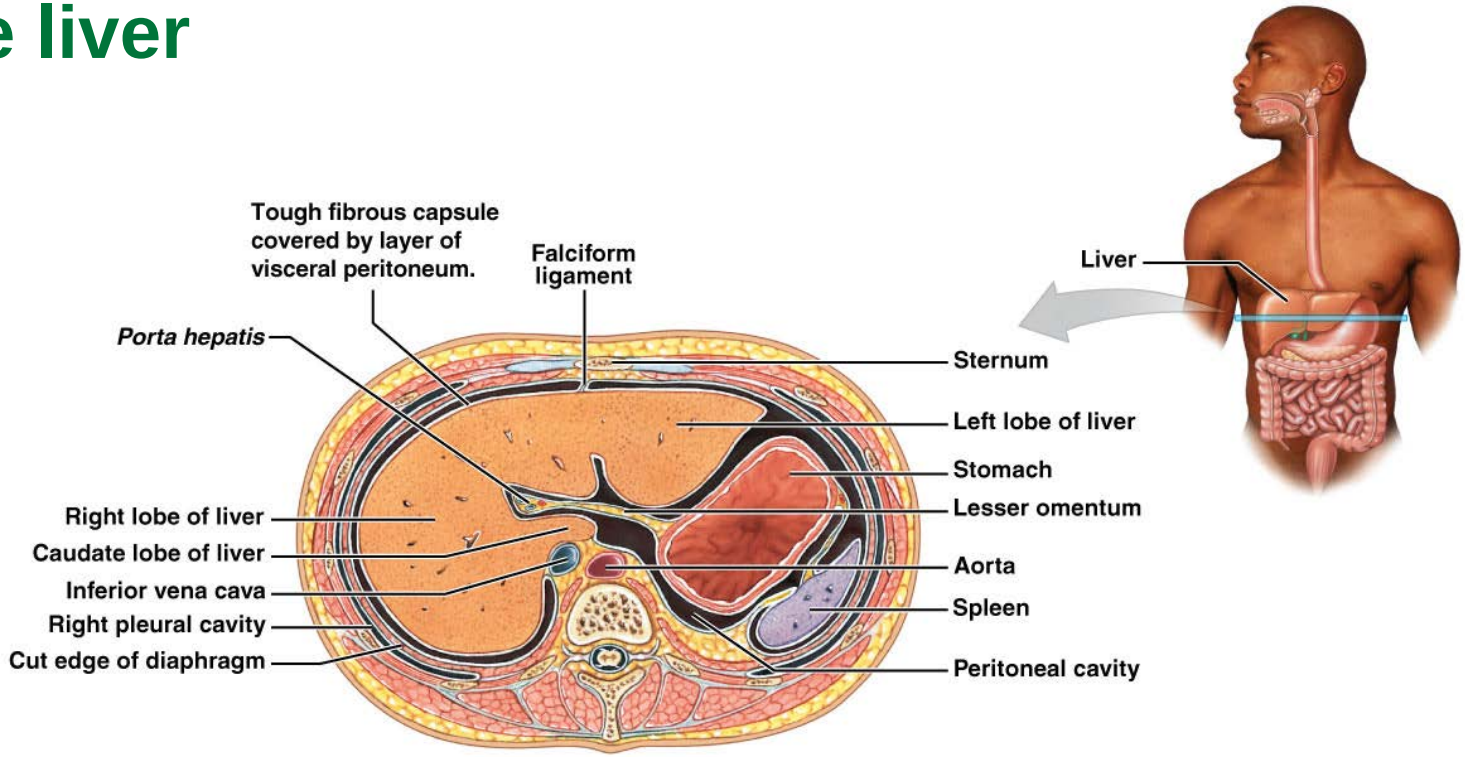
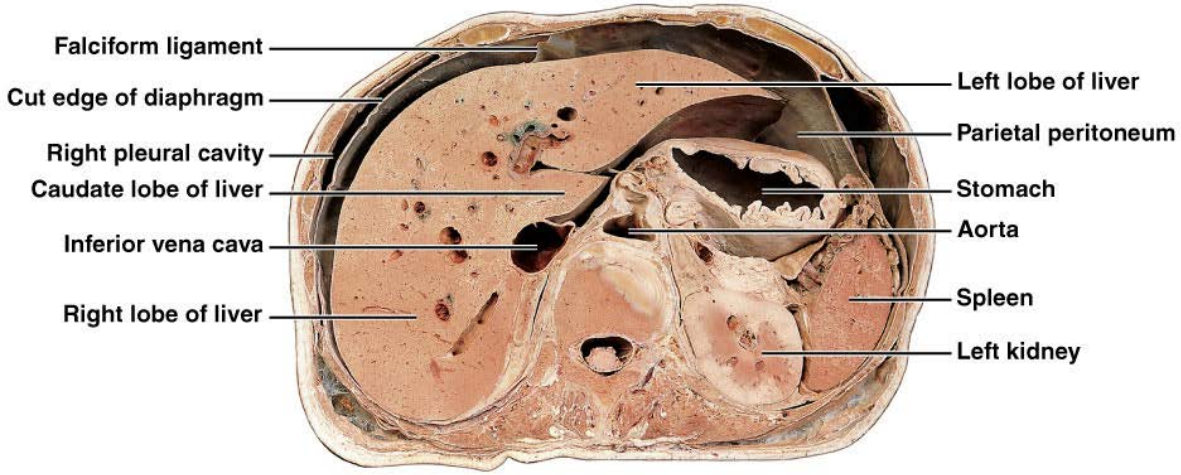
The liver



Horizontal section at the level of vertebra T_{11} (diagrammatic view)



Horizontal section at the level of vertebra T_{12} (cadaver)

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Module 22.20: The liver

Lobes of the liver

1. **Left lobe**
2. **Right lobe**
   - Separated from the left lobe by the **falciform ligament**
     - **Coronary ligament** is an extension of the falciform ligament
     - Surrounds the **bare area**
       - Region where the liver contacts the diaphragm
       - No peritoneal covering
     - **Round ligament** is a thickening in the posterior margin of the falciform ligament
       - Marks the path of the fetal umbilical vein

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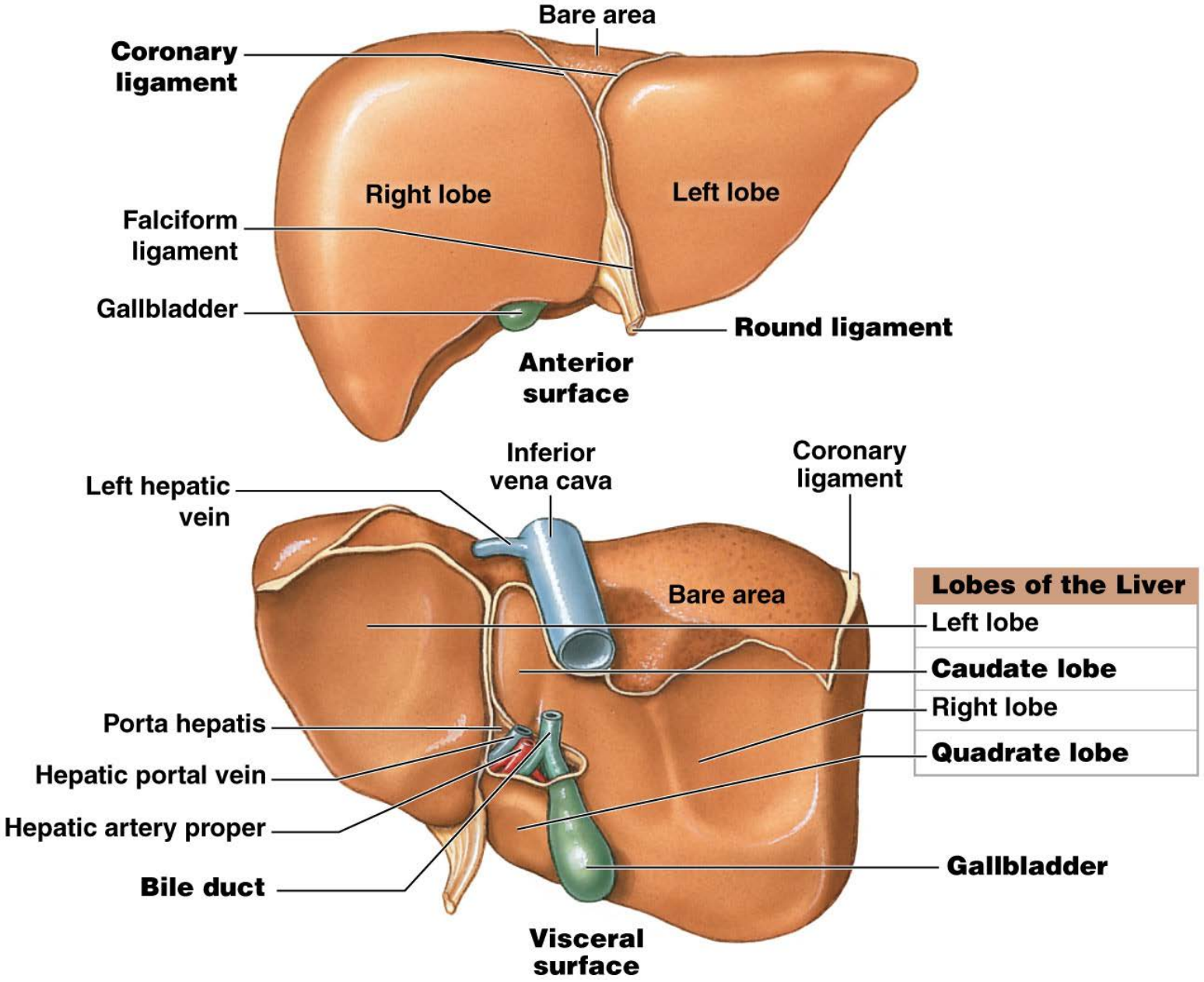
Anterior and posterior surfaces of the liver



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Module 22.20: The liver

Lobes of the liver (continued)

3. **Caudate lobe**
   - On the posterior surface of the liver
   - Separated from right lobe by an indentation left by the inferior vena cava
4. **Quadrate lobe**
   - Located between the left lobe and the gallbladder

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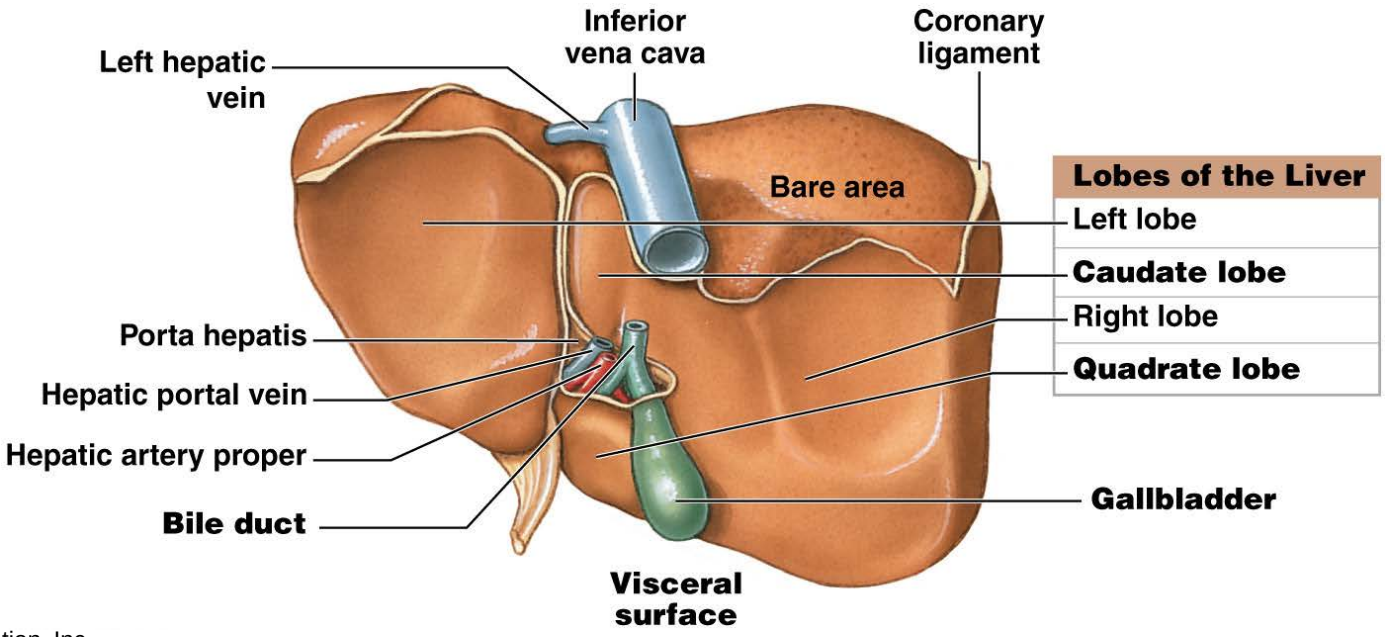
Module 22.20: The liver

Associated structures

- **Gallbladder**
  - Temporarily stores bile produced by the liver
- **Bile duct**
  - Carries bile from the liver and gallbladder to the duodenum by way of the *porta hepatis*



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Module 22.20: Review

A. Describe the outer covering of the liver.
B. What structure marks the division between the left lobe and right lobe of the liver?
C. Name the lobes of the liver.
D. What is the function of the gallbladder?

Learning Outcome: Describe the anatomy and location of the liver and gallbladder.

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Module 22.21: The liver tissues have an extensive and complex blood supply

Liver lobules

- Basic functional units of the liver
- Liver contains ~100,000 liver lobules
- Each roughly 1 mm in diameter
- Adjacent lobules are separated by an **interlobular septum**
- Hexagonal shape in cross section
  - Surrounded by six **portal areas** (one at each corner of the lobule)

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Module 22.21: Liver tissues

Portal area

- Also referred to as **portal triad**
- Contains three structures
  1. A branch of the hepatic portal vein
     - Receives blood from the **hepatic portal system** bringing blood from abdominal viscera
  2. A branch of the hepatic artery proper
  3. A bile duct
- Branches from the arteries and veins of each portal area deliver blood to liver (hepatic) sinusoids of adjacent liver lobules

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Module 22.21: Liver tissues

Liver cells and liver sinusoids

- Liver lobules contain **hepatocytes** (liver cells)
  - Form series of irregular plates arranged like the spokes of a wheel
  - Plates only one cell thick
  - Exposed surfaces covered with short microvilli
- Plates of hepatocytes are separated by **liver sinusoids**
  - Delicate blood vessels
  - Lack a basement membrane
  - Resemble large fenestrated capillaries

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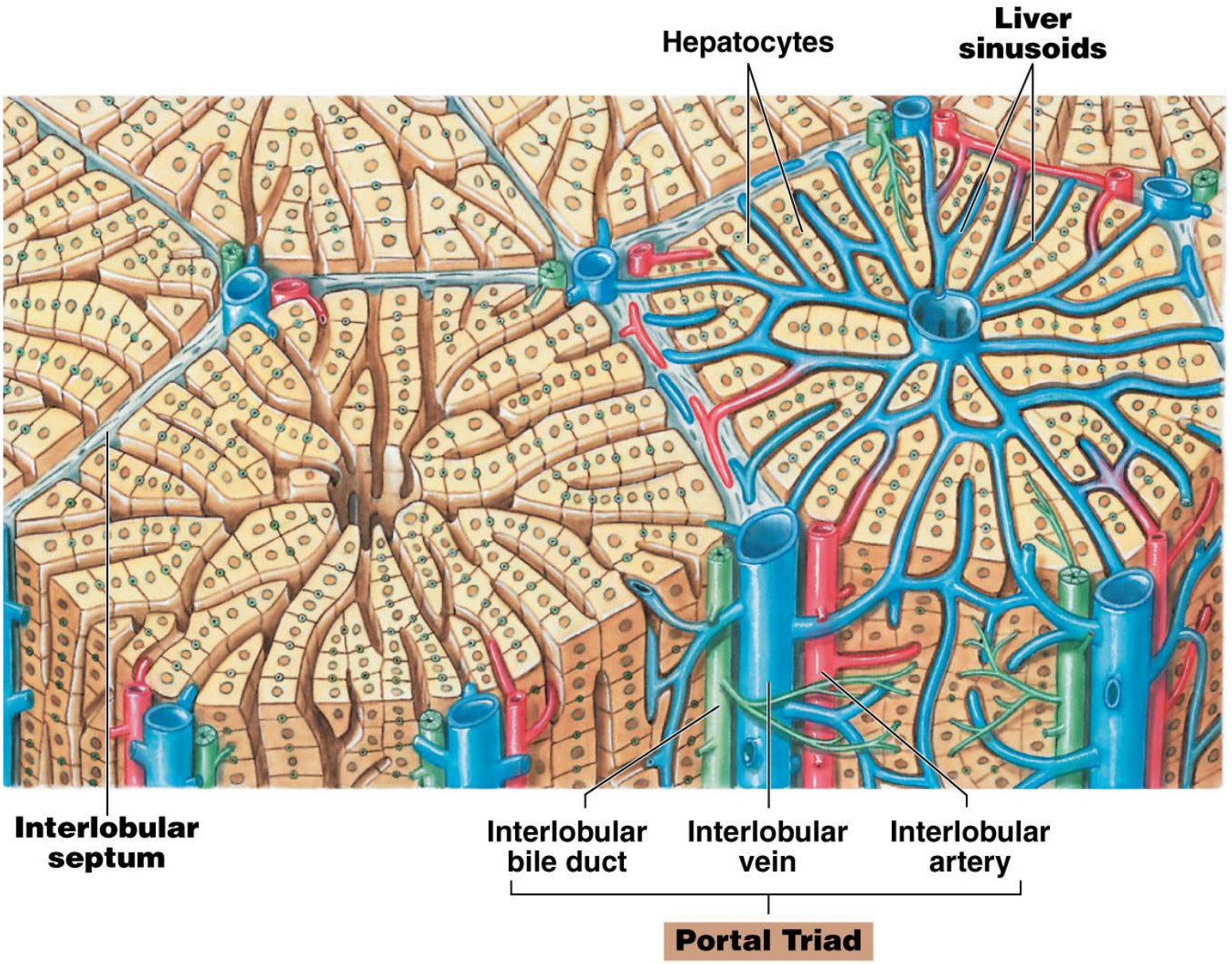
Liver tissues



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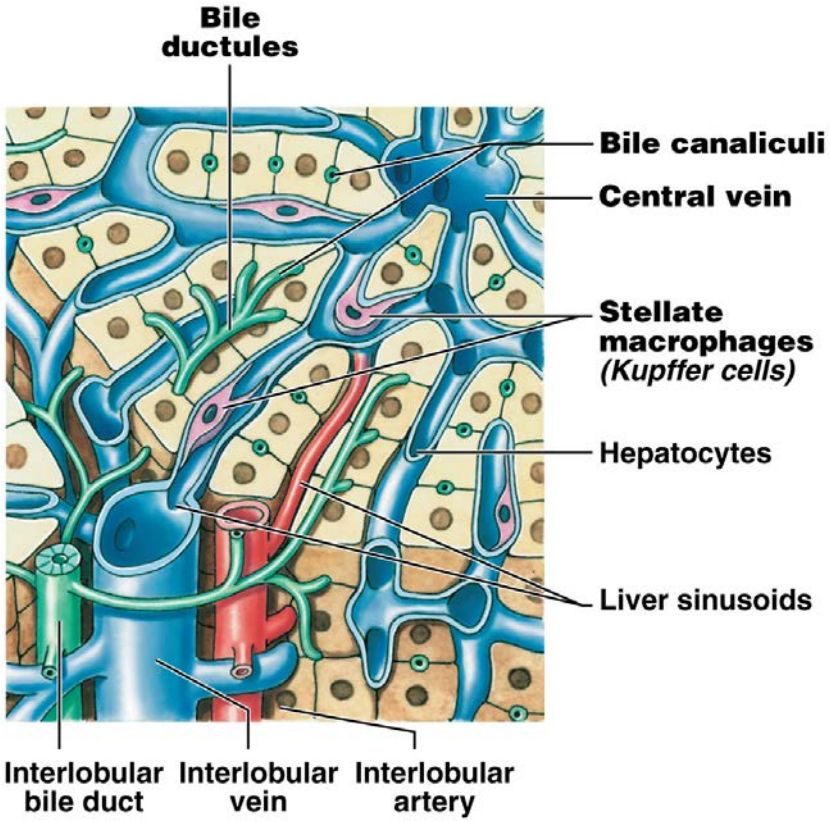
Module 22.21: Liver tissues

Functional anatomy of a liver lobule

1. Blood enters the liver sinusoids from branches of the hepatic portal vein and hepatic artery proper
   - About one-third of blood supply is arterial
   - Remainder comes from hepatic portal vein



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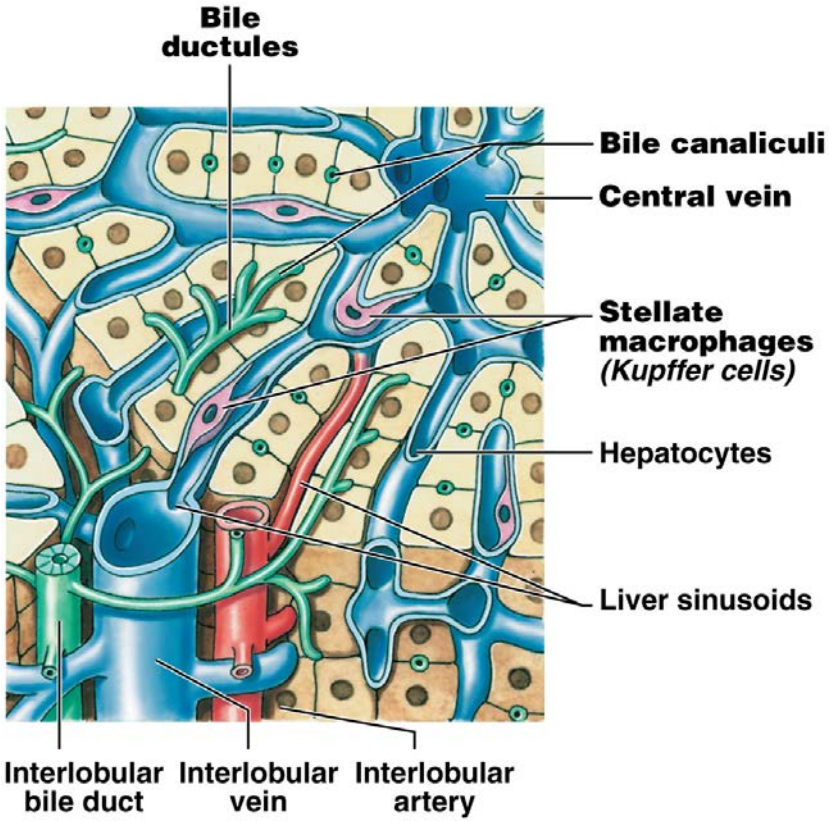
Module 22.21: Liver tissues

Functional anatomy of a liver lobule (continued)

2. Hepatocytes adjacent to the sinusoids regulate solute and nutrient levels by absorption and secretion



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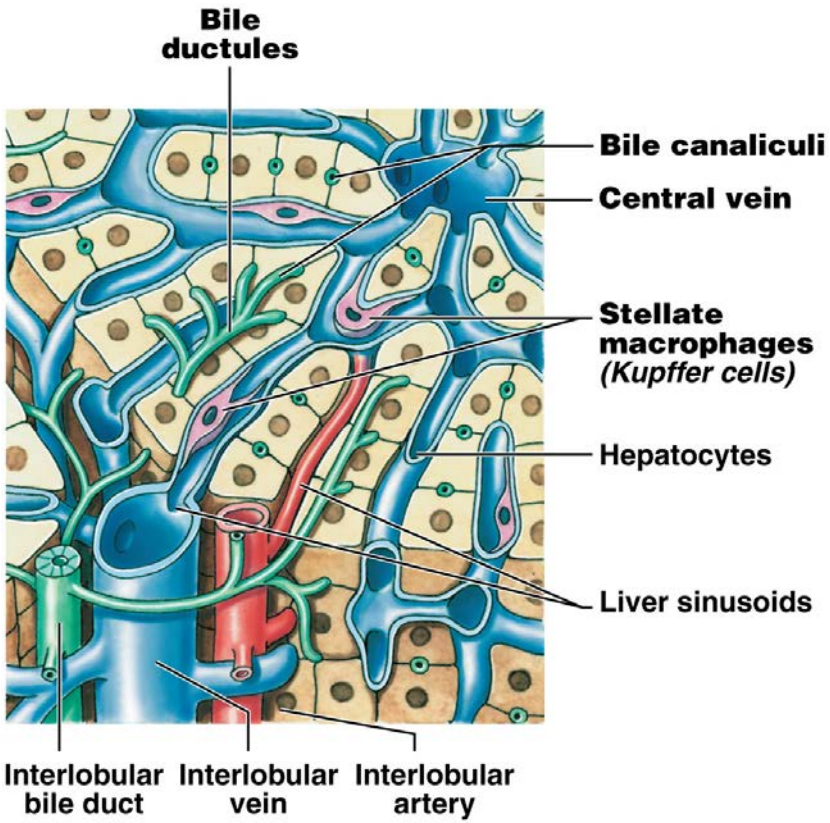
Module 22.21: Liver tissues

Functional anatomy of a liver lobule

3. **Stellate macrophages** (*Kupffer cells*) in the sinusoidal lining engulf pathogens, cell debris, and damaged blood cells
   - Also store iron, some lipids, and heavy metals (tin, mercury) absorbed by the digestive tract



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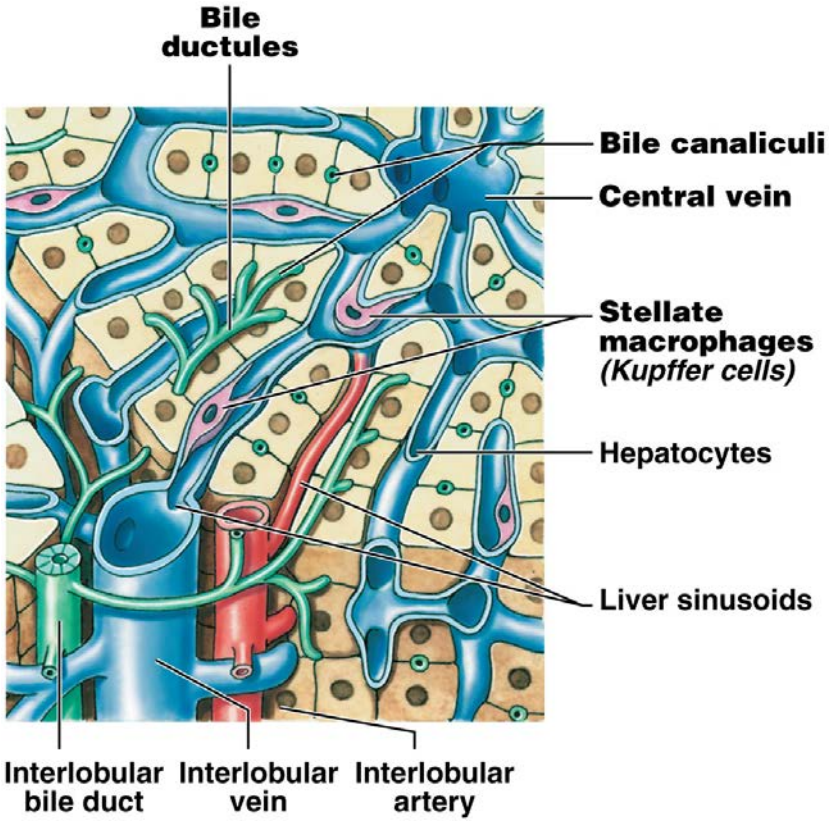
Module 22.21: Liver tissues

Functional anatomy of a liver lobule

4. Sinusoids all drain into a **central vein**
   - Central veins of all lobules merge to form the hepatic veins
   - Hepatic veins empty into the inferior vena cava



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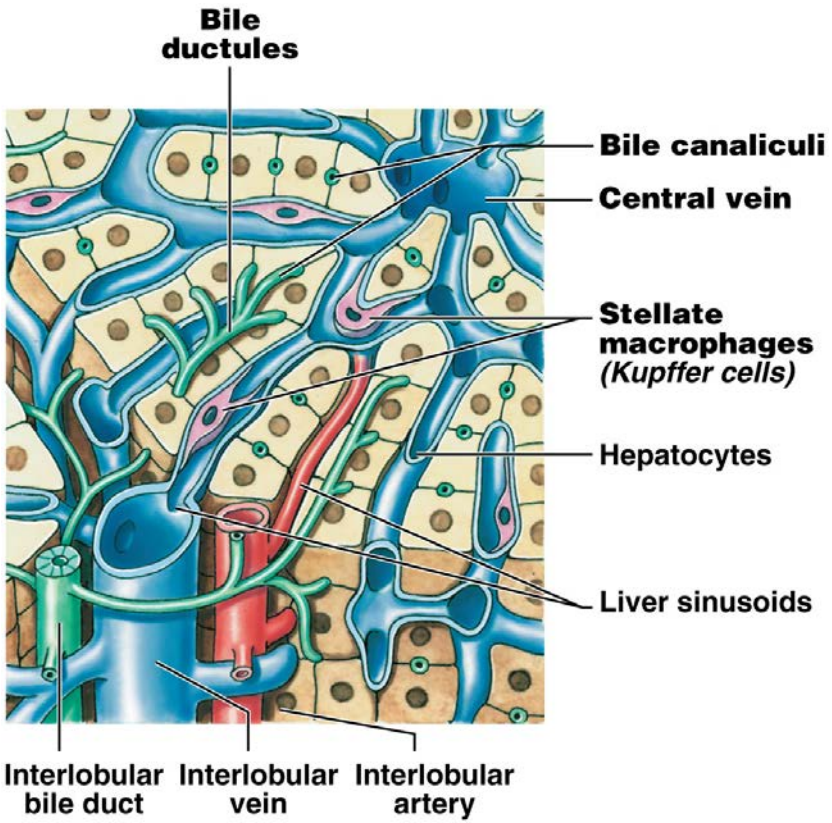
Module 22.21: Liver tissues

Functional anatomy of a liver lobule (continued)

5. Hepatocytes secrete **bile** into a network of narrow channels called **bile canaliculi**
6. Bile canaliculi merge to form **bile ductules**
   - Bile ductules carry bile to **bile ducts** in nearest portal area
   - Bile plays a role in the digestion of fats



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Module 22.21: Liver tissues

Liver diseases and conditions

- Can lead to degenerative changes in the liver tissue and constriction of blood flow
  - Examples: **viral hepatitis** and alcoholism
- Constricted blood flow from a clot or damaged tissue causes **portal hypertension**
  - Increased pressure in the hepatic portal system
  - Distends small peripheral veins and capillaries
  - Can cause rupture of those vessels
    - Leads to potentially fatal bleeding
  - Also forces fluid into the peritoneal cavity, producing ascites

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Module 22.21: Review

A. Define *hepatocyte*.
B. Describe a portal triad.
C. Define *stellate macrophages*, and indicate their functions.

Learning Outcome: Describe the histological features of liver tissue.

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Module 22.22: The gallbladder stores and concentrates bile

Gallbladder

- Hollow, pear-shaped organ
- Located in the depression on the posterior surface of the liver's right lobe
- Divided into three regions: the **fundus**, the **body**, and the **neck**
- Stores and concentrates bile secreted from the liver
  - Bile salts break lipid droplets apart
  - Process called **emulsification**
  - Increases available surface area for enzymes

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Module 22.22: The gallbladder

Path of bile

- **Right** and **left hepatic ducts** collect bile from the liver bile ducts
- Hepatic ducts unite to form the **common hepatic duct**
- Bile flows from the common hepatic duct into:
  - The **bile duct** (to the duodenum)
  - The **cystic duct** (to the gallbladder for storage)
    - When needed, contraction of the gallbladder forces bile back along the cystic duct to the common bile duct

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Module 22.22: The gallbladder

Path of bile (continued)

- The common bile duct penetrates the duodenal wall and meets the pancreatic duct at the **duodenal ampulla**
  - Chamber within the **duodenal papilla**
- The **hepatopancreatic sphincter** encircles the lumens of these areas where they enter the duodenum
  - Prevents flow of bile into the duodenum except at mealtime

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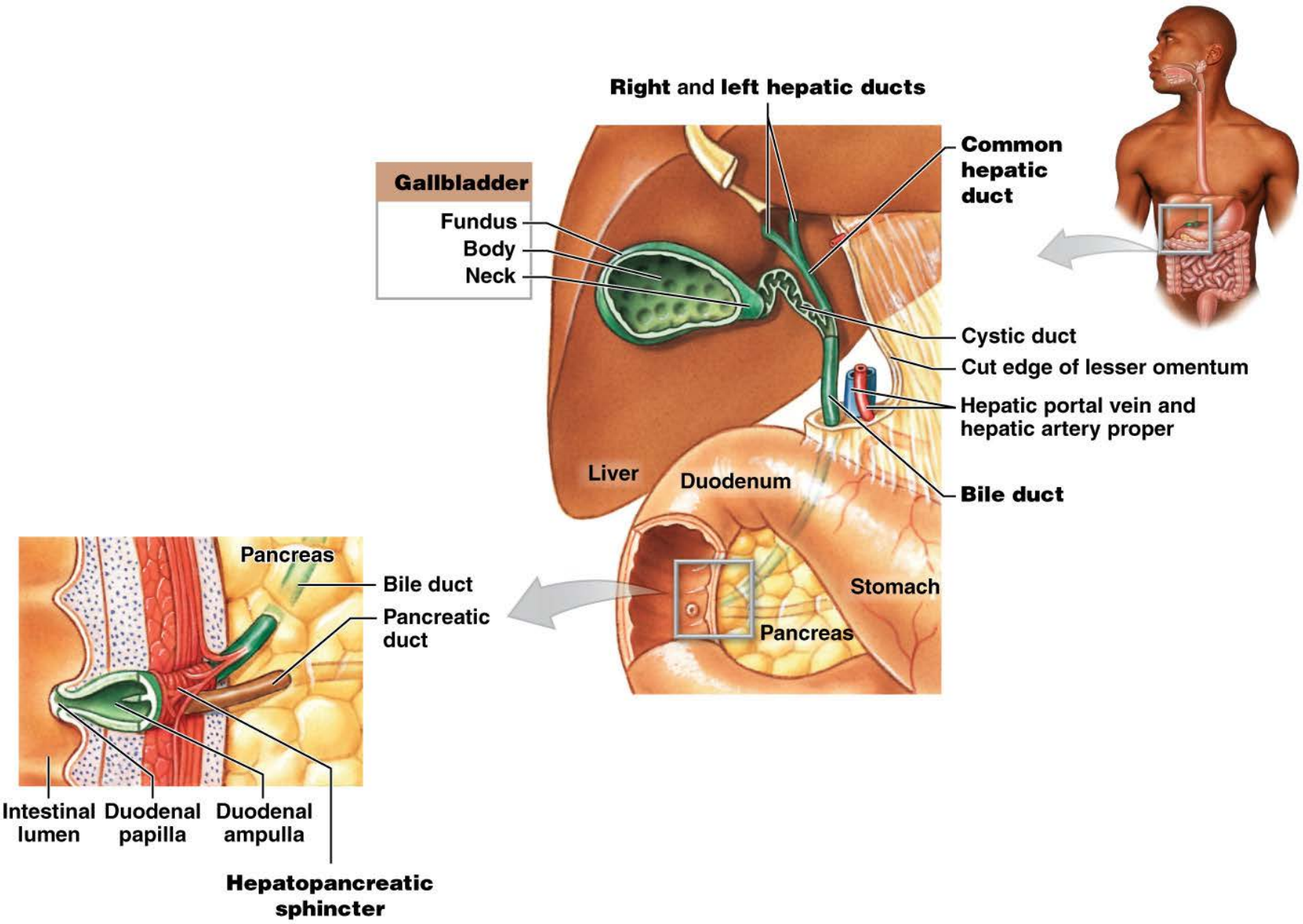
The gallbladder



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Module 22.22: The gallbladder

Functional relationships in bile storage/ejection

- Liver produces about 1 L of bile per day
- Unless hepatopancreatic sphincter is open, bile flows into the gallbladder for storage
- Release of CCK by the duodenum triggers:
  - Dilation of the hepatopancreatic sphincter
  - Contraction of the gallbladder
- Bile is ejected into the duodenum
- Bile salts break apart lipid droplets through **emulsification**

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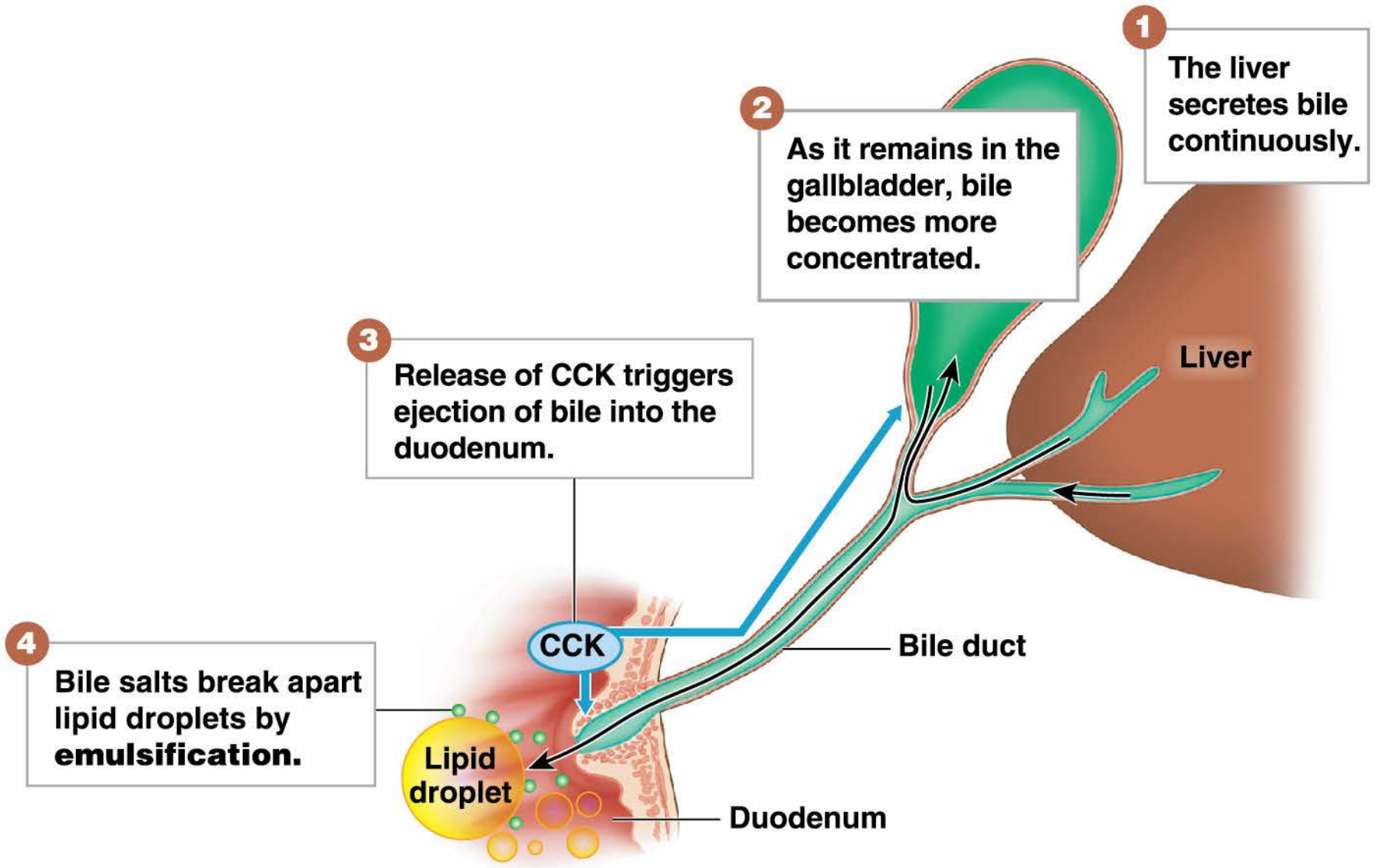
Flow and function of bile



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Module 22.22: Review

A. Define *emulsification*.
B. Trace a drop of bile from the hepatic ducts to the duodenal lumen.

Learning Outcome: Describe the structure, functions, and regulatory activities of the gallbladder.

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Module 22.23: The pancreas has vital endocrine and exocrine functions

Pancreas—posterior to stomach

- **Head**, body, tail
- **Pancreatic duct**
  - Delivers exocrine secretions to the duodenum
  - **Pancreatic juice**
    - Combination of water and ions (secreted by epithelial cells lining the duct) and exocrine secretions (enzymes and buffers)
    - About 1000 mL (1 qt) of pancreatic juice are produced each day

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Module 22.23: The pancreas

Pancreas—posterior to stomach (continued)

- **Accessory pancreatic duct** (Santorini duct)
  - Branches from the pancreatic duct and empties separately into the duodenum
  - Occurs in 3–10 percent of the population

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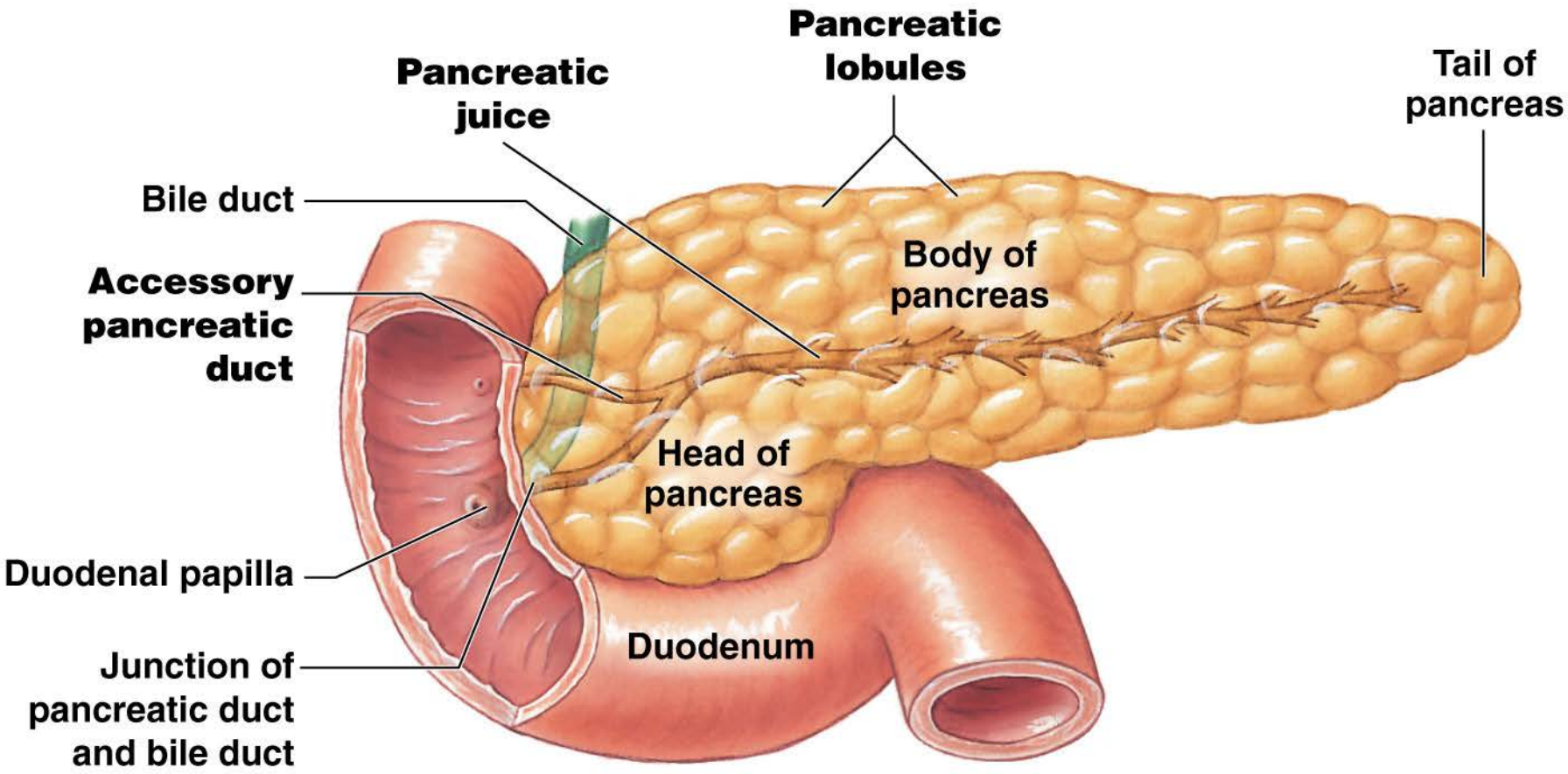
The pancreas



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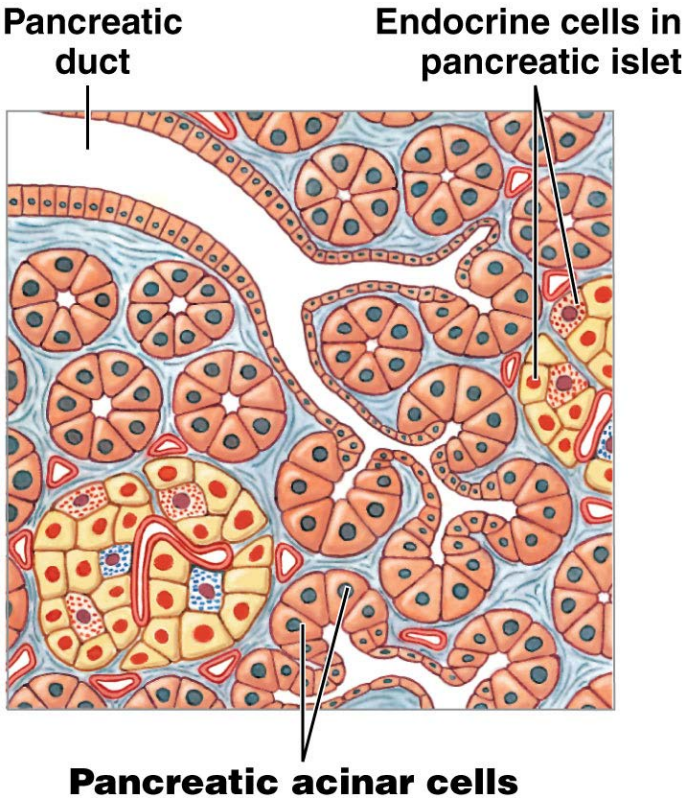
Module 22.23: The pancreas

Pancreatic tissue

- Dominated by **pancreatic acini**
  - Produce digestive enzymes and buffers
  - Contain **pancreatic acinar cells**
    - Secrete pancreatic enzymes
- Pancreatic islets
  - Contain endocrine cells



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Module 22.23: The pancreas

Major pancreatic enzymes

- **Pancreatic alpha-amylase**
  - Carbohydrase (breaks down certain starches)
  - Almost identical to salivary amylase
- **Pancreatic lipase**
  - Breaks down certain complex lipids
  - Releases products that can be easily absorbed

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Module 22.23: The pancreas

Major pancreatic enzymes (continued)

- **Nucleases**
  - Break down RNA or DNA
- **Proteolytic enzymes**
  - Break proteins apart into mixture of dipeptides, tripeptides, and amino acids
  - Secreted as inactive proenzymes
  - Activated in the duodenum
    - Active forms include trypsin, chymotrypsin, carboxypeptidase, elastase

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Module 22.23: Review

A. What is the primary digestive function of the pancreas?

Learning Outcome: Describe the structure, functions, and regulatory activities of the pancreas.

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Module 22.24: Clinical Module: Disorders of the digestive system are diverse and relatively common

Oral cavity

- **Periodontal disease**
  - Most common cause for loss of teeth
  - Occurs when dental plaque forms between gums and teeth
  - Resulting bacterial activity may cause:
    - **Gingivitis** (inflammation of the gums)
    - Tooth decay
    - Eventual breakdown of periodontal ligaments and surrounding bone

Gingivitis

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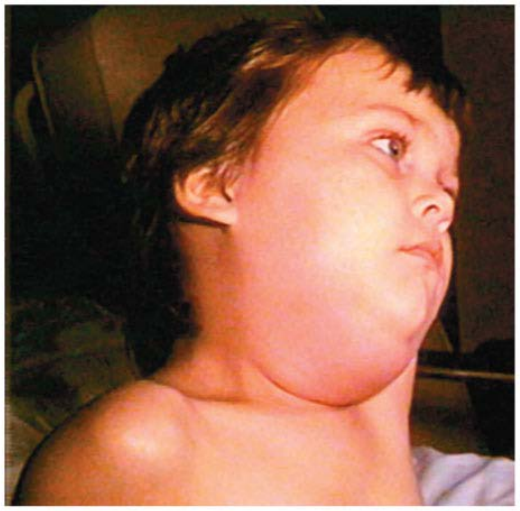
Module 22.24: Disorders of the digestive system

Salivary glands

- **Mumps**
  - Infection of the salivary glands caused by the **mumps virus**
    - Most often affects the parotid salivary gland
  - Can also affect other organs, such as the gonads and the meninges
  - Typically occurs at 5–9 years of age



Mumps in parotid gland

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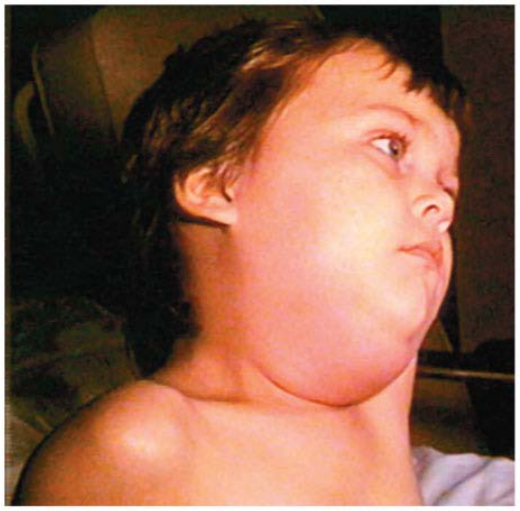
Module 22.24: Disorders of the digestive system

Salivary glands (continued)

- **Mumps** (continued)
  - May cause sterility in postadolescent males due to infection of the testes
  - Effective vaccine available, usually as part of MMR (measles, mumps, rubella) vaccine
    - Given to infants after age 15 months



Mumps in parotid gland

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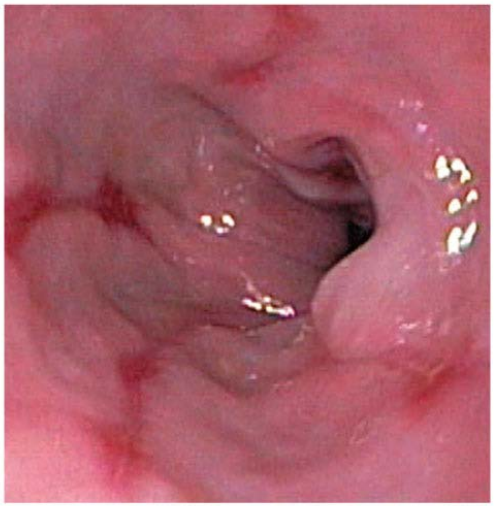
Module 22.24: Disorders of the digestive system

Esophagus

- **Esophagitis**
  - Inflammation of the esophagus
  - Usually results from stomach acids leaking through a weakened or permanently relaxed lower esophageal sphincter



Esophagitis seen on endoscopy

- **Gastro-esophageal reflux**
  - Backflow of acidic stomach contents into the esophagus
  - Results in symptoms commonly called heartburn

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Module 22.24: Disorders of the digestive system

Liver

- **Hepatitis** (inflammation of the liver)
  - Can be caused by alcohol abuse, drugs, or infection
  - **Cirrhosis**
    - Hepatitis characterized by degeneration of liver cells and replacement with scar tissue
  - **Viral hepatitis A**, **B**, and **C**
    - Virus destroys liver cells
    - Causes inflamed, tender liver and high fever
- **Jaundice**
  - Buildup of bilirubin causes yellowing of skin and eyes

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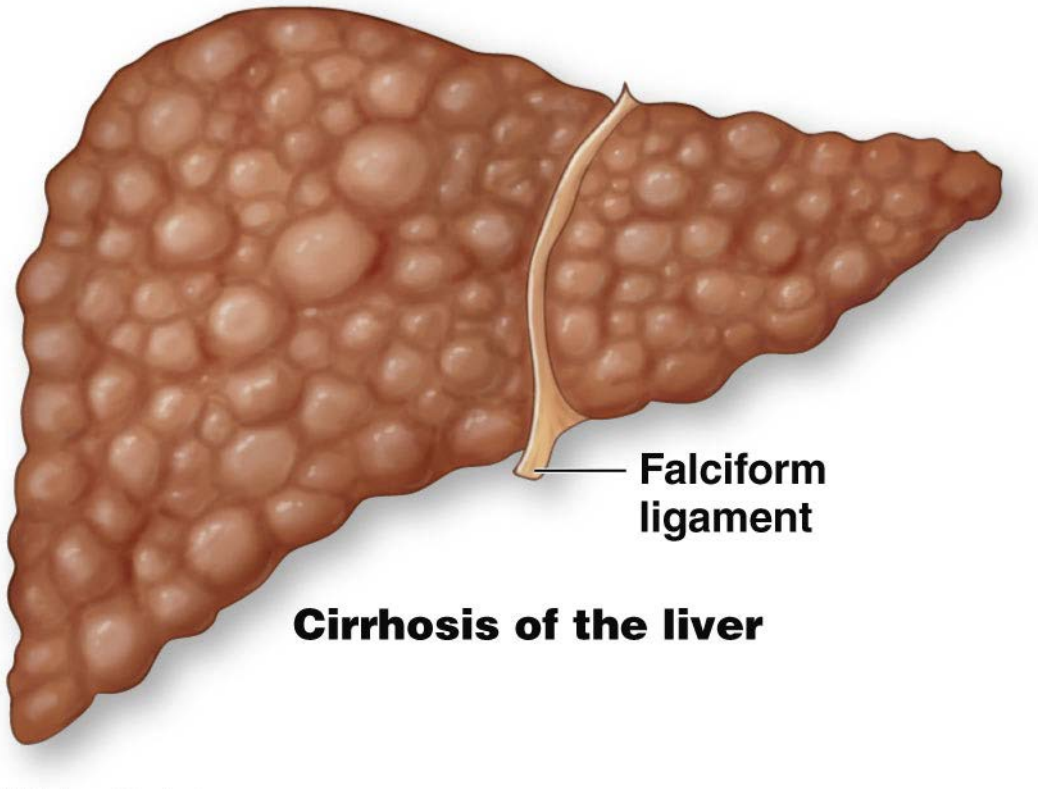
Cirrhosis of the liver



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Module 22.24: Disorders of the digestive system

Gallbladder

- **Gallstones**
  - Crystals of insoluble minerals and salts forming when bile becomes too concentrated
  - Small gallstones may be flushed through bile ducts and excreted with no problems

Gallstones

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Module 22.24: Disorders of the digestive system

Gallbladder (continued)

- **Cholecystitis** (*chole*, bile + *kystis*, bladder + *itis*, inflammation)
  - Irritation and damage to the gallbladder wall caused by gallstones too large to pass
  - Gallstones may block cystic duct or common bile duct
  - Potential treatment involves surgical removal of the gallbladder
  - Surgery has no effect on bile production

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Module 22.24: Disorders of the digestive system

Stomach

- **Gastritis**
  - Inflammation of the mucous membrane lining the stomach
  - From ingesting drugs (e.g., aspirin, alcohol), severe stress, bacterial infection, ingestion of strong chemicals

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Module 22.24: Disorders of the digestive system

Stomach (continued)

- **Peptic ulcer**
  - Forms when gastric enzymes and acids erode through the stomach or duodenal lining
  - **Gastric ulcer** is a peptic ulcer in the stomach wall
  - **Duodenal ulcer** is a peptic ulcer in the duodenum wall
  - Bacterial infection by *Helicobacter pylori* responsible for over 80 percent of peptic ulcers
- Treatment includes:
  - **Cimetidine** (Tagamet), which inhibits acid production
  - Antibiotics for *H. pylori* if present

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Gastric ulcer

Gastric ulcer

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Module 22.24: Disorders of the digestive system

Pancreas

- **Pancreatitis**
  - Inflammation of the pancreas
  - Can be due to duct blockage, viral infection, or toxic drugs (including alcohol)
  - Injury to pancreatic cells activates lysosomes
    - Digestive enzymes are activated and released within the cells
  - In about one-eighth of cases, death occurs when the digestive process does not stop
    - Lysosomal enzymes destroy the pancreas

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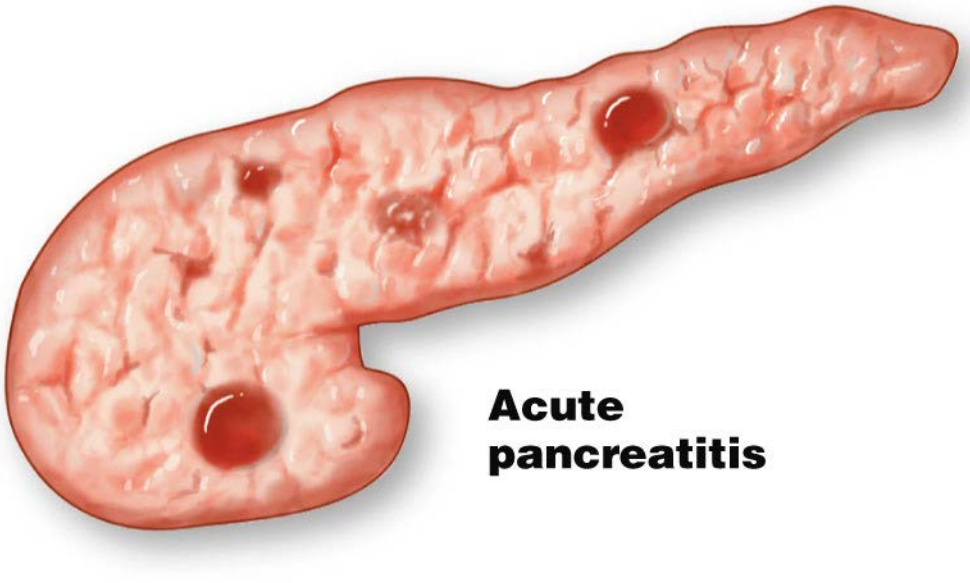
Acute pancreatitis



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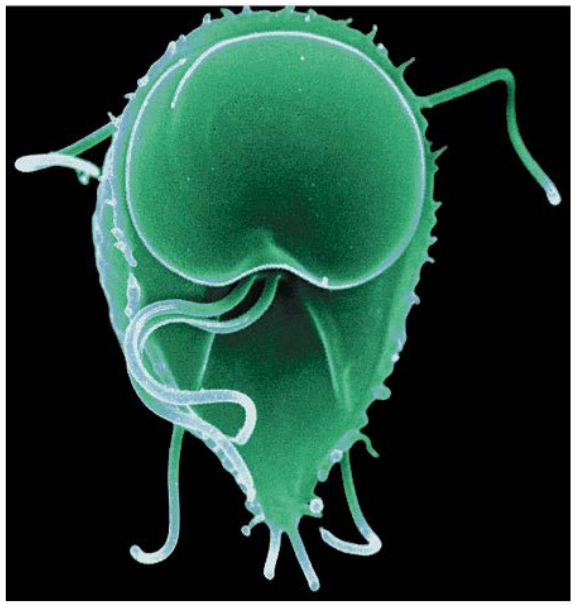
Module 22.24: Disorders of the digestive system

Small intestine

- **Enteritis**
  - Inflammation of the intestine (usually referring to the small intestine)
  - Causes watery bowel movements (**diarrhea**)
  - One cause is infection by *Giardia lamblia*



- **Dysentery**
  - Inflammation of small and large intestine, producing diarrhea containing blood and mucus

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Module 22.24: Disorders of the digestive system

Small intestine (continued)

- **Gastroenteritis**
  - Inflammation of the stomach and intestines
  - Due to pathogenic infection
  - Often in areas with poor sanitation and low water quality

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Module 22.24: Disorders of the digestive system

Large intestine

- **Colitis**
  - Inflammation of the colon
  - Often with diarrhea or **constipation**
    - Diarrhea from too much fluid or from compromised absorption capabilities
    - **Constipation**
      - Infrequent bowel movement, usually with dry, hard feces
      - Results from excess water reabsorption due to slow-moving feces

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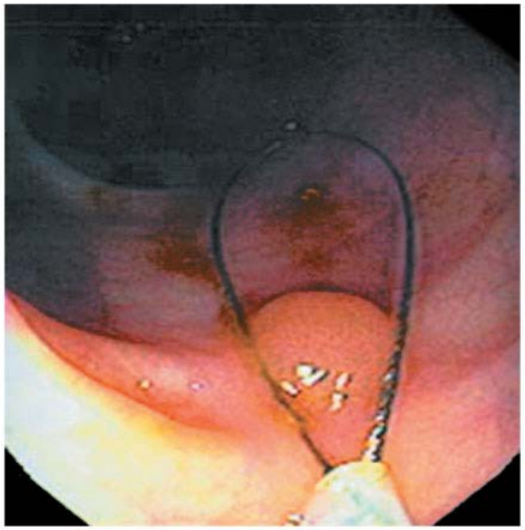
Module 22.24: Disorders of the digestive system

Large intestine (continued)

- **Colorectal cancer**
  - Third most common cancer in the U.S.
  - Affects both men and women
  - Most common in those over age 50
  - Risk factors include diet rich in animal fat and low in fiber
  - Inherited disorders may also promote the formation of epithelial tumors



Colon polyp seen on colonoscopy

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Module 22.24: Disorders of the digestive system

Large intestine (continued)

- Begin as small, localized tumors (**polyps**)
- Greatly improved prognosis if polyps are removed before metastasis

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Module 22.24: Review

A. Describe hepatitis.
B. Describe cholecystitis.
C. What bacterium is responsible for most peptic ulcers?

Learning Outcome: Briefly describe several digestive system disorders.

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