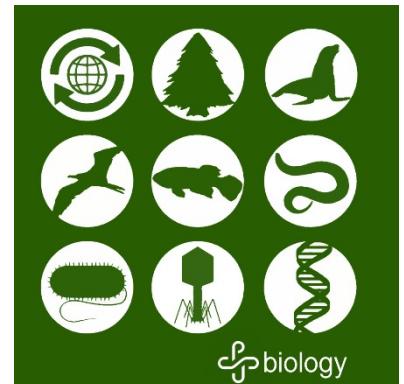


## Lymphatic, Digestive, and Associated Organs of the Digestive System

# BI 455 CHAPTER 14-16

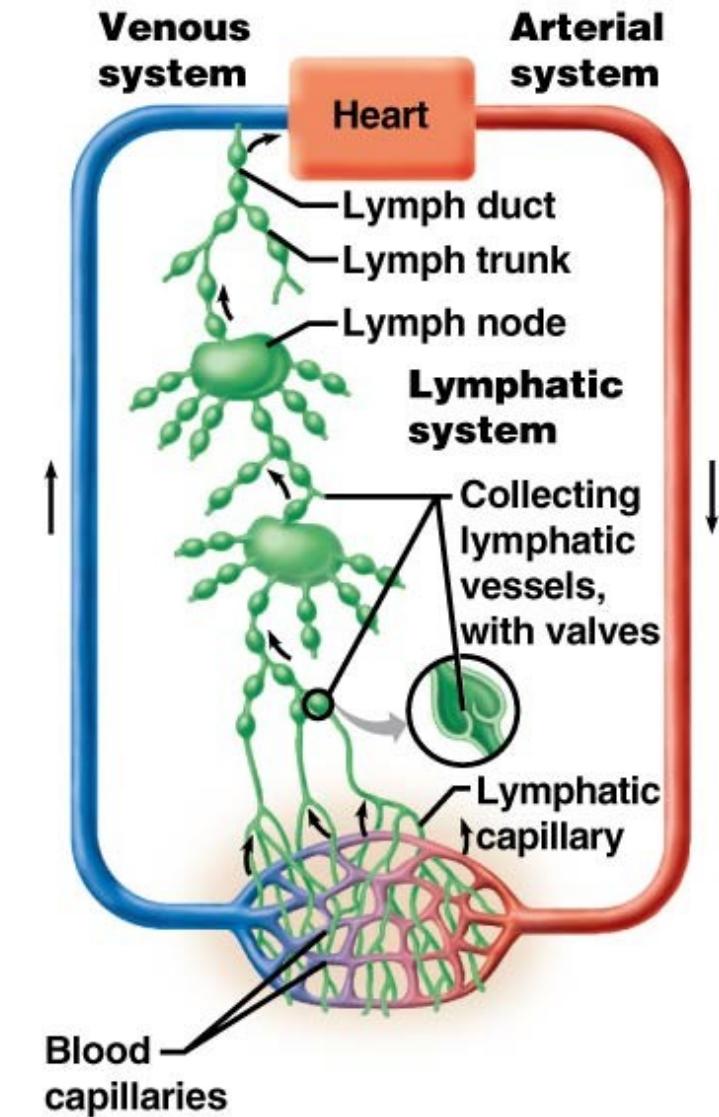


# Chapter 14: The Immune System and Lymphatic Organs

**Immune system:** Cell populations defending body from disease which are especially concentrated in lymphatic system

Fluid continually filters from the blood capillaries into the tissue spaces

- Blood capillaries reabsorb 85%
- lymphatic system absorbs 15% (2 to 4 L/day) of the water and about half of the plasma proteins enter the and then are returned to the blood



(a)

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# Mechanisms of Immune Defense

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Defenses against pathogens (environmental agents capable of producing disease such as Infectious organisms, toxic chemicals, and radiation)

**Innate (Nonspecific) Immunity:** does not depend on prior exposure

**1<sup>st</sup> defense:** External barriers, skin, and mucous membranes

**2<sup>nd</sup> defense:** Leukocytes and macrophages, antimicrobial proteins (interferons, complement system), immune surveillance, inflammation, and fever

**Adaptive (Specific) Immunity**

**3<sup>rd</sup> defense:** Relies on prior exposure of memory of pathogen, enabling faster defense in the future

Humoral: antibody marks invaders for other immune cells

Cellular: infected cells are destroyed by “killer” cells

Overview of Immune System: <http://www.youtube.com/watch?v=lWMJIMzsEMg>

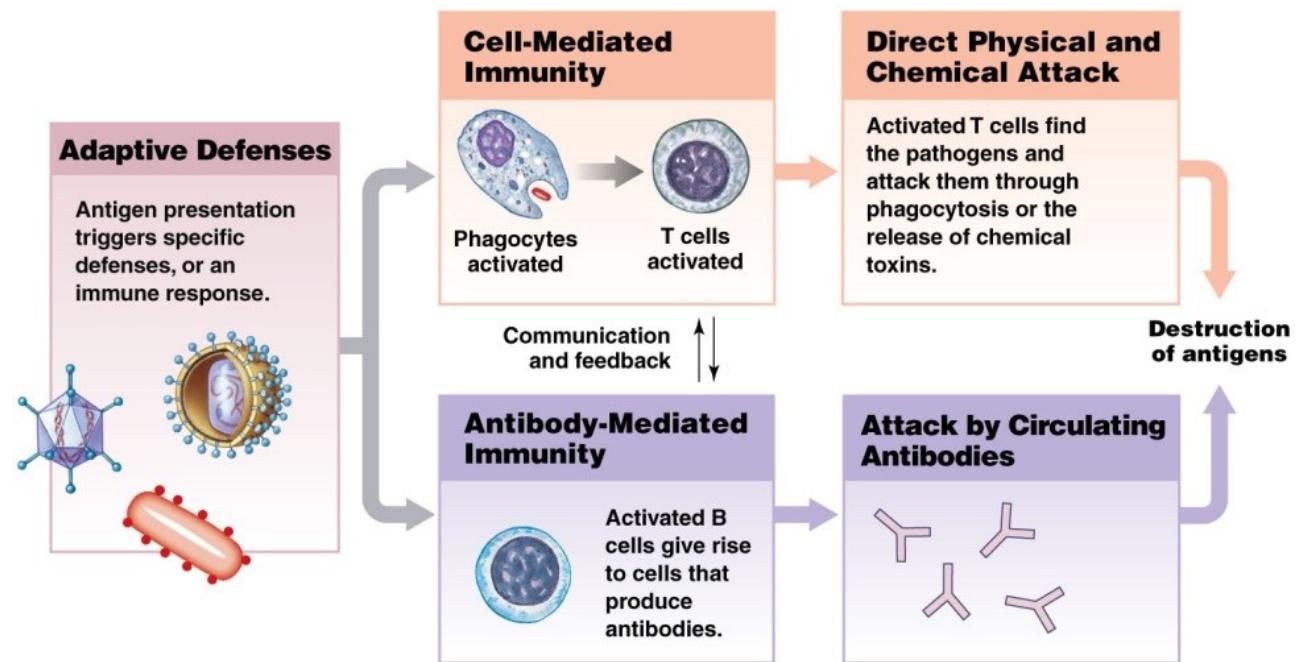
Crash Course The Immune System (long):

<https://www.khanacademy.org/partner-content/crash-course1/crash-course-biology/v/crash-course-biology-131>

# Functional classes of Adaptive Immunity

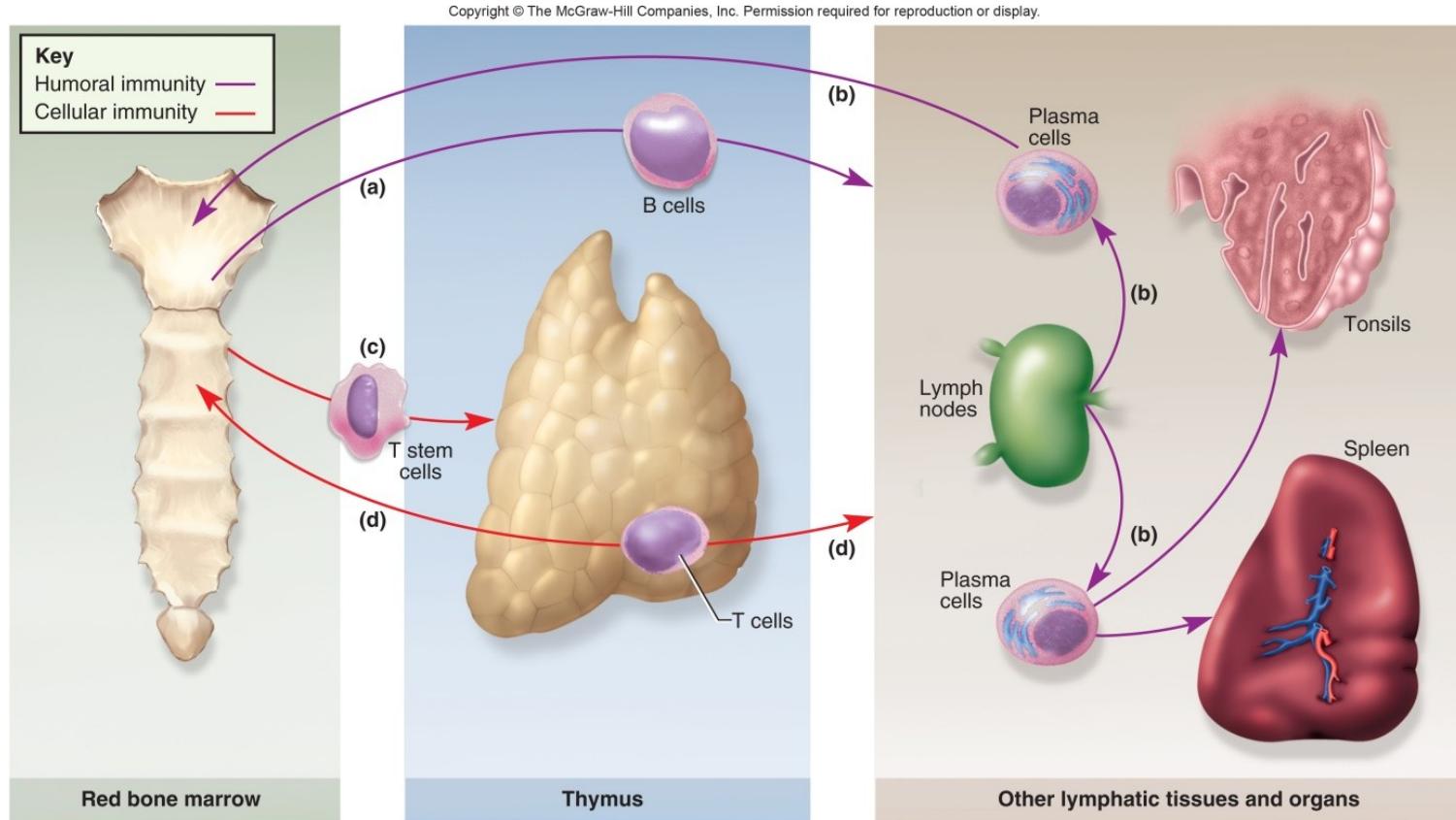
**Cellular (cell-mediated) immunity:** T cells respond to intracellular pathogens which are inaccessible to antibodies, and kill cells that harbor them

**Humoral (antibody-mediated) immunity:** B cells produce antibodies, which assault extracellular pathogens “Humoral”: relating to body fluids



# T Lymphocytes (T Cells) are “born” in the red bone marrow, but mature in thymus

- Reticuloendothelial (RE) cells secrete hormones which stimulate production of surface antigen receptors in T-cells
- Thymus “teaches T-cells to distinguish “self” from “non-self”



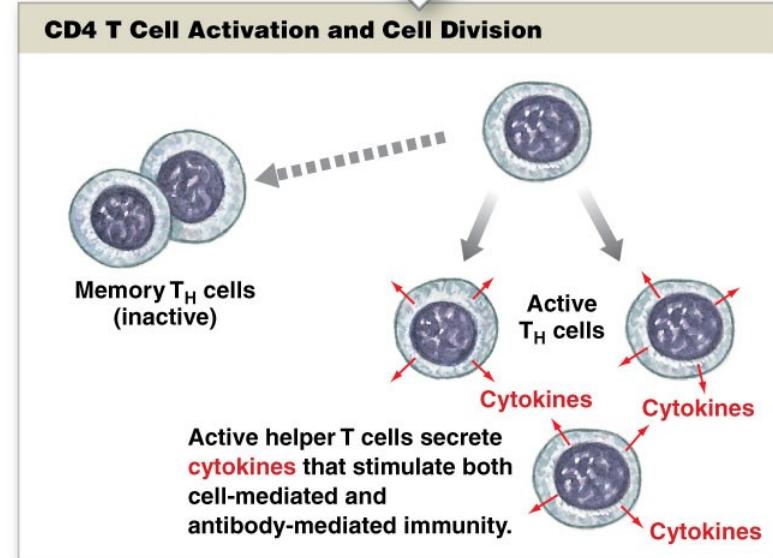
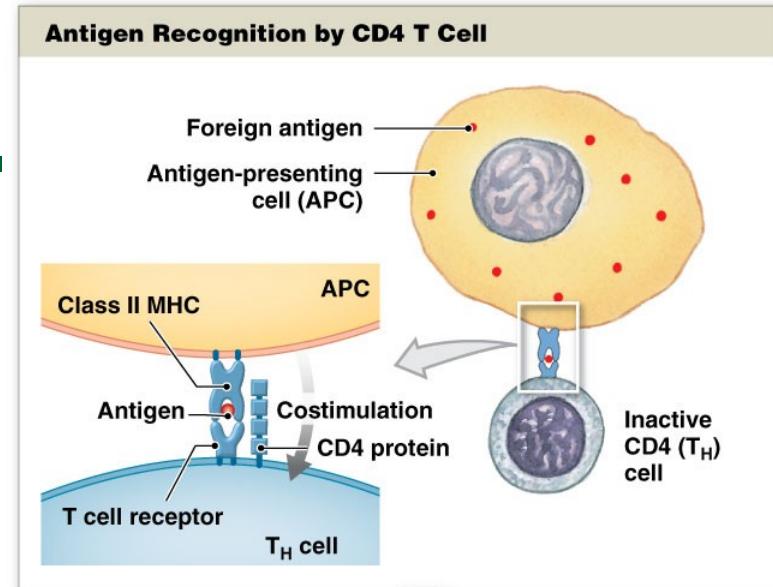
# Memory

Some  $T_c$  and  $T_h$  cells become **memory cells**

- respond more rapidly than naïve T cells
- Upon re-exposure to same pathogen later in life, memory cells launch a quick attack so that no noticeable illness occurs
- The person is immune to the disease

## » MEDICAL APPLICATION

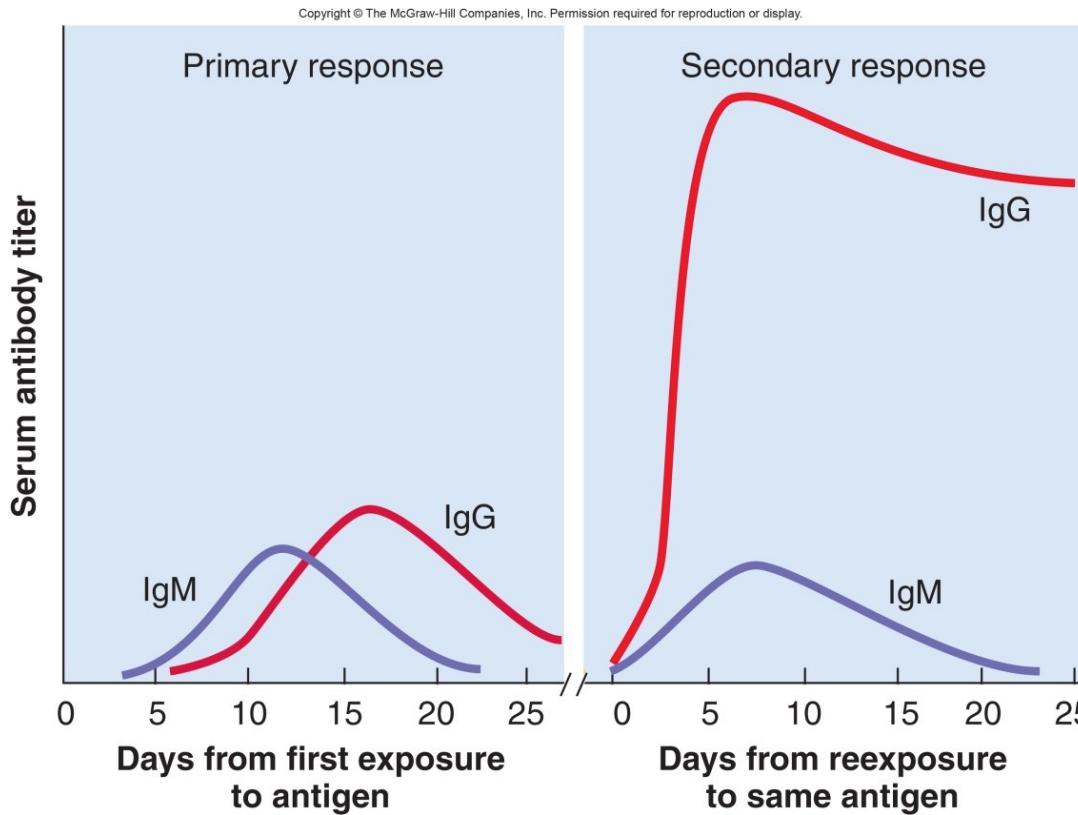
The retrovirus that produces acquired immunodeficiency syndrome (AIDS) infects and rapidly kills helper T cells, crippling the immune system rendering them susceptible to other infections.



# Memory

**Primary immune response:** antibody production upon first exposure to an antigen, 3 to 6 days

**Secondary (anamnestic) response:** Plasma cells form from Memory B cells within hours and no illness results

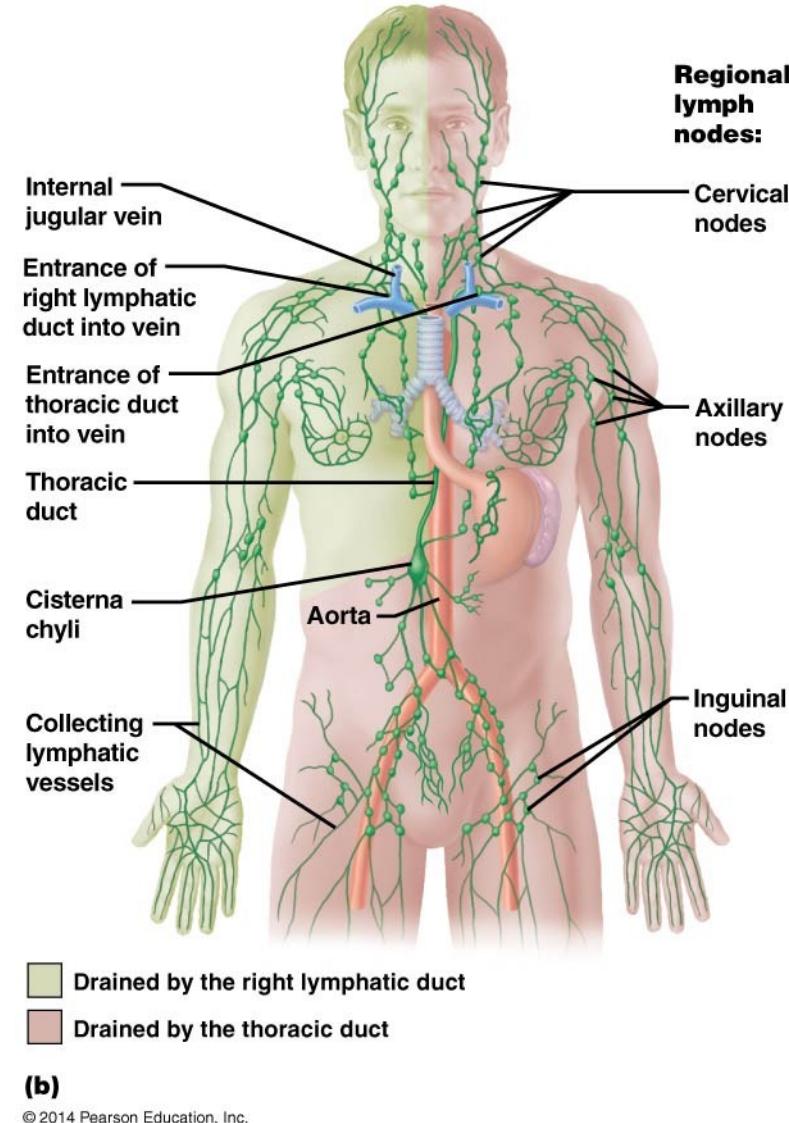


The immune response animation: [http://highered.mheducation.com/sites/0072495855/student\\_view/chapter24/animation\\_the\\_immune\\_response.html](http://highered.mheducation.com/sites/0072495855/student_view/chapter24/animation_the_immune_response.html)

# The Lymphatic System

Excess filtered fluid picks up foreign cells and chemicals from the tissues. This fluid passes through lymph nodes where **immune cells** “clean” it

- 1. Lymph:** Extracellular clear, colorless fluid, similar to plasma, but much less protein.
- 2. Lymphatic vessels:** Transport the lymph
- 3. Lymphatic tissues:** lymphocyte and macrophage rich aggregates
- 4. Lymphatic organs:** organs with concentrated populations of lymphatic cells



# Lymphatic Tissues

**Diffuse lymphatic tissue:** simplest form

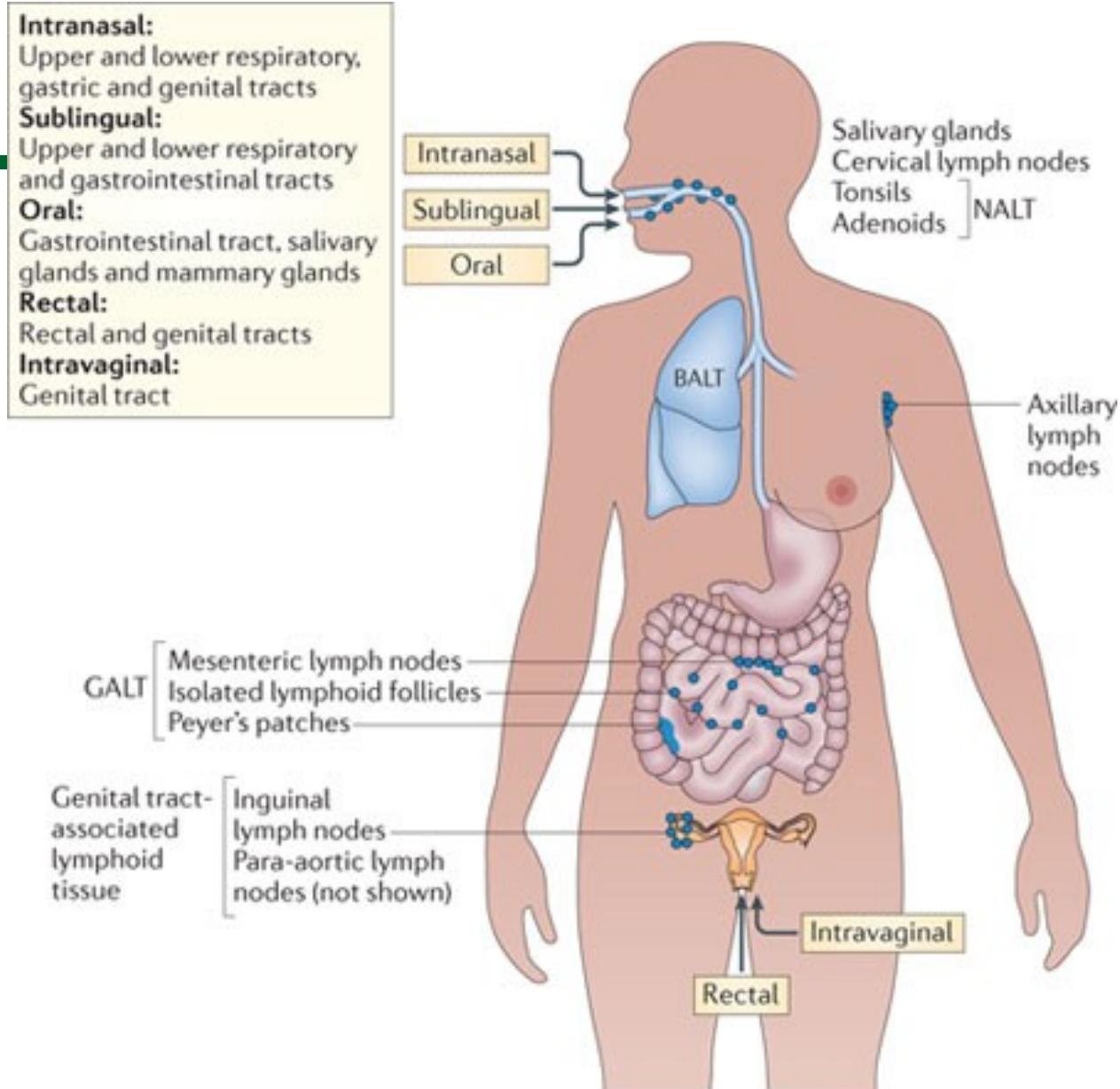
scattered lymphocytes are, body passages open to the exterior

**Ex Mucosa-associated lymphatic tissue (MALT):** Respiratory, digestive, urinary, and reproductive tracts

**Lymphatic nodules (follicles):** Dense congregate of lymphocytes

**Peyer patches:** lymph node clusters in small intestine

<b>Intranasal:</b> Upper and lower respiratory, gastric and genital tracts
<b>Sublingual:</b> Upper and lower respiratory and gastrointestinal tracts
<b>Oral:</b> Gastrointestinal tract, salivary glands and mammary glands
<b>Rectal:</b> Rectal and genital tracts
<b>Intravaginal:</b> Genital tract



# Lymphatic Organs

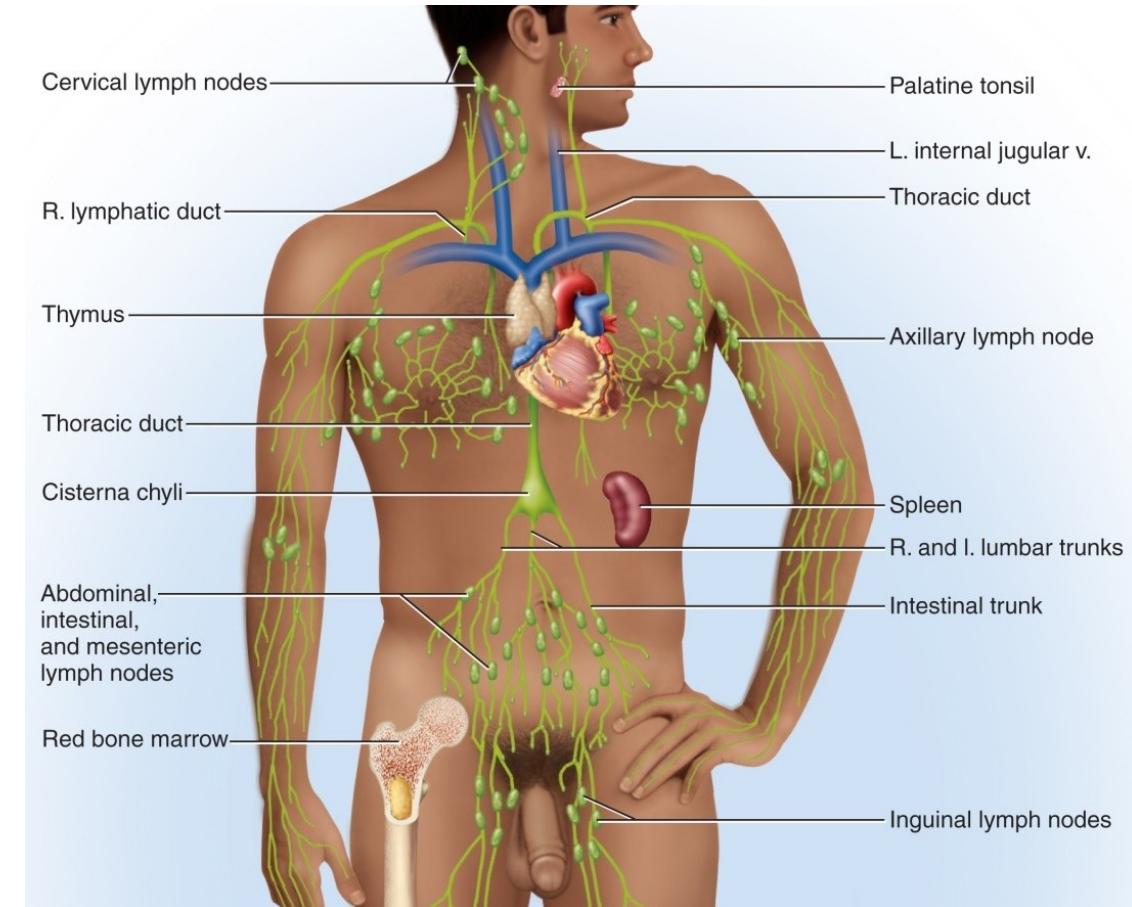
**Lymphatic organs** are surrounded by connective tissue capsule, separating them from neighboring tissues

**Primary lymphatic organs:** Site where T and B cells become immunocompetent (able to recognize and respond to antigens)

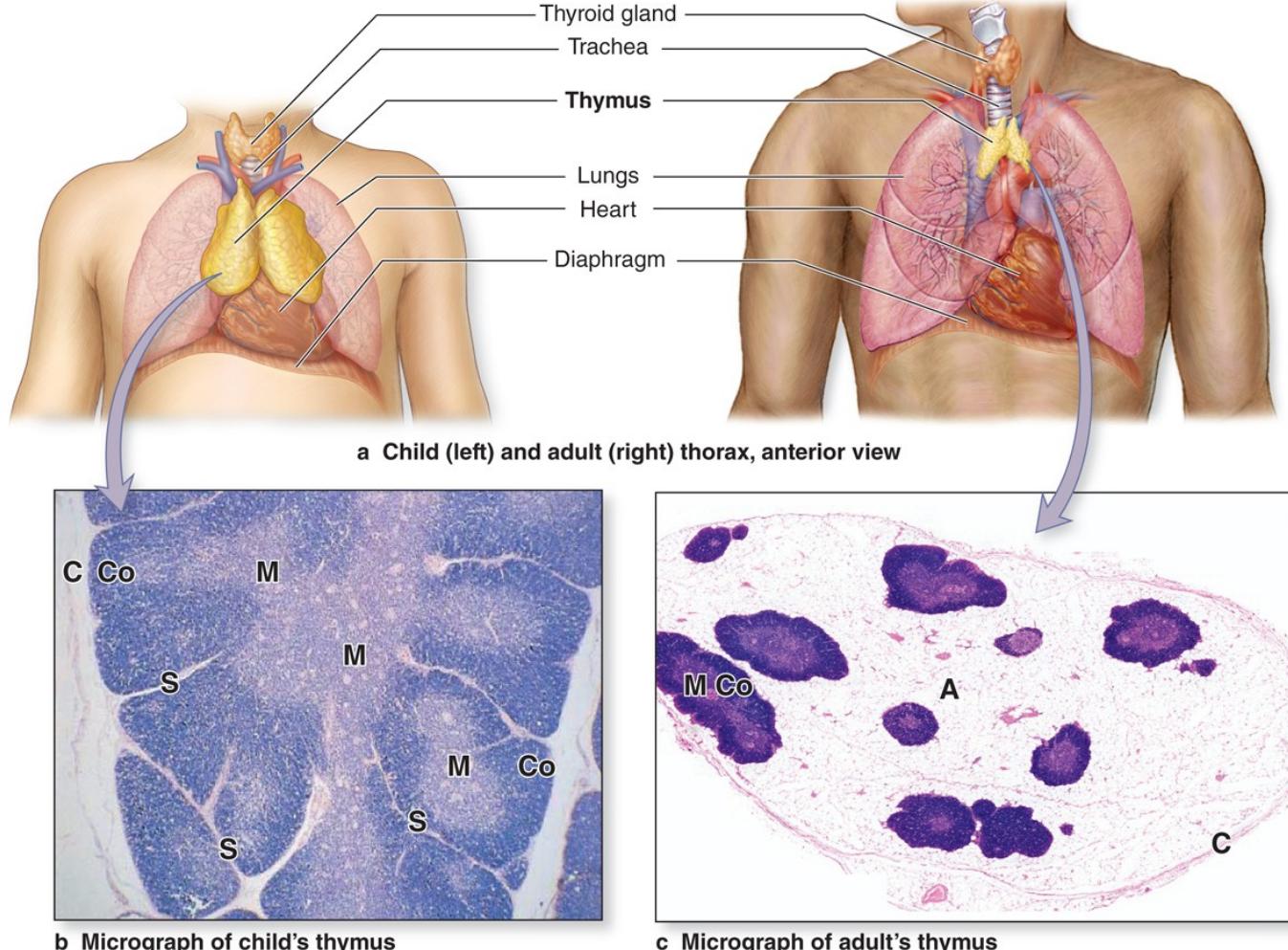
1. Red bone marrow
2. Thymus

**Secondary lymphatic organs:** populated by Immunocompetent cells

3. Lymph nodes
4. Tonsils
5. Spleen



**The thymus is a bilobed organ in the mediastinum that is most active and prominent before puberty and undergoes involution with less activity in the adult.**

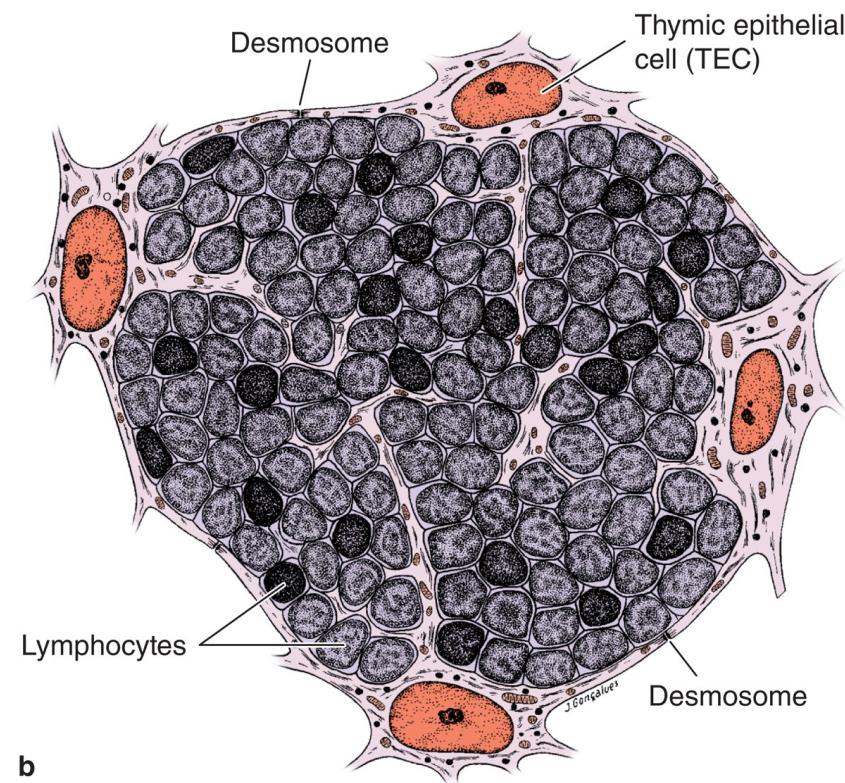
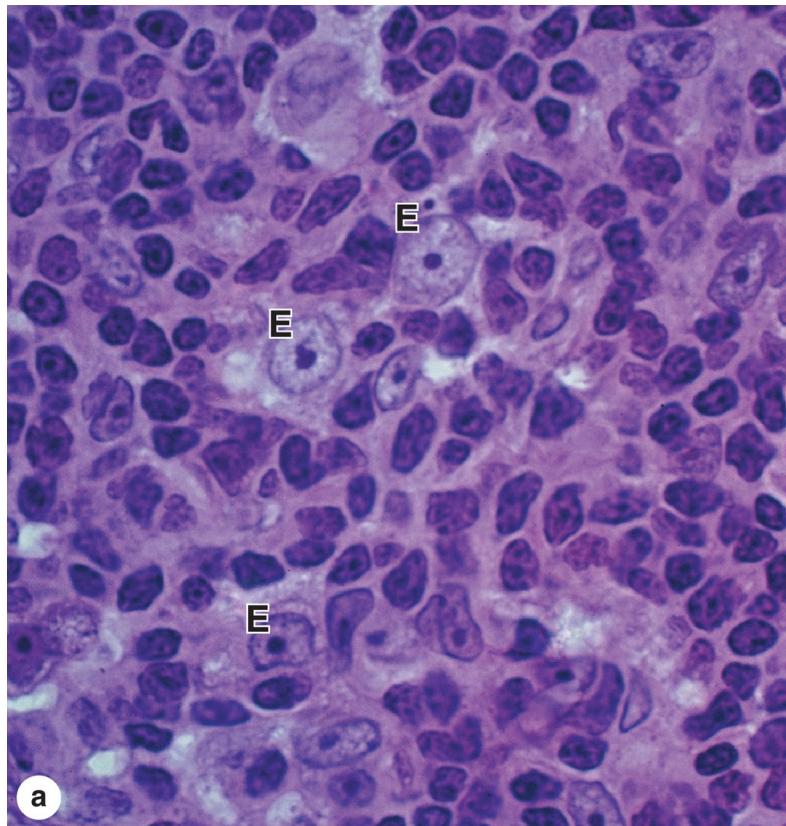


**(b) A child's thymus**, showing connective tissue of the capsule (**C**) and septa (**S**) -between thymic lobules, each having an outer cortex (**Co**) and -incompletely separated medulla (**M**) of lymphoid tissue.

**(c)** After- involution the thymus shows only small regions of lymphoid tissue, here still with cortex (**Co**) and medulla (**M**), and these are embedded in adipose tissue

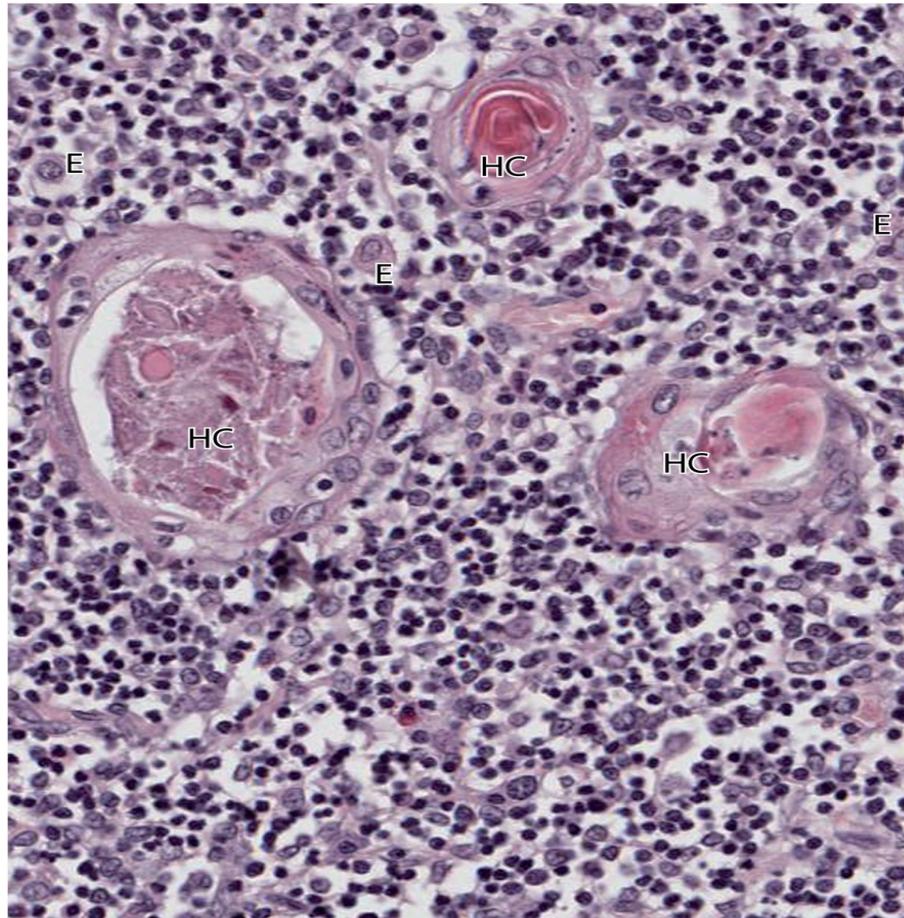
## Thymic Cortex: early T cell development

- (a) The cortical zone of an active thymus is packed with small **lymphoblasts**, and epithelial cells (**E**).
- (b) The epithelial reticular cells throughout the cortex secrete cytokines that promote T-cell maturation.



# Thymic (Hassall's) Corporcles are a distinguishing feature of the thymic medulla

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The most characteristic feature of the medulla in humans is the presence of thymic (Hassall) corpuscles (H).

These are of variable size and contain aggregates of thymic epithelial cells releasing many cytokines important for the later differentiation of regulatory T cells.

# Structure of a lymph node.

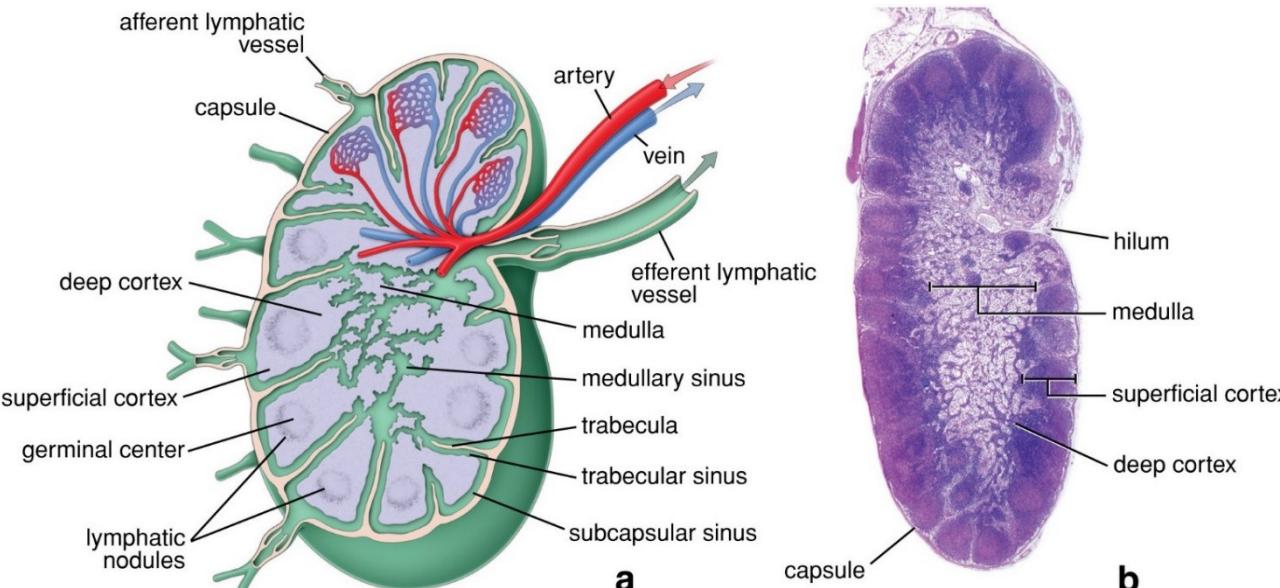
**Cortex:** contains lymphatic nodules with aggregates of lymphocytes.

**Germinal center:** region in nodule where lymphocytes are activated

**Medulla:** lymphatic tissue separated by lymphatic medullary sinuses.

**Capsule:** dense connective tissue from which trabeculae extend into the substance of the node.

**Flow of lymph:** afferent lymphatic vessels → subcapsular sinus. → trabecular sinus → medullary sinuses.

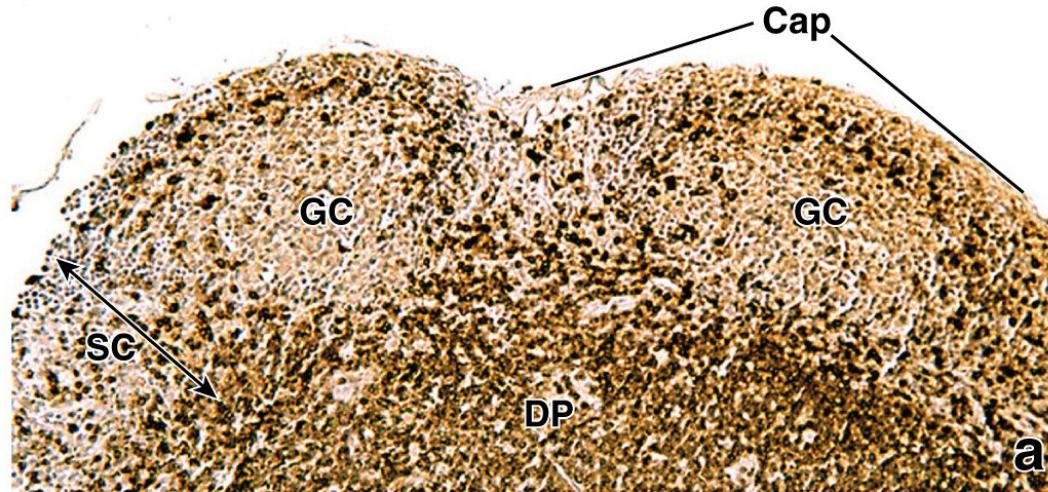


## »» MEDICAL APPLICATION

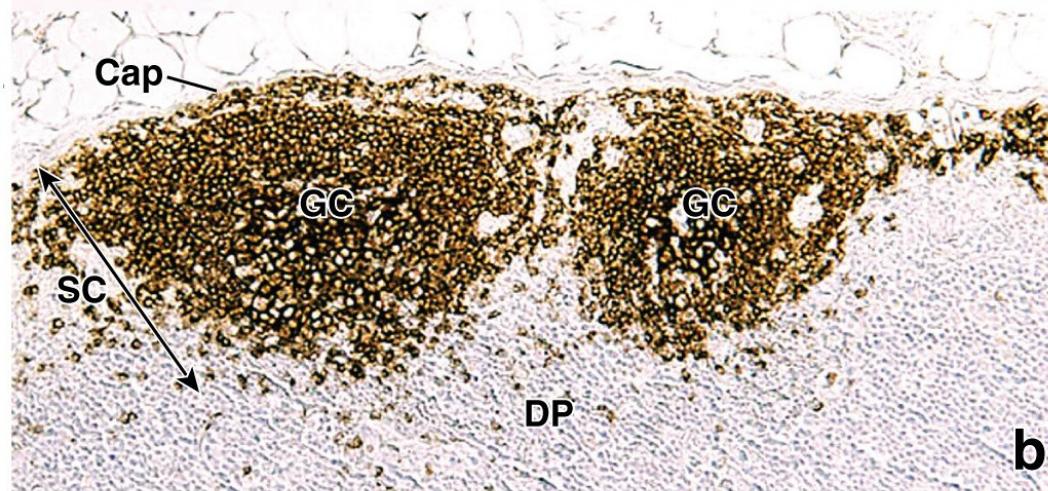
Metastatic cancer cells can be carried to nearby lymph nodes. The sentinel lymph node (first one downstream of tumor) is examined by pathologists for the presence of cancer cells.

Sentinel Lymph Node Biopsy: <https://www.youtube.com/watch?v=Cdl2JhhTfYc>

# B and T Lymphocytes in the Superficial Cortex of a Marmoset Monkey Lymph Node



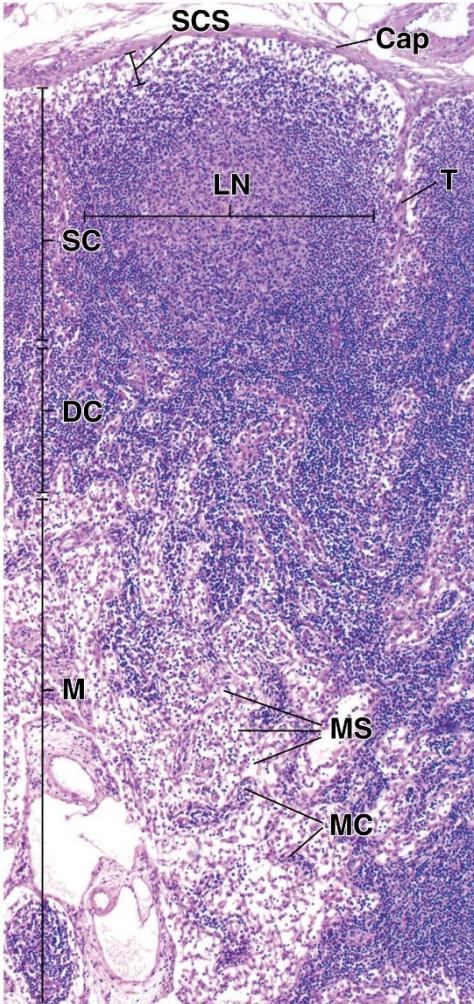
a: Anti CD3 (**T lymphocytes marker**) stain: Note that the majority of T cells are distributed within the deep cortex (DP); a small number of T cells are present in the superficial cortex (SC ), mainly around germinal centers (GC).



b: anti CD20 (**B lymphocytes marker**) stain: B cells accumulate in germinal centers (GC) of the superficial cortex (SC)

# H & E of a lymph node

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**Capsule (Cap):** dense connective tissue from which trabeculae (T) penetrate into the organ

**Subcapsular sinus (SCS):** receives lymph from afferent lymphatic vessels that penetrate the capsule.

**trabecular sinuses (T)**

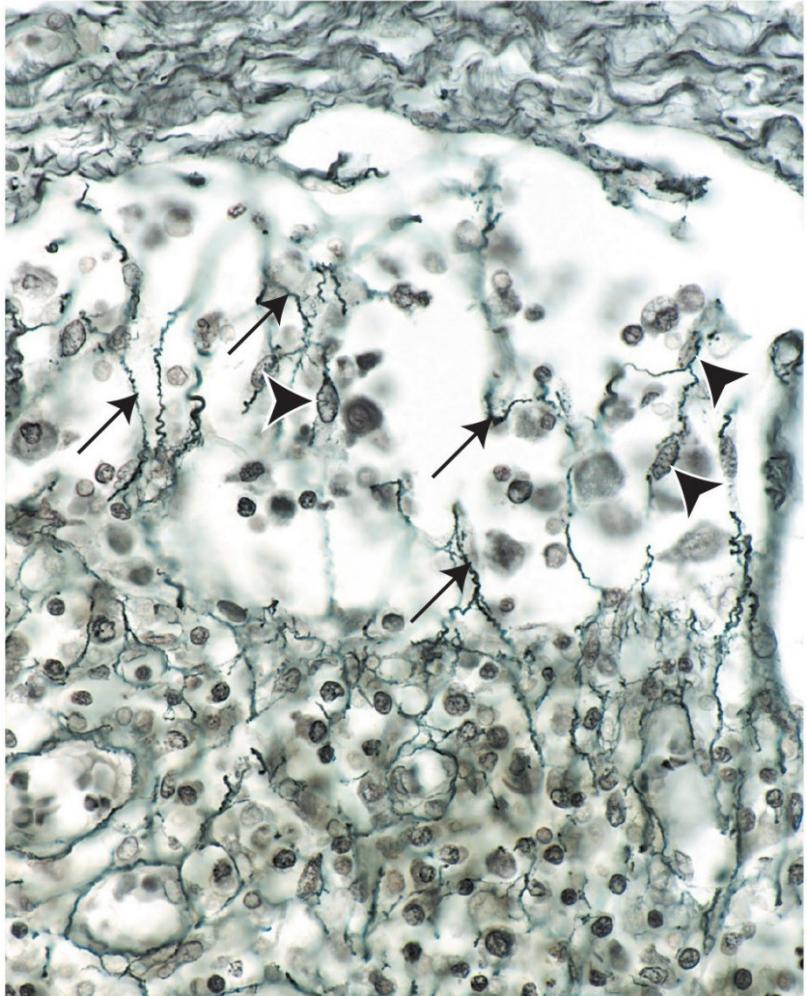
The **superficial cortex (SC)** contains the lymphatic nodules (LN)

**Deep cortex (DC)** is nodule-free: contains densely packed lymphocytes

**Medulla (M):** contains medullary cords (MC), which are separated by light-appearing spaces, the medullary sinuses (MS). The medullary sinuses receive lymph from the trabecular sinuses as well as lymph that has filtered through the cortical tissue.

# Silver Stain of a Lymph Node

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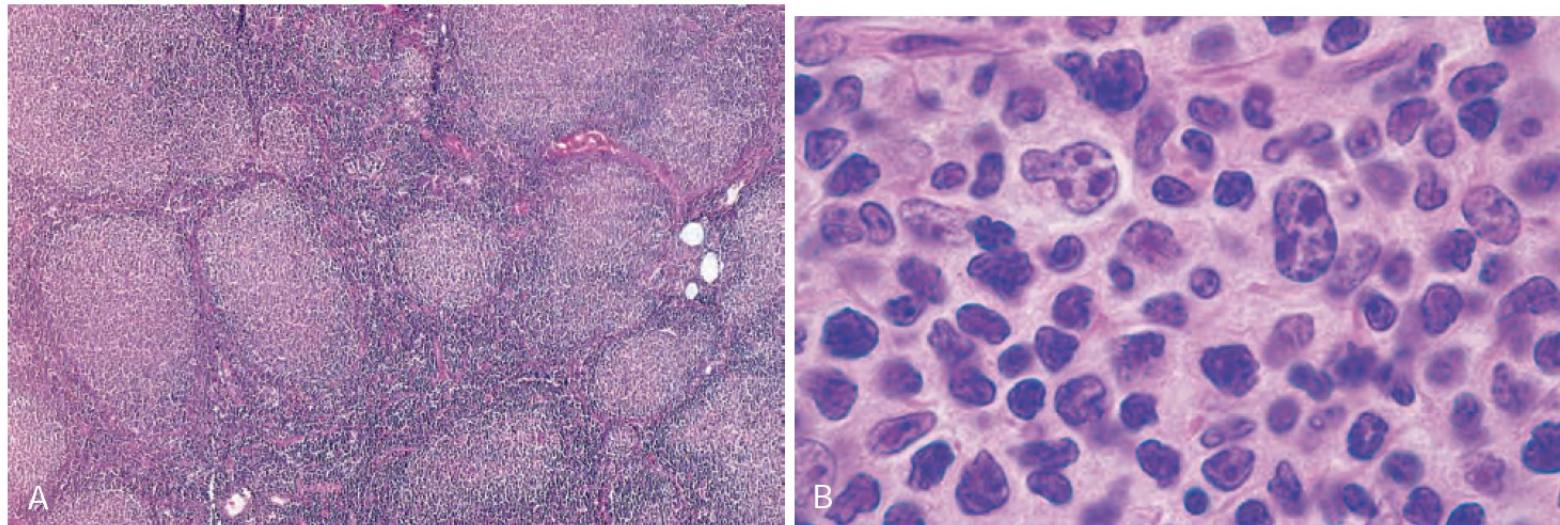


**Connective tissue capsule** (at the top)  
Subcapsular sinus, and the superficial cortex of the lymph node (at the bottom).

The reticular fibers (arrows) form an irregular anastomosing network throughout the stroma of the lymph node. Note elongated oval nuclei of reticular cells (arrow-heads), which are in intimate contact with reticular fibers in the sinus.

# Lymphoma

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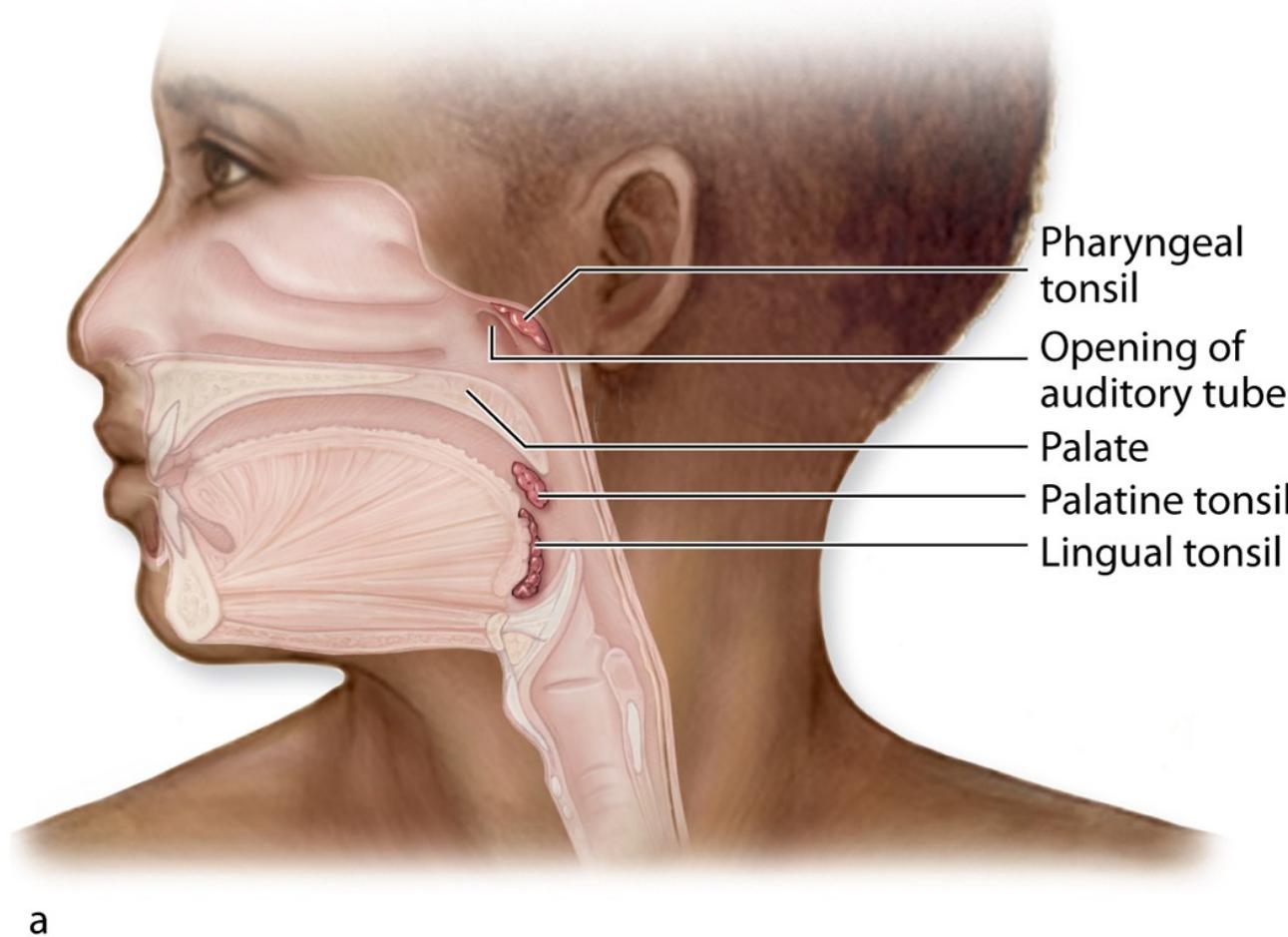


## >> MEDICAL APPLICATION

Neoplastic proliferation of lymphocytes can completely change the normal architecture of the node to a structure filled with lymphocytes, a condition called lymphadenopathy.

- A. Nodular aggregates of lymphoma cells are present throughout lymph node.
- B. At high magnification, small lymphoid cells with condensed chromatin and irregular or cleaved nuclear outlines are mixed with a population of larger cells with nucleoli.

# Masses of lymphoid nodules comprising tonsils are collected in three general locations in the wall of the pharynx.



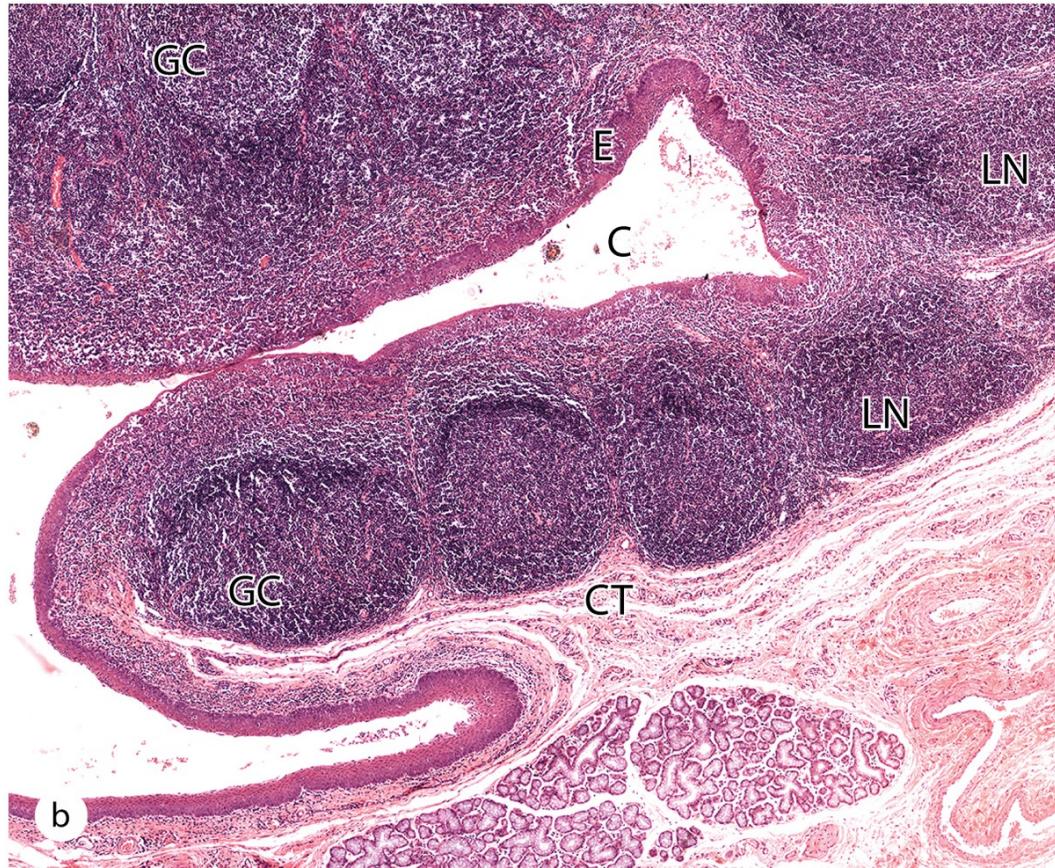
**Palatine tonsils:** posterior

**Lingual tonsils:** posterior third of the tongue. Both are covered with stratified squamous epithelium.

**Pharyngeal tonsil:** single medial mass situated in the posterior wall of the nasopharynx. It is usually covered by ciliated pseudostratified columnar epithelium,

Hypertrophied regions of pharyngeal tonsils resulting from chronic inflammation are called **adenoids**.

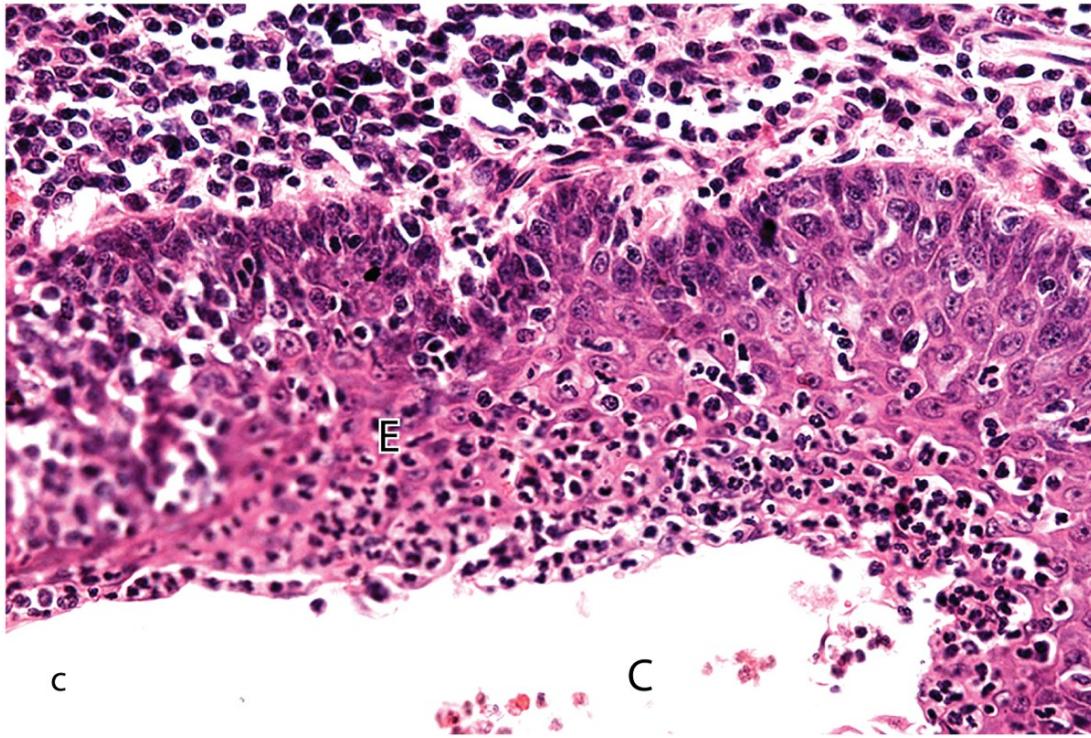
# Lymphoid Nodules of the Tonsils



lymphoid nodules (**LN**), -collectively covered by stratified squamous epithelium (**E**) on one side and a connective tissue capsule (**CT**) on the other.

Some nodules show lighter staining germinal centers (**GC**). Infoldings of the mucosa in some tonsils form **crypts** (**C**), along which nodules are especially numerous. Lumens of crypts contain desquamated epithelial cells, live and dead lymphocytes, and bacteria.

# Epithelium surrounding tonsillar crypts



Epithelium (**E**) surrounding tonsillar crypts (**C**) often becomes infiltrated with lymphocytes and other leukocytes and can become difficult to recognize histologically. Adjacent connective tissue at the top of the photo also contains numerous lymphocytes.

» **MEDICAL APPLICATION** Chronic inflammation of the pharyngeal lymphoid tissue and tonsils of children often produces hyperplasia and enlargement of the tonsils to form “adenoids,” which can obstruct the eustachian tube and lead to middle ear infections.

# Spleen: body's largest lymphatic organ, highly vascular and vulnerable to trauma and infection

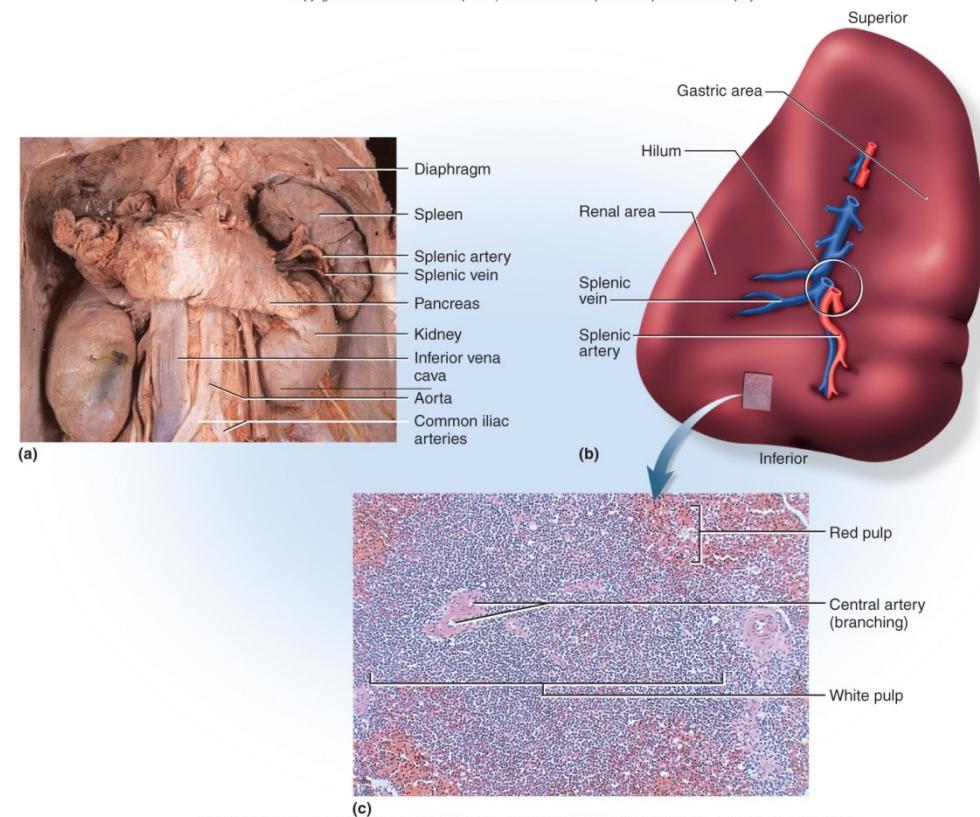
Ruptured spleen requires splenectomy

**Red pulp:** sinuses filled with erythrocytes

- Blood reservoir
- RBC disposal
- Blood production in fetus

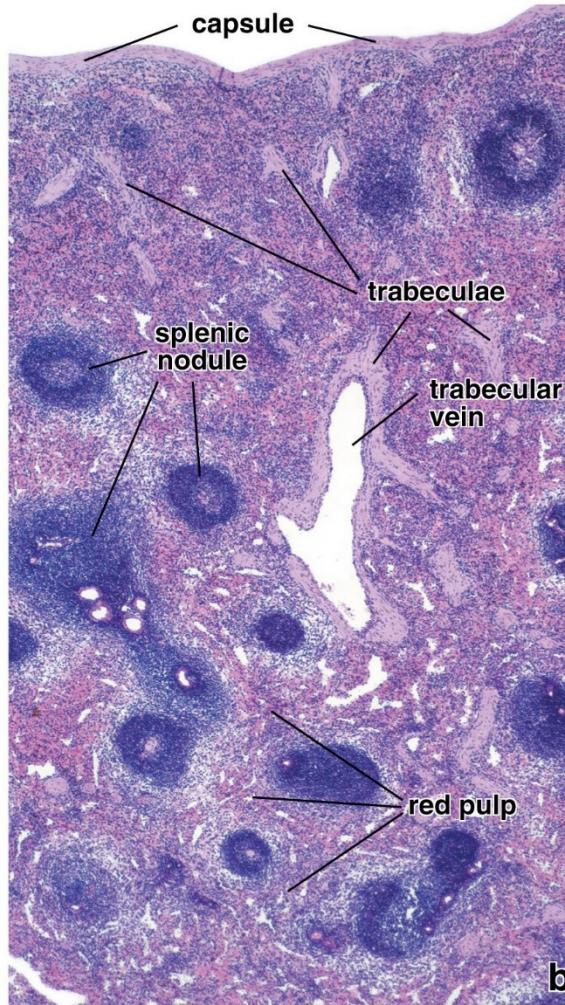
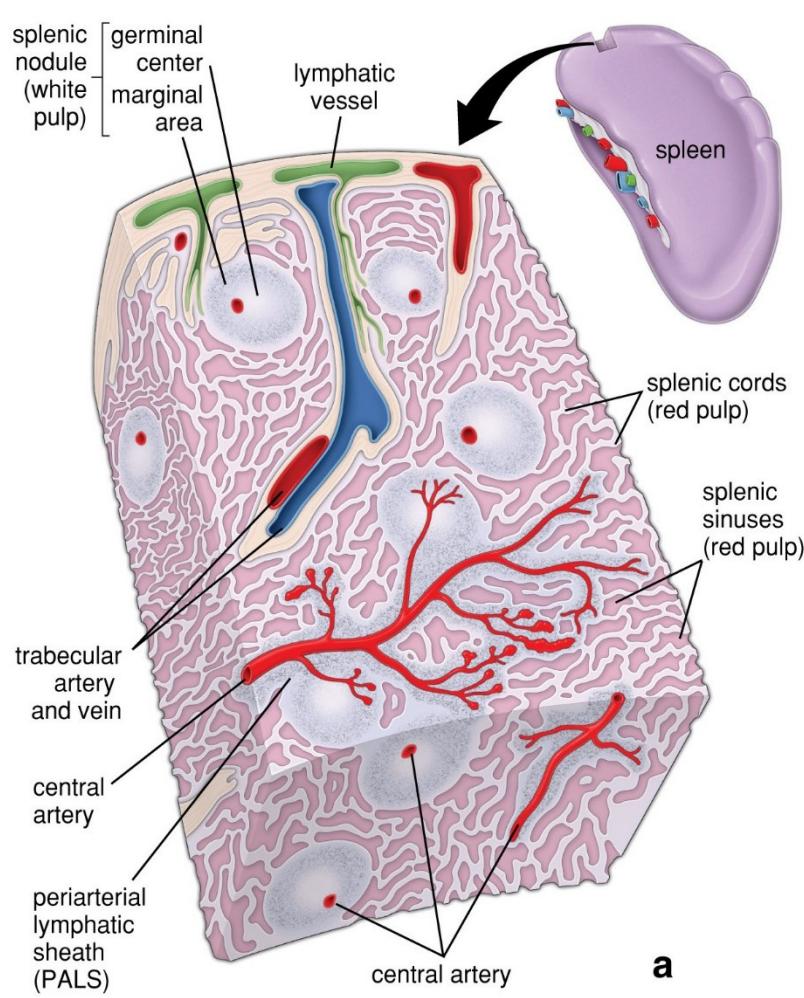
**White pulp:** lymphocytes, macrophages surrounding small branches of splenic artery, monitors blood for foreign antigens

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a: © The McGraw-Hill Companies, Inc./Dennis Strete, photographer; c: © The McGraw-Hill Companies, Inc./Photo by Dr. Alvin Telser

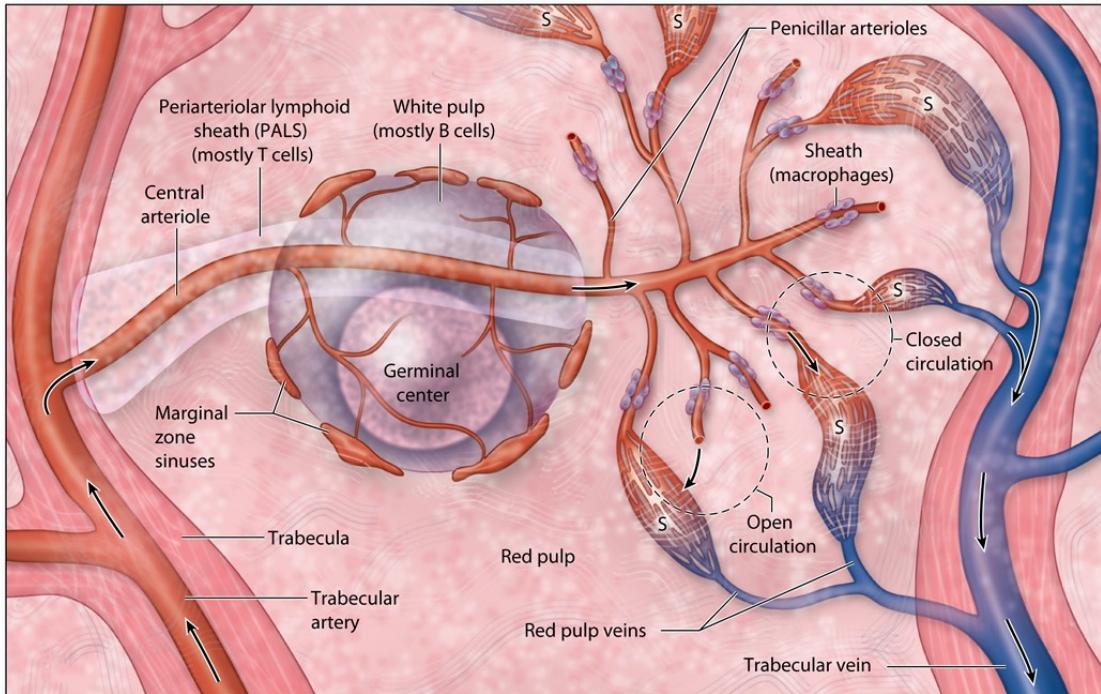
# Splenic Structure



**White pulp:** mass of lymphocytes. Expansion of the white pulp creates the **splenic nodules**.

**Red pulp:** splenic sinuses surrounded by splenic cords (cords of Billroth). Blood vessels traverse the capsule and trabeculae before and after passage within the substance of the spleen.

# Blood circulation and the structure of the spleen: trabecular artery to the trabecular vein



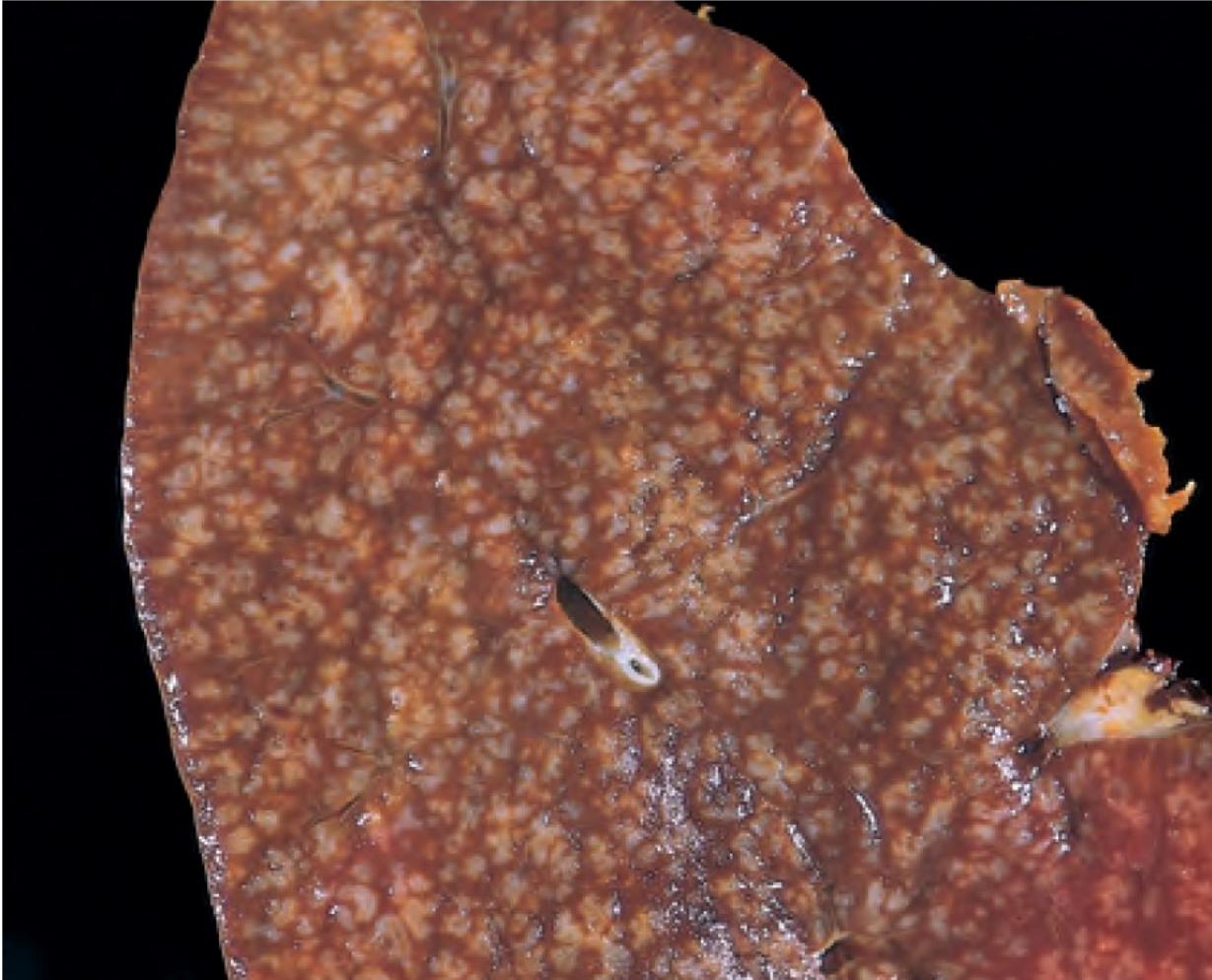
**central arterioles** are enclosed by lymphoid cell rich **periarteriolar lymphoid sheath (PALS)**, in white pulp.

B cells in these sheaths can form nodules as the largest masses of white pulp

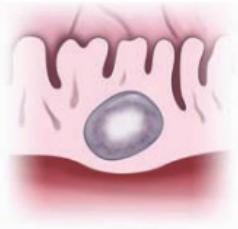
Blood flows into either a **closed circulation** passing directly into splenic sinuses (**S**) or an **open circulation**, being dumped from the vasculature into the lymphoid tissue of the red pulp's splenic cords. From there viable blood cells reenter the vasculature through the walls of the sinuses.

## Follicular lymphoma (spleen).

---



Prominent nodules represent white pulp follicles expanded by follicular lymphoma cells. Other indolent B-cell lymphomas (small lymphocytic lymphoma, mantle cell lymphoma, marginal zone lymphoma) can produce an identical pattern of involvement.

Features	(BALT, GALT, MALT)	Lymph Nodes	Thymus	Spleen
				
<b>Major function</b>	Immune surveillance of mucosal membranes	Filter lymph Generate immune responses to antigens in the lymph	Develops immunocompetent T lymphocytes	Filters blood Eliminates senescent erythrocytes Generates immune responses to circulating antigens
<b>Connective tissue capsule</b>	No	Yes	Yes	Yes; contains myofibroblasts
<b>Cortex</b>	No	Yes	Yes	No
<b>Medulla</b>	No	Yes	Yes	No
<b>Lymph nodules</b>	Yes	Yes; in the superficial cortex only	No	Yes; in white pulp only
<b>Afferent lymphatic vessels</b>	No	Yes; passing through the capsule	No	No
<b>Efferent lymphatic vessels</b>	Yes	Yes; leaving the node at the hilum	Yes (few); originate in connective tissue septa and capsule	Yes; inconspicuous, originate in white pulp near trabeculae
<b>High endothelial venules (HEVs)</b>	Yes; in well-established lymph nodules (i.e., tonsils, appendix, Peyer's patches)	Yes; associated with deep cortex	No	No
<b>Characteristic features</b>	Diffuse lymphatic tissue with randomly distributed lymphatic nodules underlying epithelial surface	Presence of lymphatic sinuses (subcapsular, trabecular, and medullary) Reticular meshwork	Thymic lobules Meshwork of epithelioreticular cells Hassall's corpuscles in medulla only	White pulp with PALS splenic nodules containing central artery Red pulp containing splenic sinuses, penicillar arteries, sheathed capillaries, and splenic cords

BALT, bronchus-associated lymphatic tissue; GALT, gut-associated lymphatic tissue; MALT, mucosa-associated lymphatic tissue; PALS, periarterial lymphatic sheath.

1) http://

ed.ted.com/lessons/you-are-your-microbes-jessica-green-and-karen-guillemin

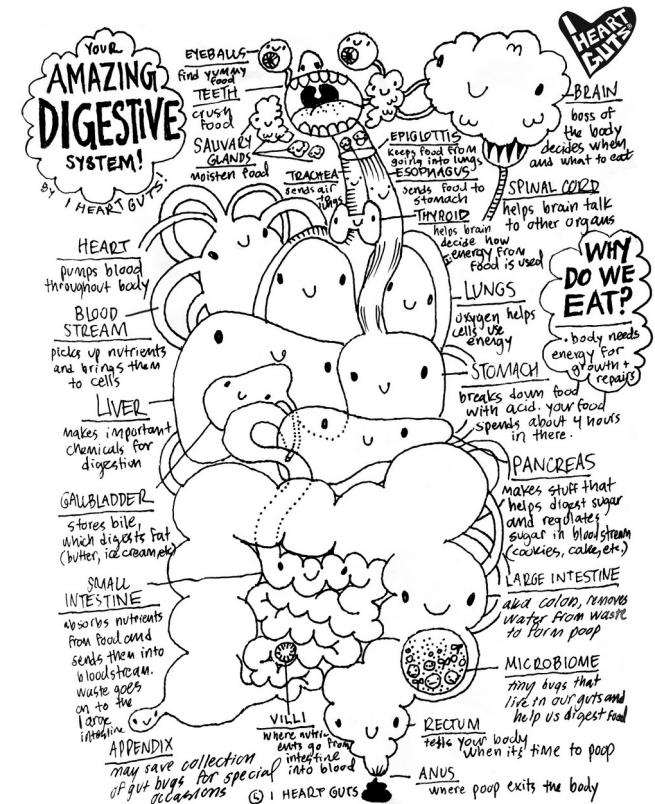
2) http://www.bozemanscience.com/digestive-system/

3) https://

www.khanacademy.org/partner-content/crash-course1/partner-topic-crash-course-bio-ecology/crash-course-biology/v/crash-course-biology-127

## Digestive Tract

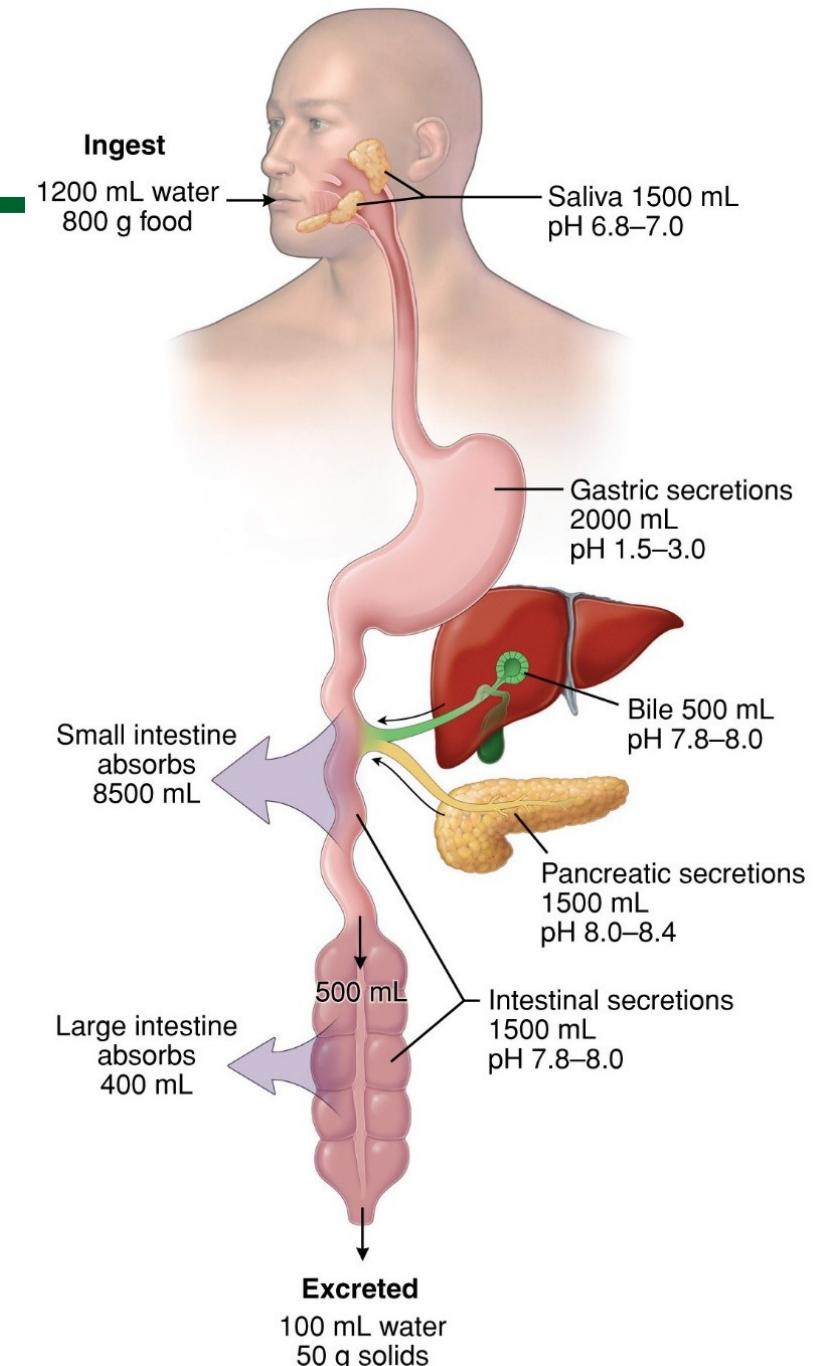
# BI 455 CHAPTER 15



# Digestive system has two anatomical subdivisions

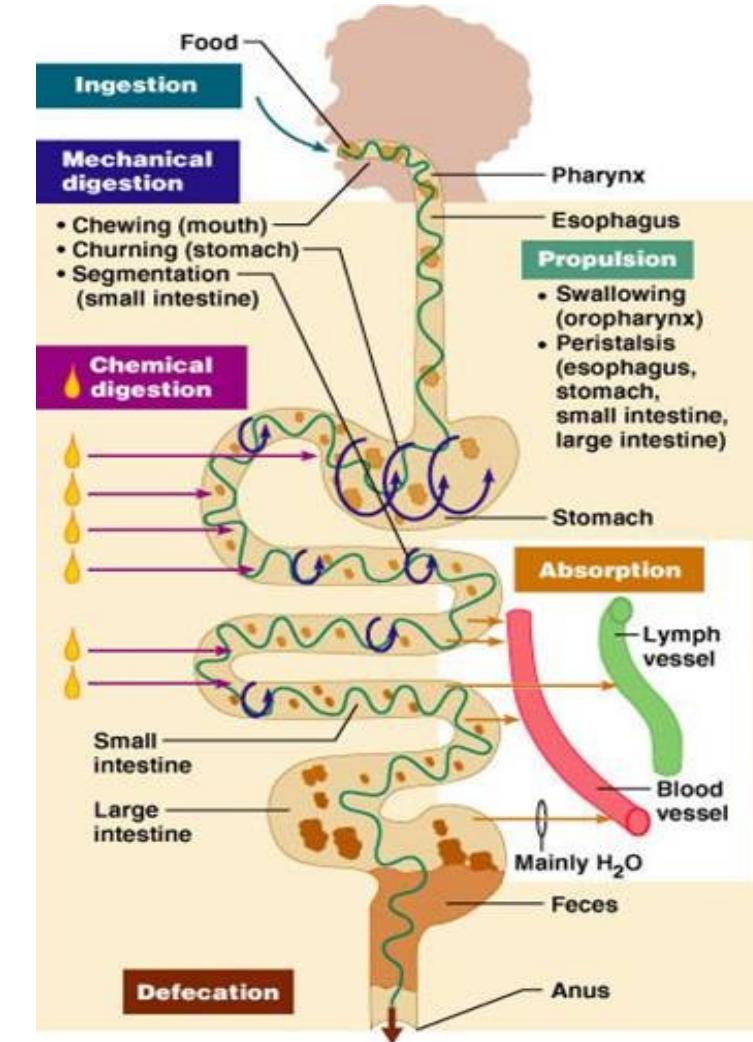
1. **Digestive tract (alimentary canal):** 30 ft long muscular tube extending from mouth to anus including mouth, pharynx, esophagus, stomach, small intestine, and large intestine
2. **Gastrointestinal (GI) tract:** stomach and intestines

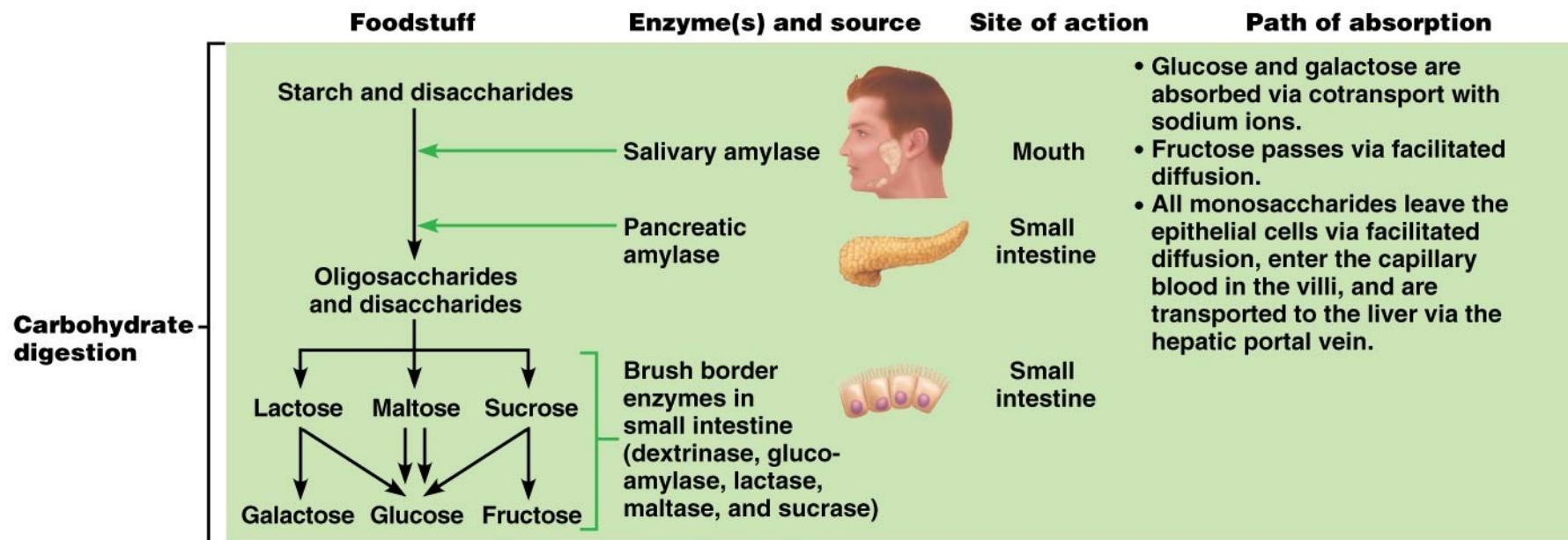
Accessory organs: Teeth, tongue, salivary glands, liver, gallbladder, and pancreas



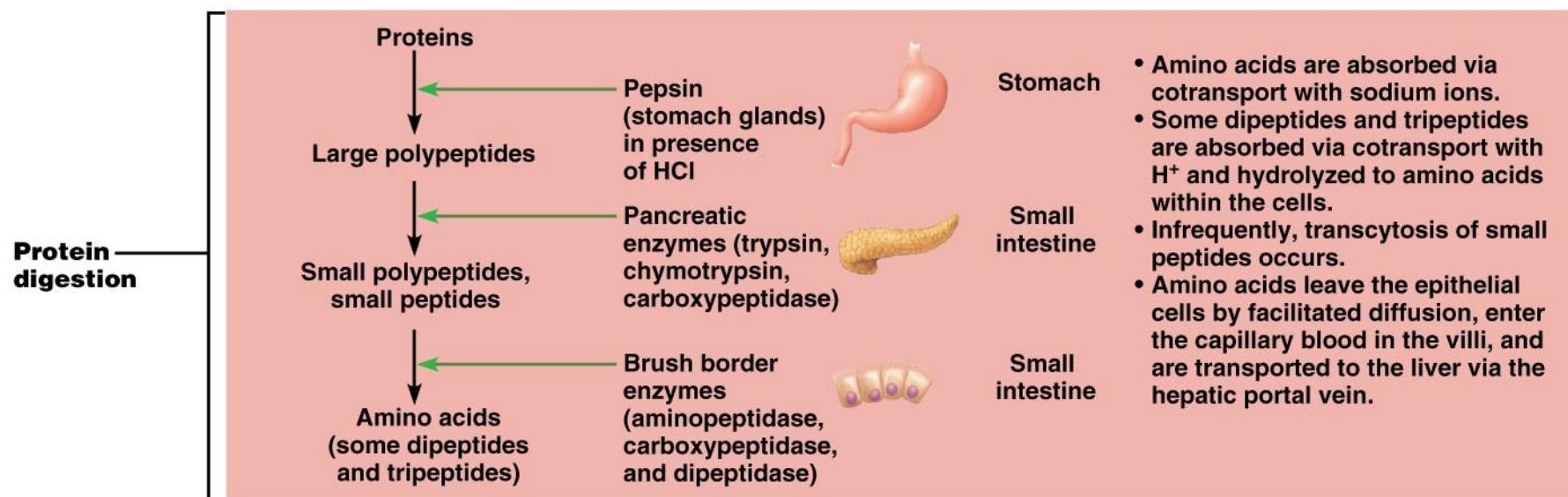
# Five stages of digestion

- 1. Ingestion:** selective intake of food
- 2. Digestion:** mechanical and chemical breakdown of food into a form usable by the body
- 3. Absorption:** uptake of nutrient molecules into the epithelial cells of the digestive tract and then into the blood and lymph
- 4. Compaction:** absorbing water and consolidating the indigestible residue into feces
- 5. Defecation:** elimination of feces

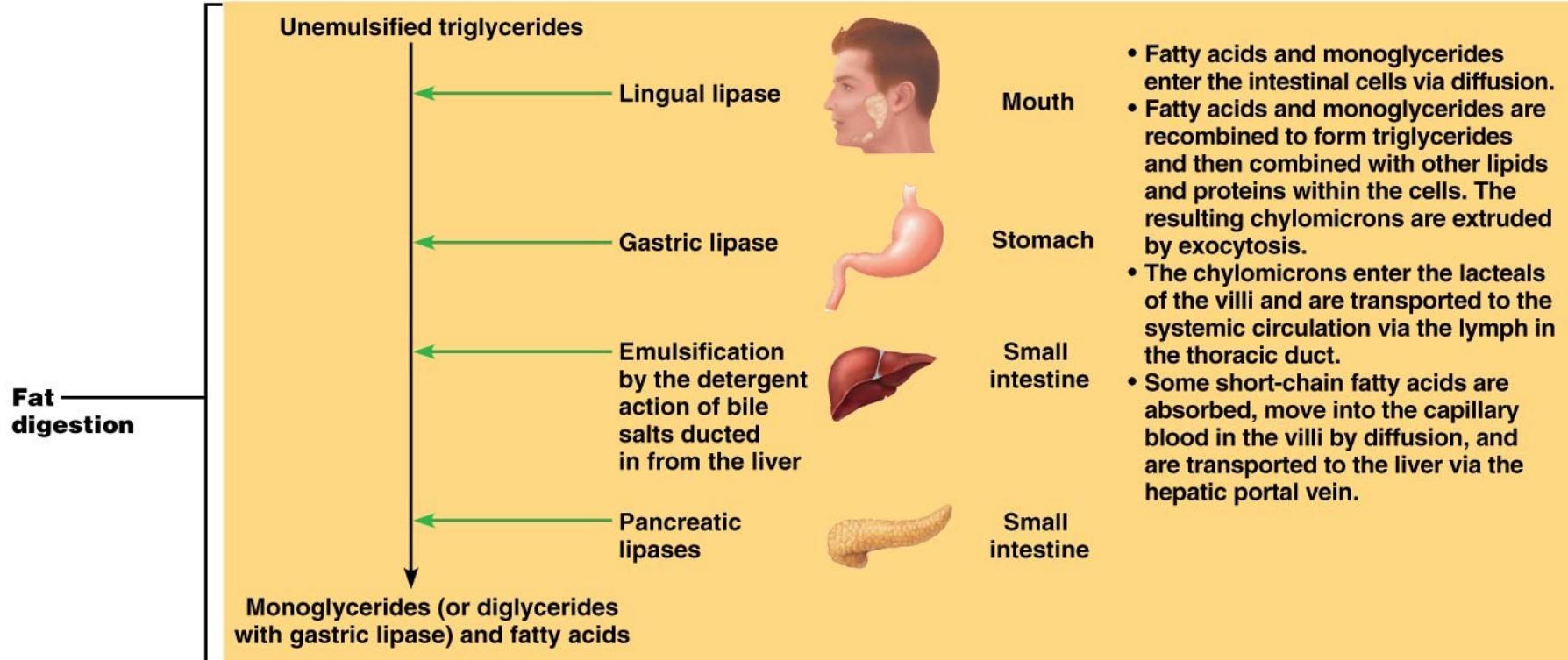




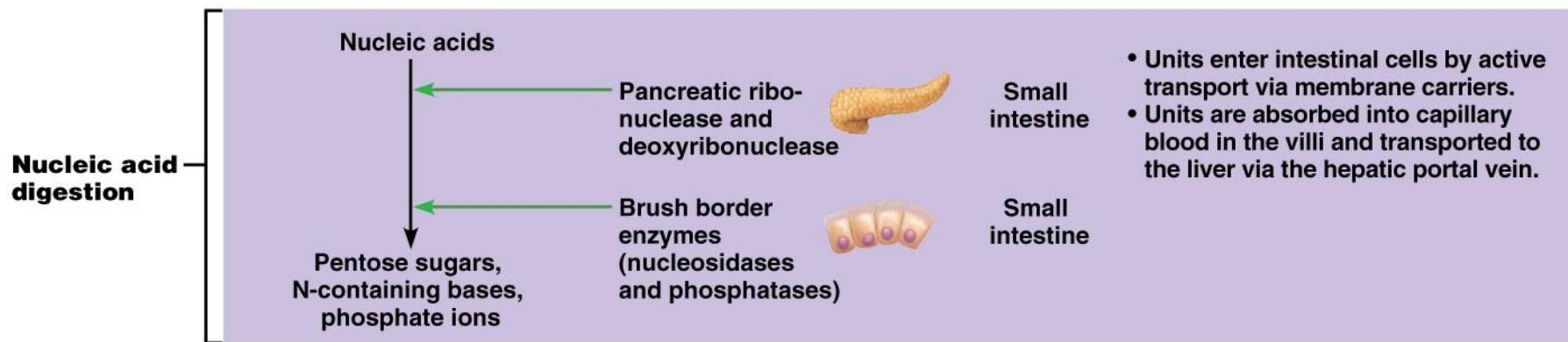
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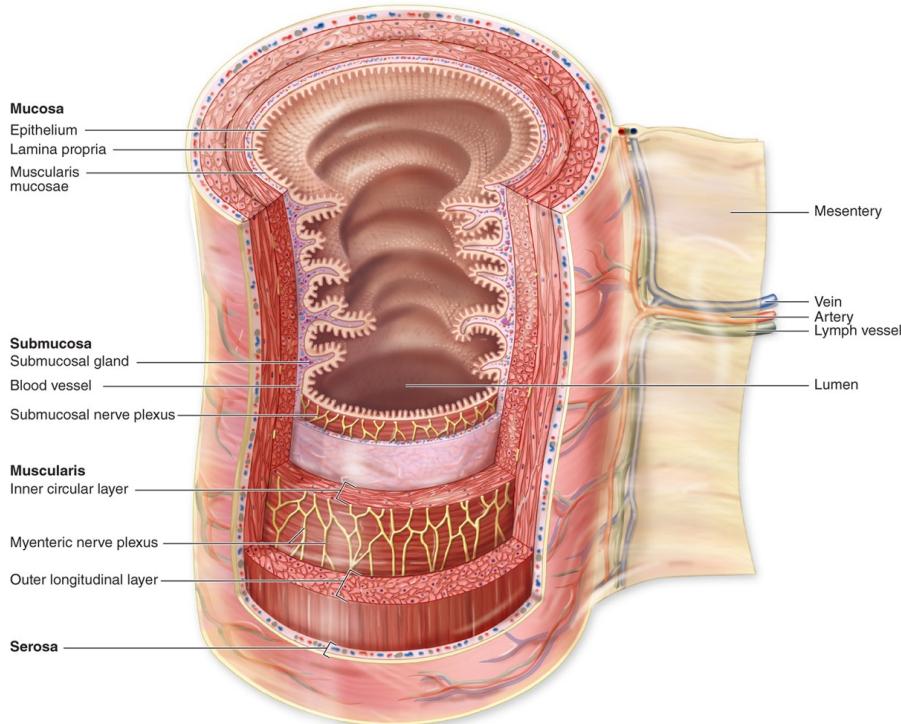
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- Fatty acids and monoglycerides enter the intestinal cells via diffusion.
- Fatty acids and monoglycerides are recombined to form triglycerides and then combined with other lipids and proteins within the cells. The resulting chylomicrons are extruded by exocytosis.
- The chylomicrons enter the lacteals of the villi and are transported to the systemic circulation via the lymph in the thoracic duct.
- Some short-chain fatty acids are absorbed, move into the capillary blood in the villi by diffusion, and are transported to the liver via the hepatic portal vein.

# Basic structural plan of digestive tract wall



## Mucosa:

- Epithelium
- Lamina propria (sometimes with MALT)
- Muscularis mucosae (smooth muscle)

**Submucosa:** blood vessels, lymphatic vessels, a nerve plexus, glands

## Muscularis externa

Inner circular layer: valves (sphincters)  
Outer longitudinal layer: propels food and residue through the tract

## Serosa (sometimes adventitia)

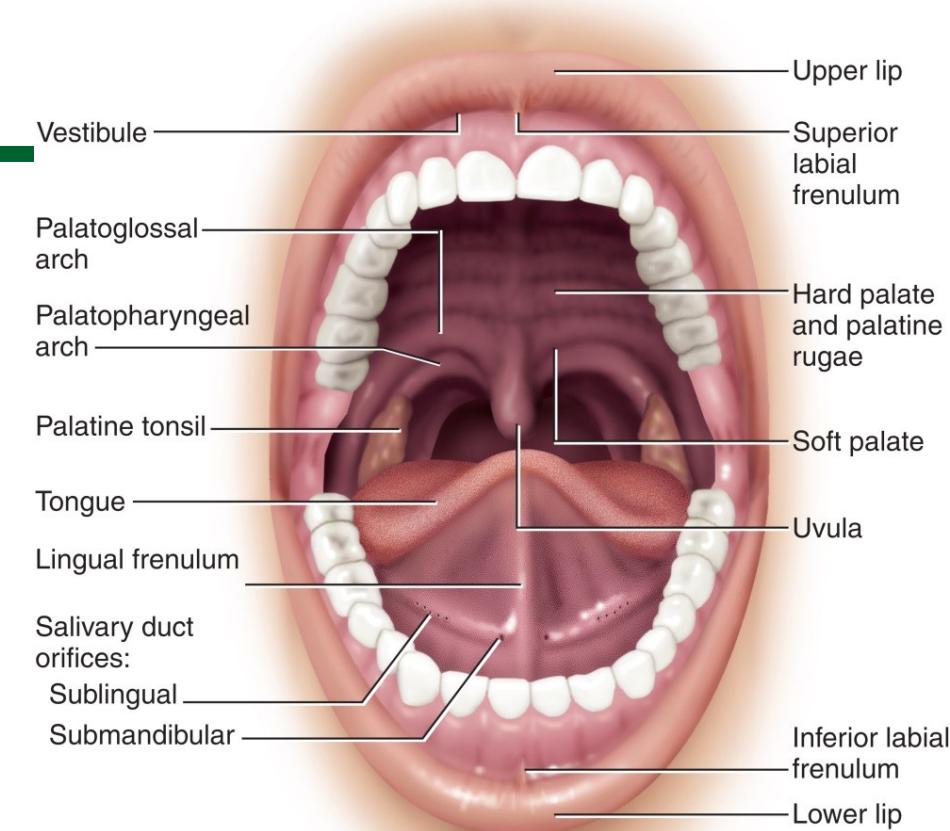
**>> MEDICAL APPLICATION** Infection disturbs plexuses in the digestive tract's enteric nervous system which then digestive tract motility and produces dilations in some areas. The rich autonomic innervation of the enteric nervous system also provides an anatomic explanation of the well-known actions of emotional stress on the stomach and other regions of the GI tract.

# The Mouth (oral or buccal cavity)

**Functions:** Ingestion (food intake), sensory responses to food (chewing and chemical digestion), swallowing, speech, and respiration

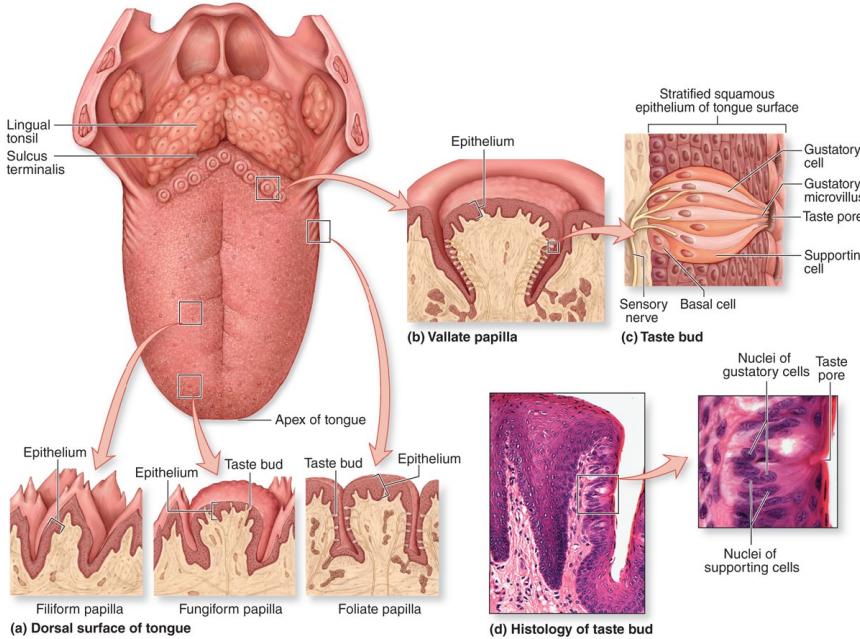
## Stratified squamous epithelium lining

- **Keratinized** in areas subject to food abrasion: gums and hard palate
- **Nonkeratinized** in other areas: floor of mouth, soft palate, and insides of cheeks and lips



» **MEDICAL APPLICATION** Viral infections with herpes simplex 1 cause death of infected epithelial cells that can lead to vesicular or ulcerating lesions of the oral mucosa or skin near the mouth. Such lesions, often painful and clustered, occur when the immune defenses are weakened by emotional stress, fever, illness, or local skin damage, allowing the virus, present in the local nerves, to move into the epithelial cells.

# Tongue, lingual papillae, and taste buds.



**Filiform papillae** provide friction to help move food during chewing.

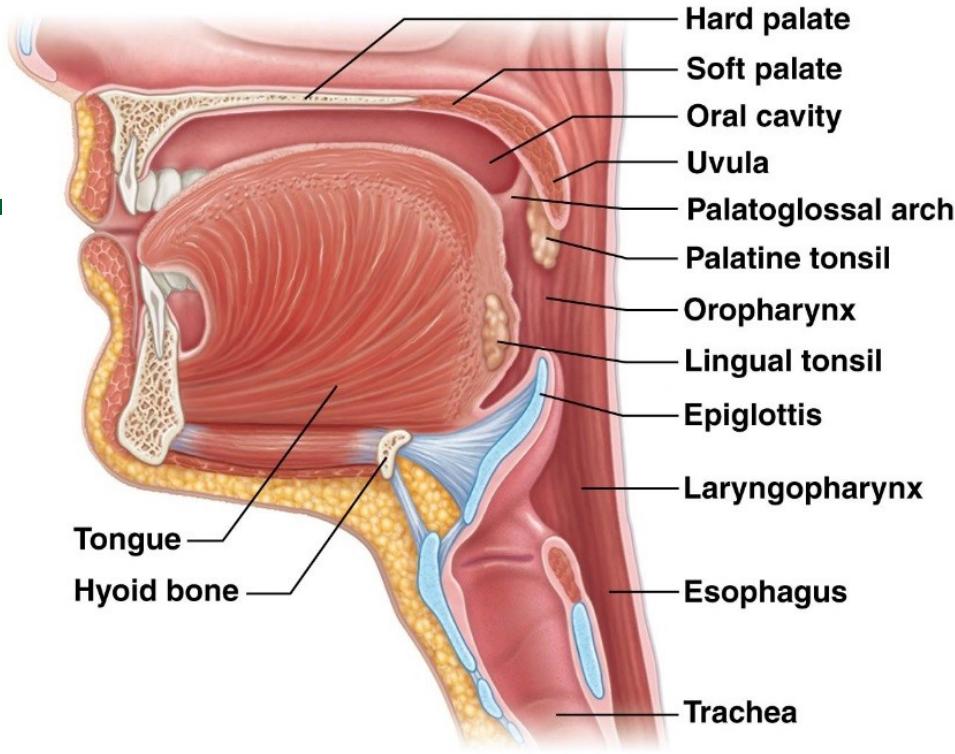
**Foliate papillae**: sides of the tongue, best developed in young children

**Fungiform papillae**: dorsal surface,

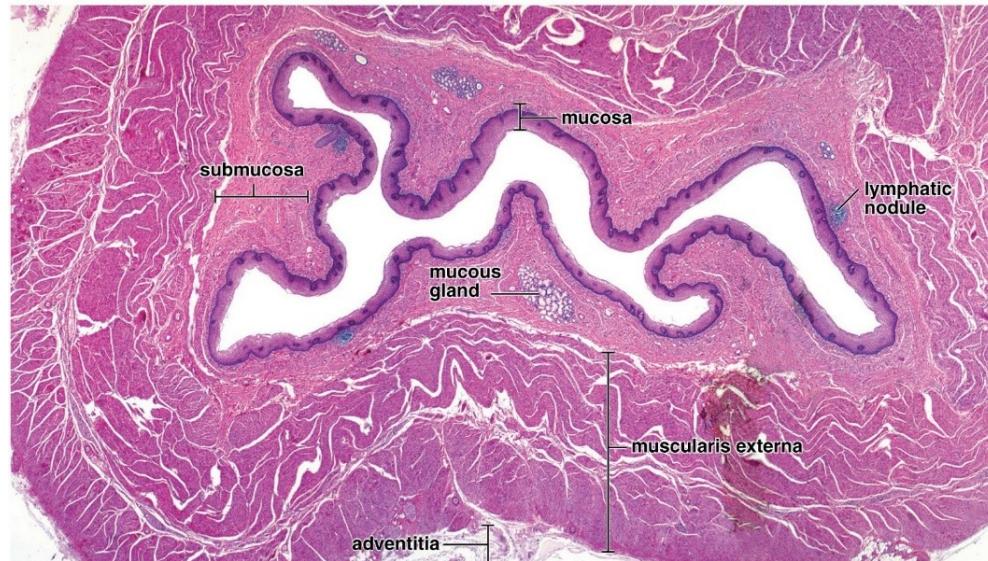
**Vallate papillae**: V-shaped line near the terminal sulcus.

**Taste buds** are present on fungiform and foliate papillae but are much more abundant on vallate papillae.

**Gustatory (taste) cells**: Microvilli at the ends of the gustatory cells project through an opening in the epithelium, the **taste pore**. Afferent sensory axons enter the basal end of taste buds and synapse with the gustatory cells.



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# The Esophagus

## Mucosa:

- thick stratified squamous epithelium,
- thin lamina propria containing occasional lymphatic nodules
- muscularis mucosae.

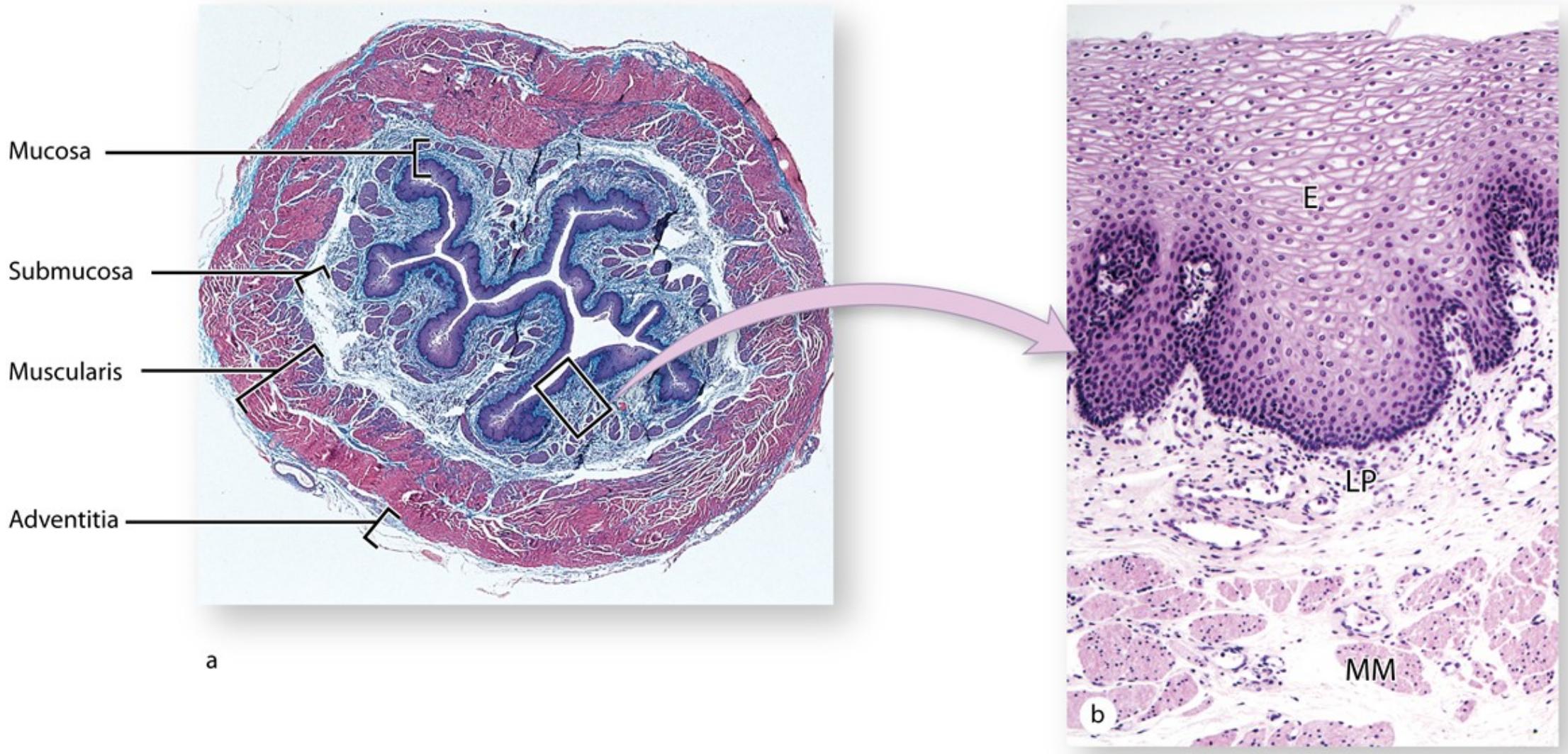
## Submucosa:

Mucous glands with ducts emptying into esophagus

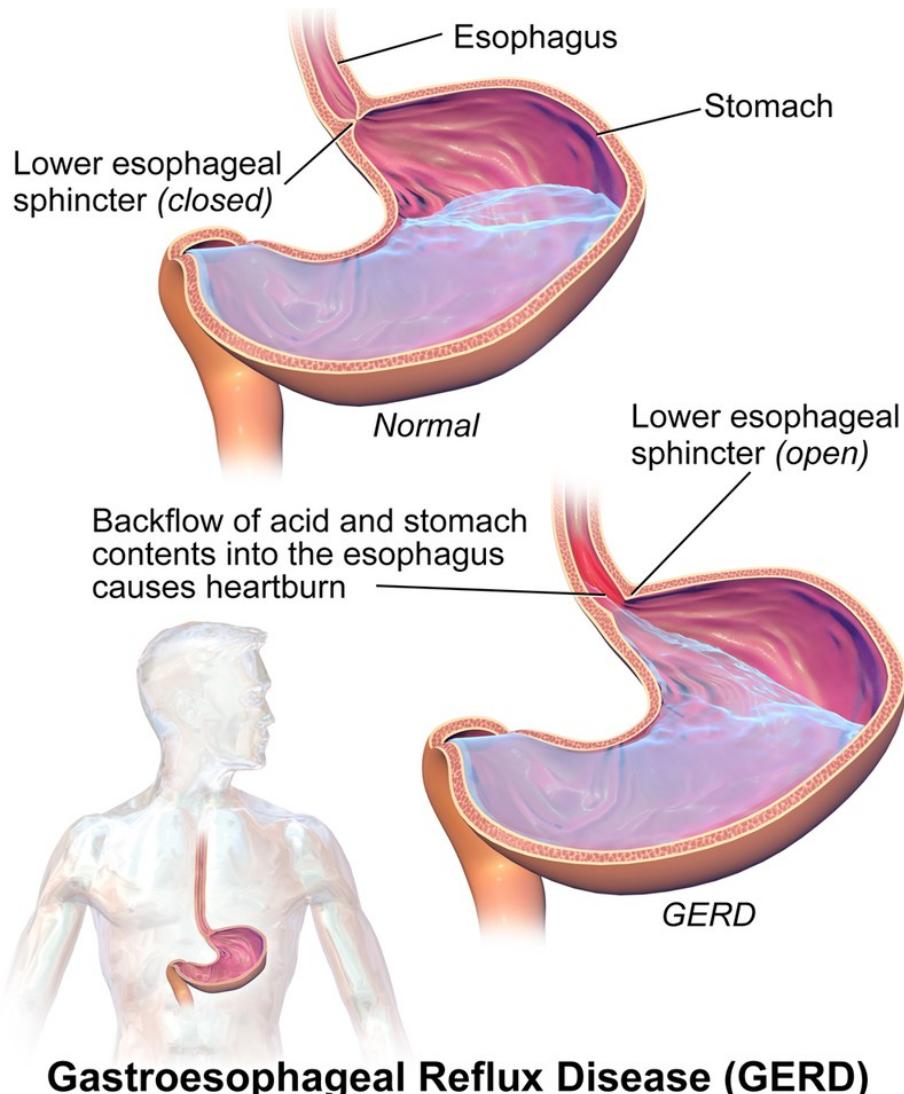
**Muscularis externa:** Thick inner layer circular smooth muscle outer layer longitudinal smooth muscle

## Adventitia

# The esophagus



# The esophagus transports swallowed material from the larynx to the stomach



## >> MEDICAL APPLICATION

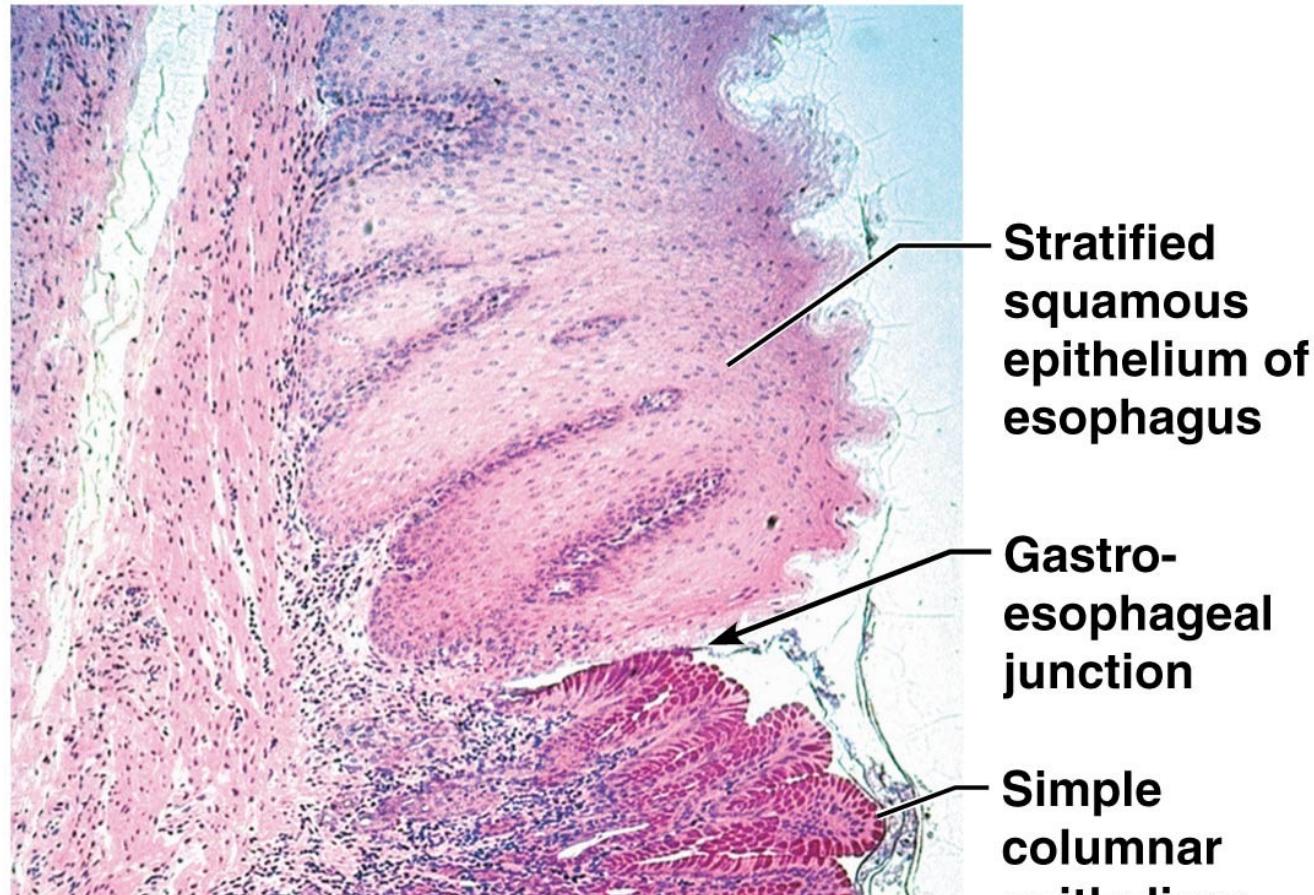
Those glands near the stomach tend to protect the esophagus from regurgitated gastric contents.

Under certain conditions they are not fully effective, and reflux results in pyrosis (heartburn).

This condition may progress to fully developed gastroesophageal reflux disease (GERD).

Understanding GERD (GERD #1): <https://www.youtube.com/watch?v=o8iShP84HP4>

# Esophogastric Junction



Esophagus: **stratified squamous epithelium** (to handle abrasion)

Stomach: **simple columnar epithelium** (secretory & some absorptive functions), acid resistance

The main function of simple columnar epithelial cells are protection. The epithelium in the stomach and digestive tract provides an impermeable barrier against any bacteria that could be ingested but is permeable to any necessary ions.

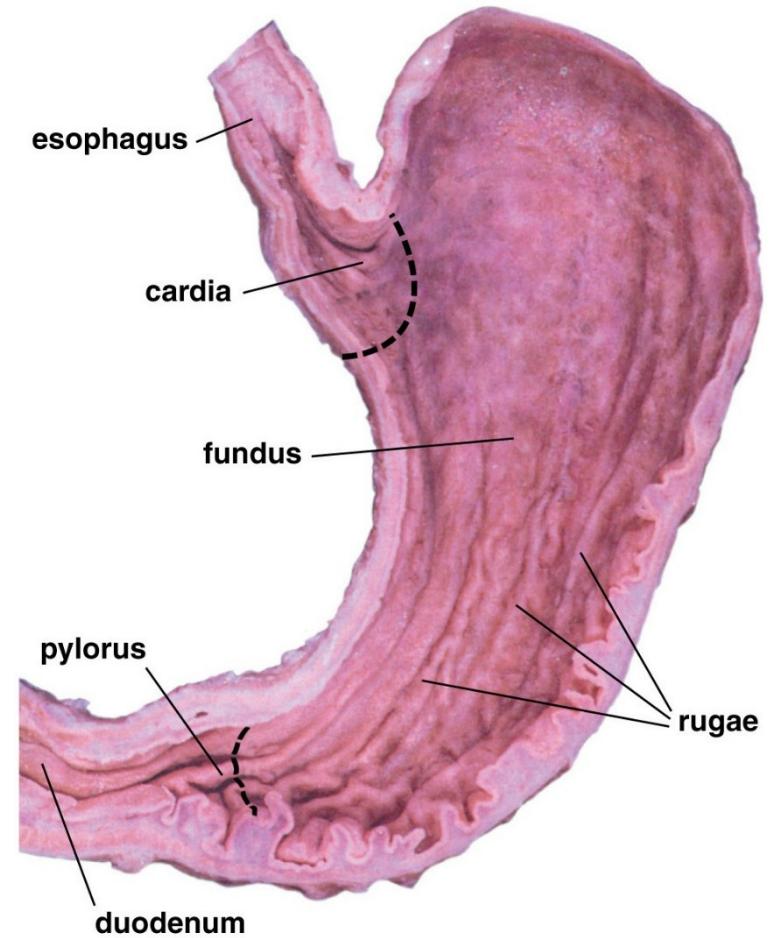
# The stomach is divided histologically into three regions based on the type of gland that each contains.

The stomach is a J shaped muscular sac which liquefies the food into **chyme**, and begins chemical digestion of protein and fat 50 mL (empty) to 4 L (full)

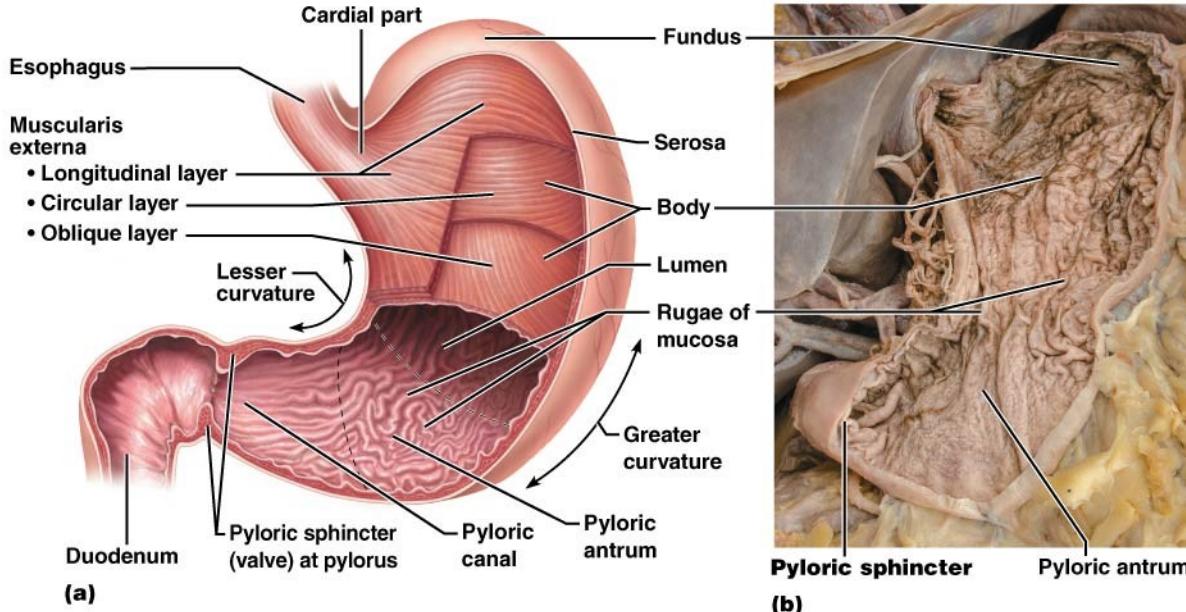
**Cardiac region (cardia):** near the esophageal orifice, contains the cardiac glands

**Pyloric region (pylorus):** proximal to the pyloric sphincter and contains the pyloric glands

**Fundic region (fundus):** situated between the cardia and pylorus and contains the fundic or gastric glands



# The major anatomical (as opposed to histological) stomach regions are the cardia, fundus, body, and pylorus



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**Longitudinal gastric folds, or rugae:**  
Increase surface area

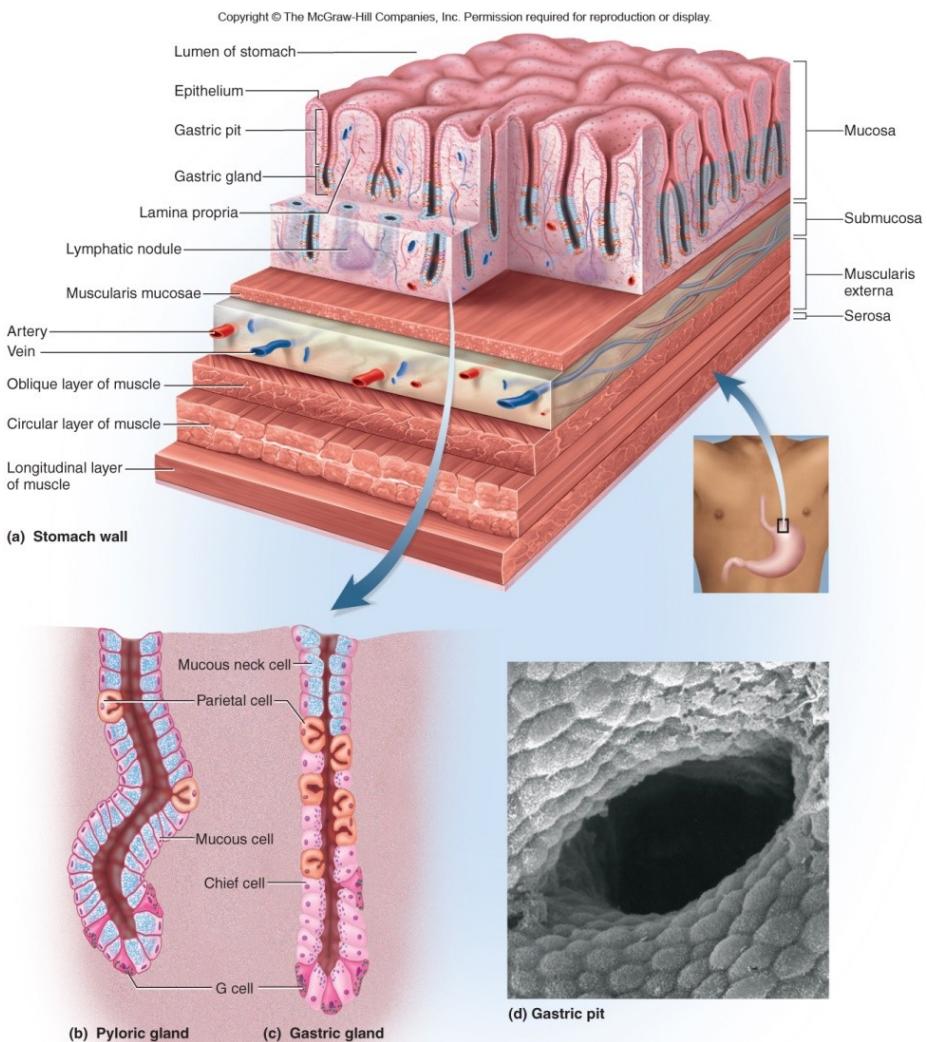
3 layers of **muscular externa** serves vigorous churning of food.

**Medical Application:**  
The stomach lining is not absorptive. However, some water, salts, and lipid-soluble drugs may be absorbed. For instance, alcohol and certain drugs such as aspirin or nonsteroidal anti-inflammatory drugs (NSAIDs) enter the lamina propria by damaging the surface epithelium.

# Mucosa: contains gastric pits that lead into gastric glands, lined by simple columnar epithelium containing five functional cell types.

Gastric pits: contain glands (gastric, pyloric, or cardiac)

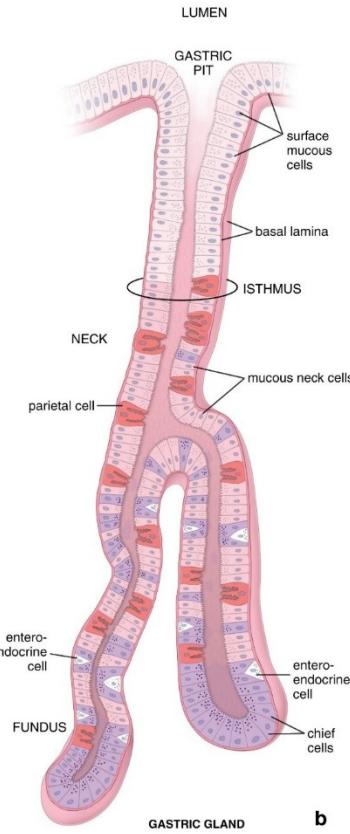
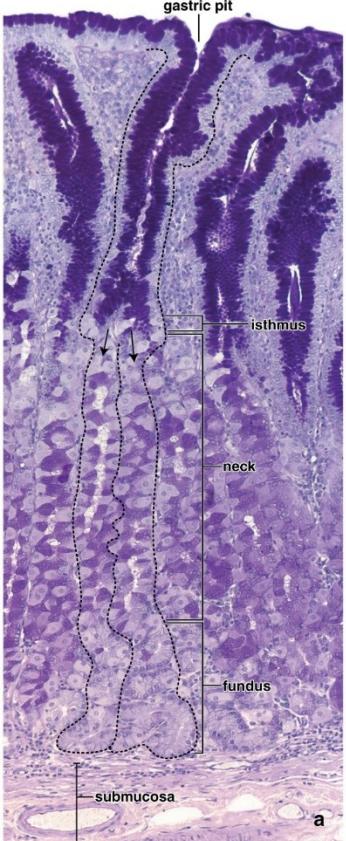
- **Mucous cells:** secrete mucus
- **Regenerative (stem) cells**
- **Parietal cells:** HCl, intrinsic factor (B12 absorption), ghrelin (hunger hormone)
- **Chief Cells:** produce gastric lipase (digests fats), pepsinogen (converted to pepsin, digests peptides)
- **Enteroendocrine (G) cells:** produces hormones, paracrine secretions, brain- gut peptides



**TABLE 25.1****Major Secretions of the Gastric Glands**

<b>Secretory Cells</b>	<b>Secretion</b>	<b>Function</b>
Mucous neck cells	Mucus	Protects mucosa from HCl and enzymes
Parietal cells	Hydrochloric acid	Activates pepsin and lingual lipase; helps liquefy food; reduces dietary iron to usable form ( $\text{Fe}^{2+}$ ); destroys ingested pathogens
	Intrinsic factor	Enables small intestine to absorb vitamin $\text{B}_{12}$
Chief cells	Pepsinogen	Converted to pepsin, which digests protein
	Gastric lipase	Digests fat
Enteroendocrine cells	Gastrin	Stimulates gastric glands to secrete HCl and enzymes; stimulates intestinal motility; relaxes ileocecal valve
	Serotonin	Stimulates gastric motility
	Histamine	Stimulates HCl secretion
	Somatostatin	Inhibits gastric secretion and motility; delays emptying of stomach; inhibits secretion by pancreas; inhibits gallbladder contraction and bile secretion; reduces blood circulation and nutrient absorption in small intestine
	Gut-brain peptides	Various roles in short- and long-term appetite regulation and energy balance

# Gastric Glands



**Medical Application:** Most of the bacteria entering the stomach are destroyed by HCl. However, some bacteria can adapt to the low pH of the gastric contents. ***Helicobacter pylori*** can create a protective basic “ammonia cloud” around itself, allowing it to survive. This bacteria degrades gastric epithelium, leading to 95% of all **Peptic Ulcer Disease (PUD)**.

**Medical Application: Intrinsic factor** complexes with **vitamin B12** in the stomach and duodenum, a step necessary for subsequent absorption of the vitamin in the ileum. Autoantibodies directed against intrinsic factor or parietal cells themselves lead to an intrinsic factor deficiency, resulting in malabsorption of vitamin B12 and **pernicious anemia** (loss of RBCs)

# **Small Intestine: most chemical digestion and nutrient absorption**

## **Duodenum:** pyloric valve to **duodenojejunal flexure**

- Receives stomach contents, pancreatic juice, and bile
- Neutralizes stomach acid is neutralized here
- Breaks down fats
- Pancreatic enzymes perform chemical digestion

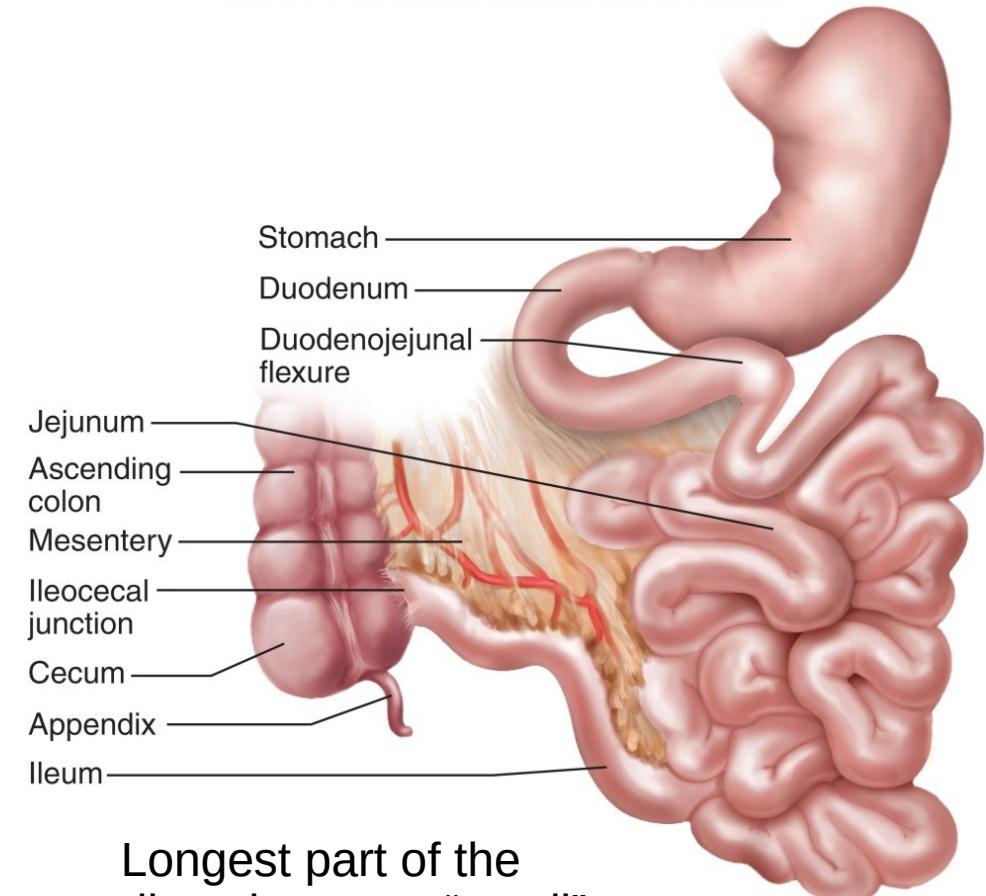
**Jejunum:** Most digestion and nutrient absorption, highly vascularized

**Ileum:** Peyer patches

**Ileocecal junction:** ileum to cecum

**Ileocecal valve:** sphincter, regulates food residue into large intestine

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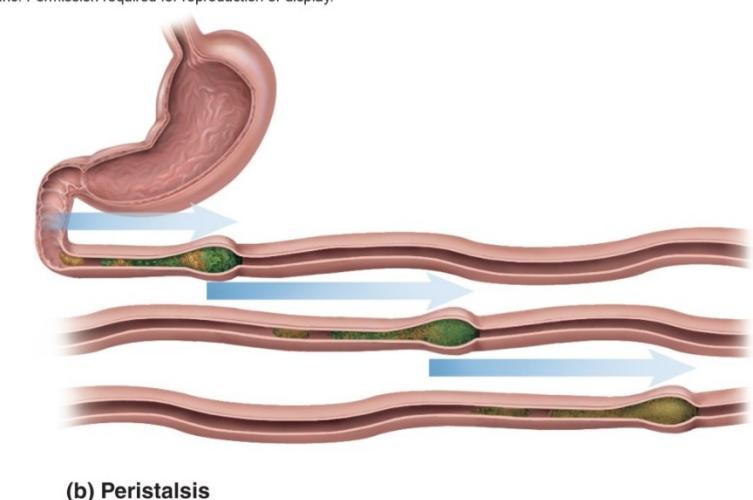
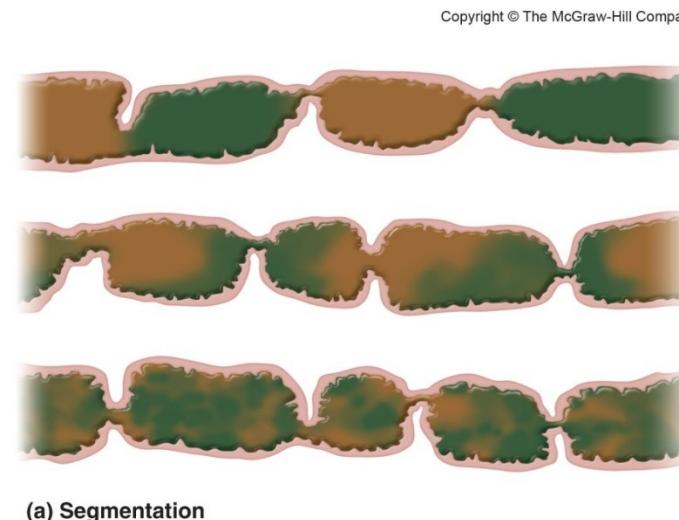
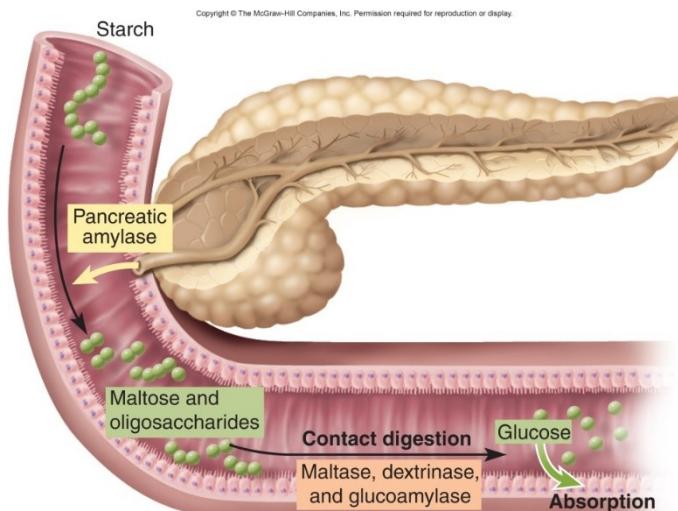
Longest part of the digestive tract, “small” refers to diameter

# Digestion Small Intestine

Pancreatic enzymes work together with brush border enzymes to accomplish chemical digestion

**Segmentation:** Pacemaker cells induce ring like constrictions which appear and disappear, allowing chyme to pass over microvilli for contact digestion

**Peristaltic wave** begins after segmentation, moving chyme toward colon over a period of 2 hours



Surface area for effective digestion and absorption increased by:

**Circular folds** (plicae circulares)

**Villi**

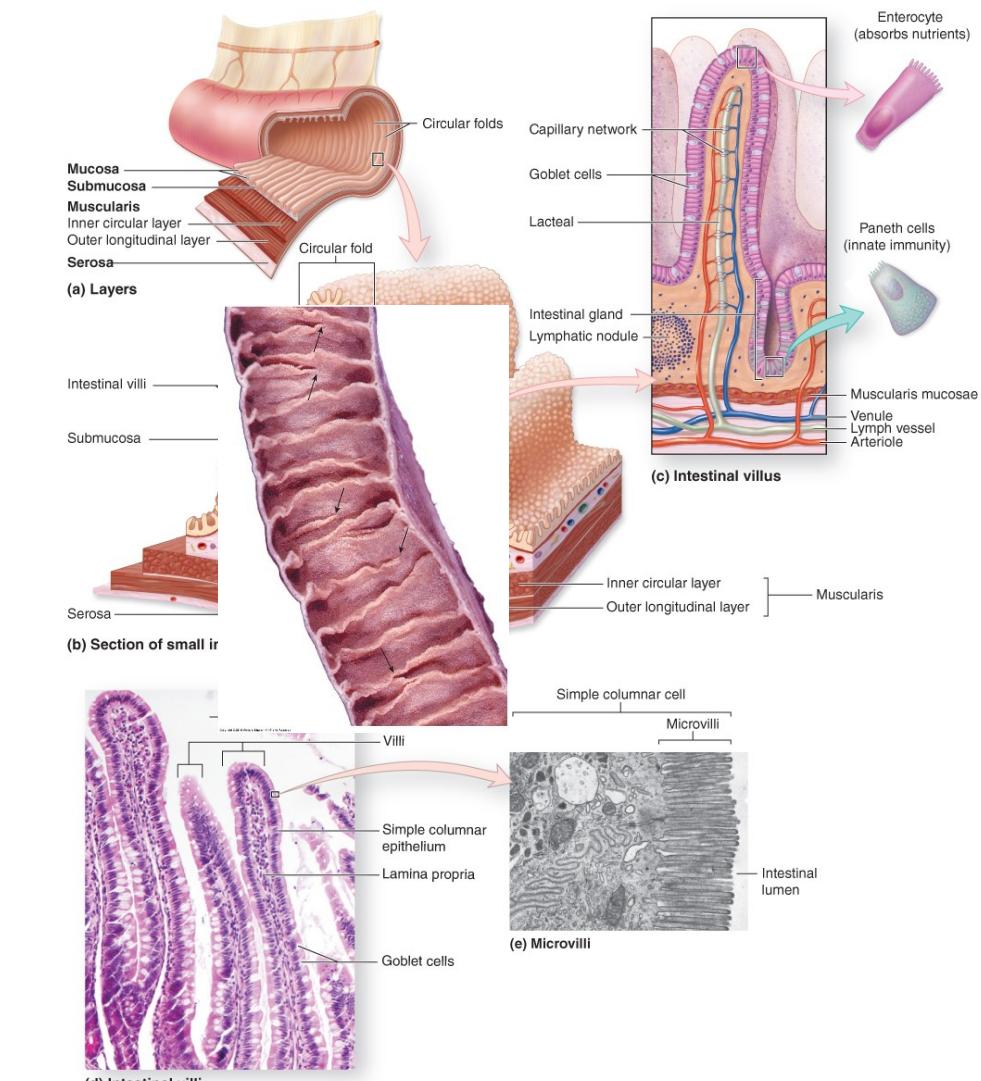
**Microvilli:** contain **brush border enzymes** for contact digestion (chyme must contact the brush border for digestion to occur)

Intestinal churning of chyme ensures contact with the mucosa

**Intestinal crypts** (crypts of Lieberkühn): dividing stem cells, and Paneth cells which secrete lysozyme, phospholipase, and defensins (resist bacterial invasion of the mucosa)

**Duodenal glands:** Neutralize stomach acid and shield the mucosa from its erosive effects

## Microscopic Anatomy of Small Intestine



# **Cells of the Intestinal Mucosal Epithelium**

**Enterocytes:** absorption

**Goblet cells:** unicellular mucin-secreting gland

**Paneth cells:** secrete antimicrobial substances

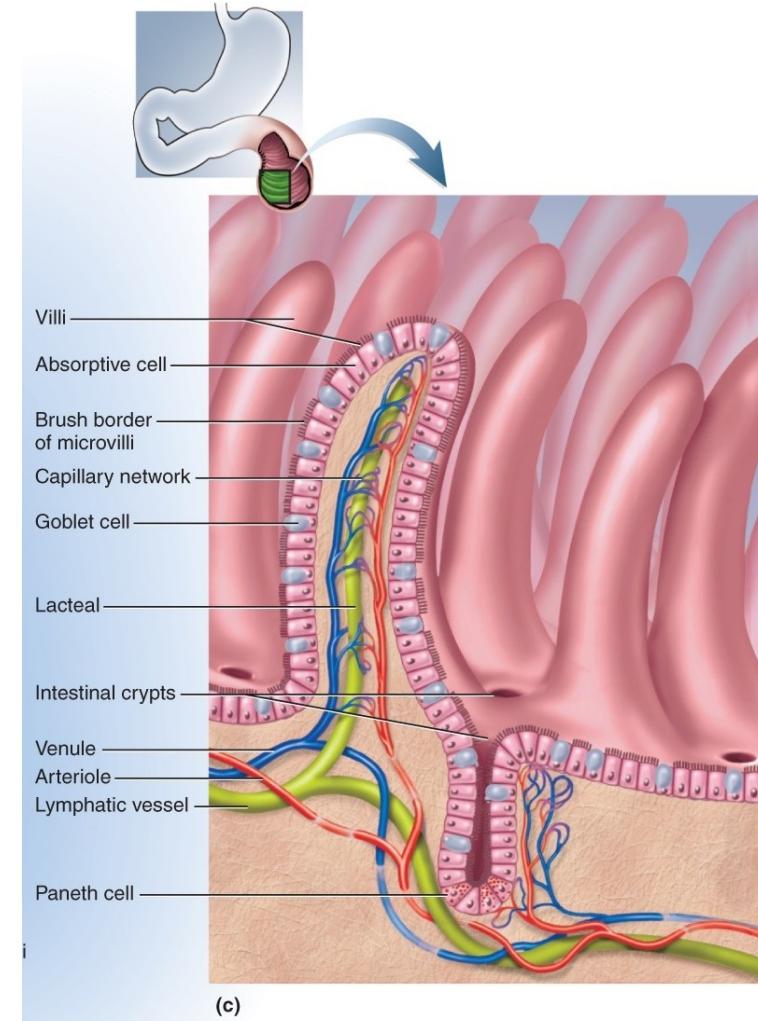
**Enteroendocrine cells:** produce endocrine hormones

**M cells (microfold cells):** specialized cells located in the epithelium that covers lymphatic nodules in the lamina propria

## **MEDICAL APPLICATION:**

Celiac disease (celiac sprue) is a disorder of the small intestine mucosa that causes malabsorption and can lead to damage or destruction of the villi. The cause of celiac disease is an immune reaction against gluten or other proteins in wheat and certain other types of grain. The resulting inflammation affects the enterocytes, leading to reduced nutrient absorption.

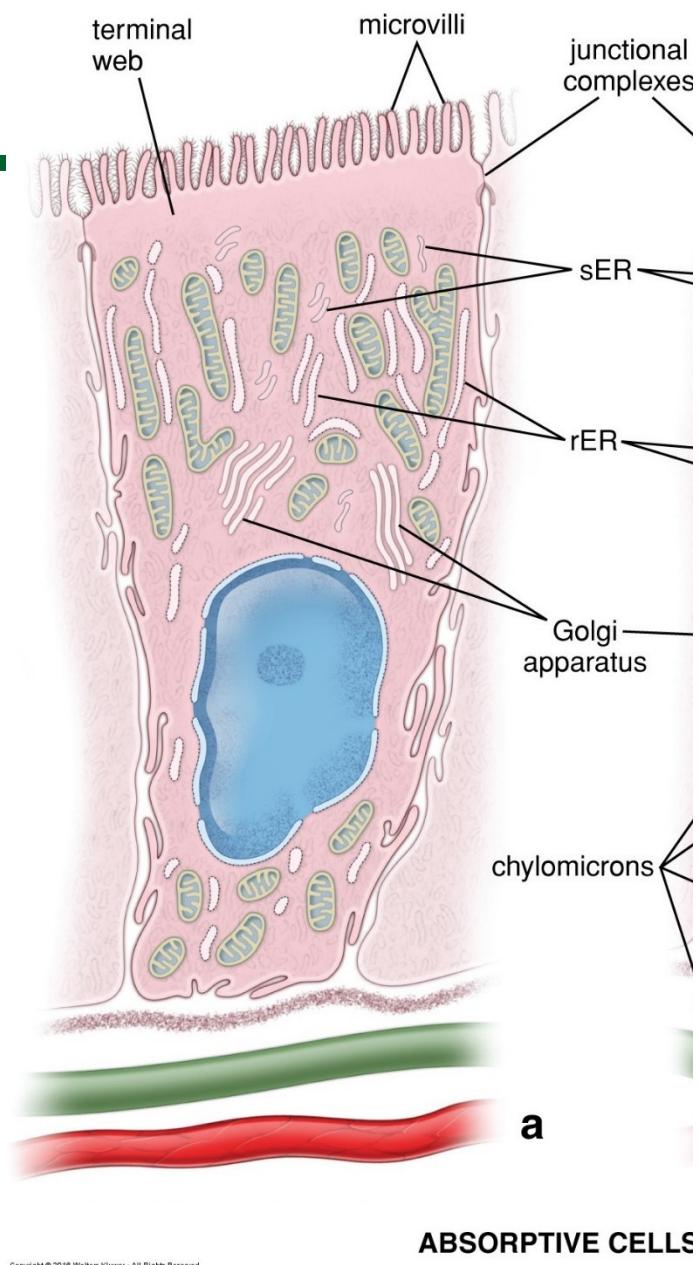
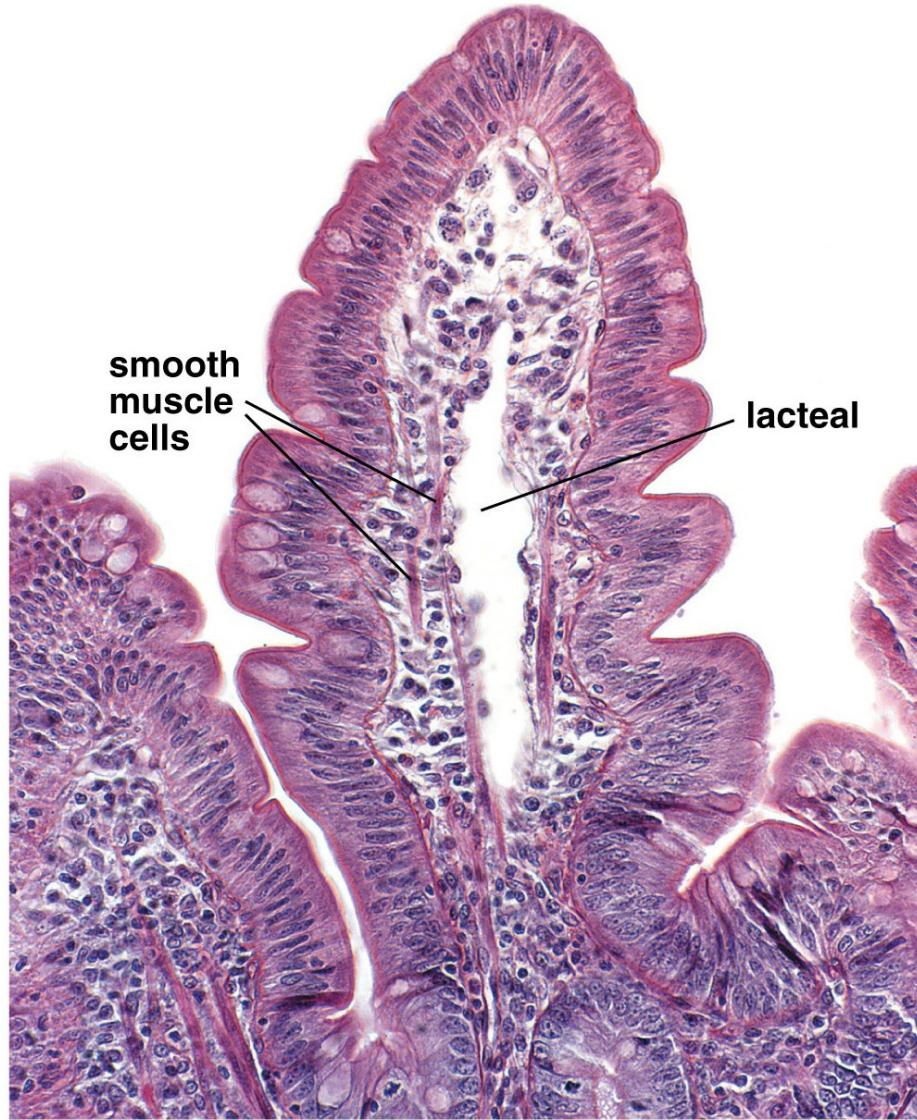
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# Enterocytes Absorb and Transport Substances to Circulation

**Tight junctions** establish a barrier between the intestinal lumen and the epithelial intercellular compartment.

**Enterocytes** are also secretory cells, producing enzymes needed for terminal digestion and absorption as well as secretion of water and electrolytes.



ABSORPTIVE CELLS

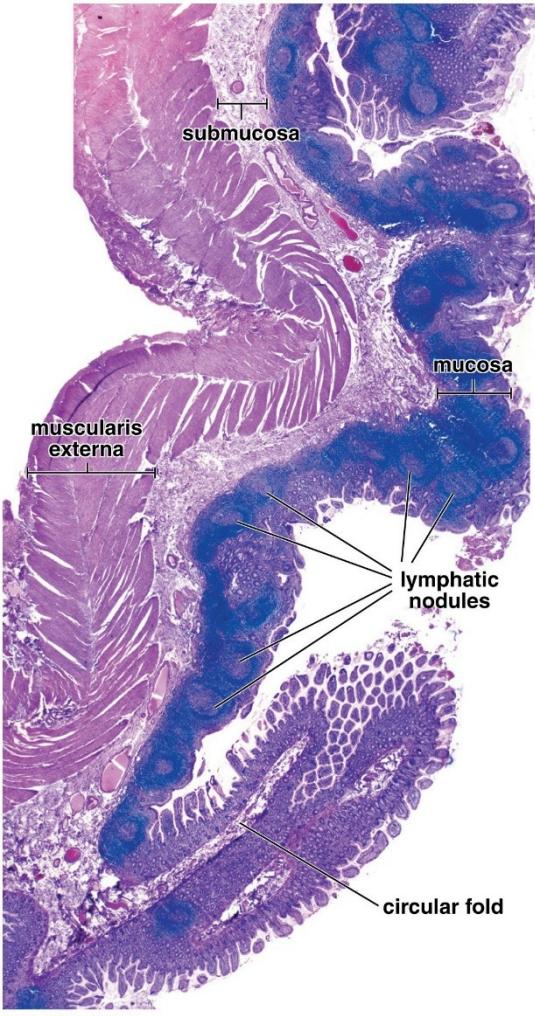
# Duodenal Brunner's Glands De-acidify Stomach Chyme



Submucosa (dense connective tissue) in duodenum contains Brunner's glands.

**Brunner's Glands** are branched, tubular glands with secretions of pH of 8.1 to 9.3 which protect the proximal small intestine by neutralizing the acid containing chime. It also brings the intestinal contents close to the optimal pH for the pancreatic enzymes that are also delivered to the duodenum.

# GALT in the Lamina Propria of the SI



Mucosal surface of the gut tube is constantly challenged by the presence of ingested microorganisms (i.e., viruses, bacteria, parasites) and toxins.

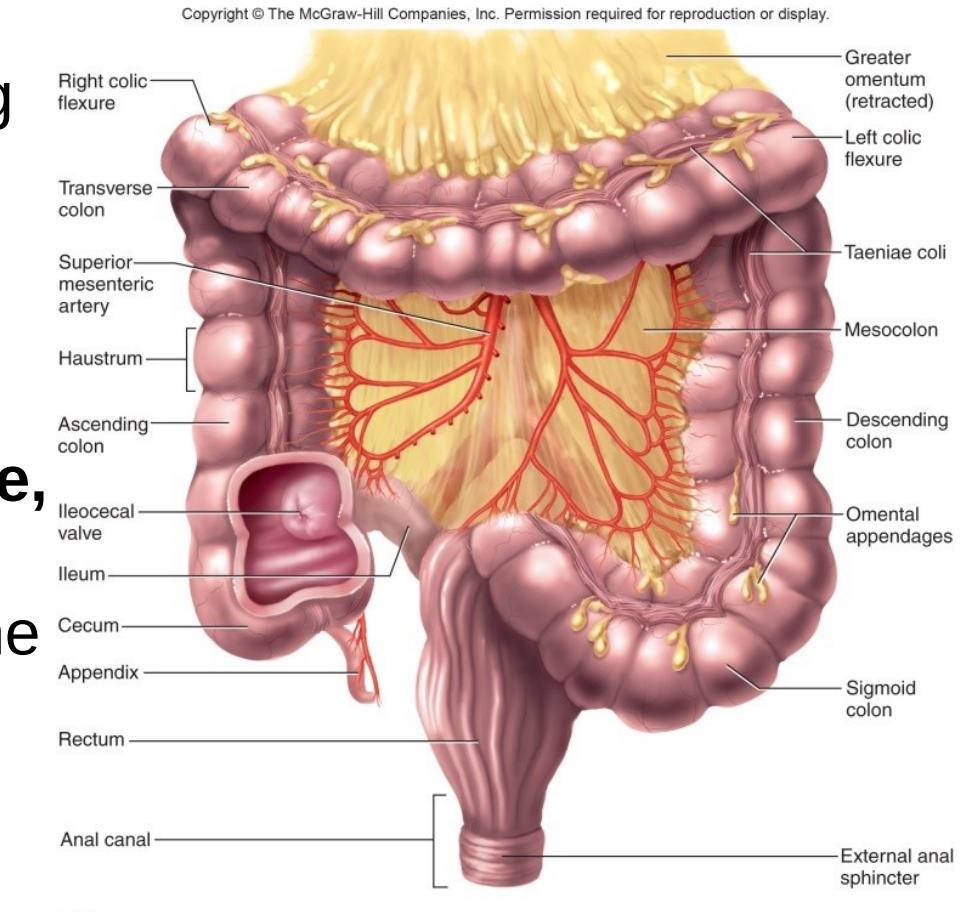
GALT serves as an immunologic barrier throughout the length of the gastrointestinal tract.

**MEDICAL APPLICATION:** Crohn's disease is a chronic inflammatory bowel disease that occurs most commonly in the ileum or colon, resulting from a poorly understood combination of immune, environmental, and genetic factors. Excessive lymphocytic activity and inflammation occur in any or all layers of the tract wall, producing pain, localized bleeding, malabsorption, and diarrhea.

# Large Intestine Receives Undigestible Residue

Large intestine receives about 500 mL/day, reduces it to about 150 mL of **feces** by absorbing water and salts. Eliminates feces by **defecation**

- **Cecum:** inferior to ileocecal valve
- **Vermiform appendix:** attached to lower end of cecum, densely populated with lymphocytes
- **Ascending colon, right colic (hepatic) flexure, transverse colon, left colic (splenic) flexure, and descending colon** frame the small intestine
- **Sigmoid colon** is S-shaped portion leading down into pelvis
- **Rectum:** portion ending at anal canal
- **Anal canal:** final 3 cm of the large intestine



**Taenia coli:** longitudinal fibers

**Haustra Coli:** pouches in the colon caused by the muscle tone of the taeniae coli

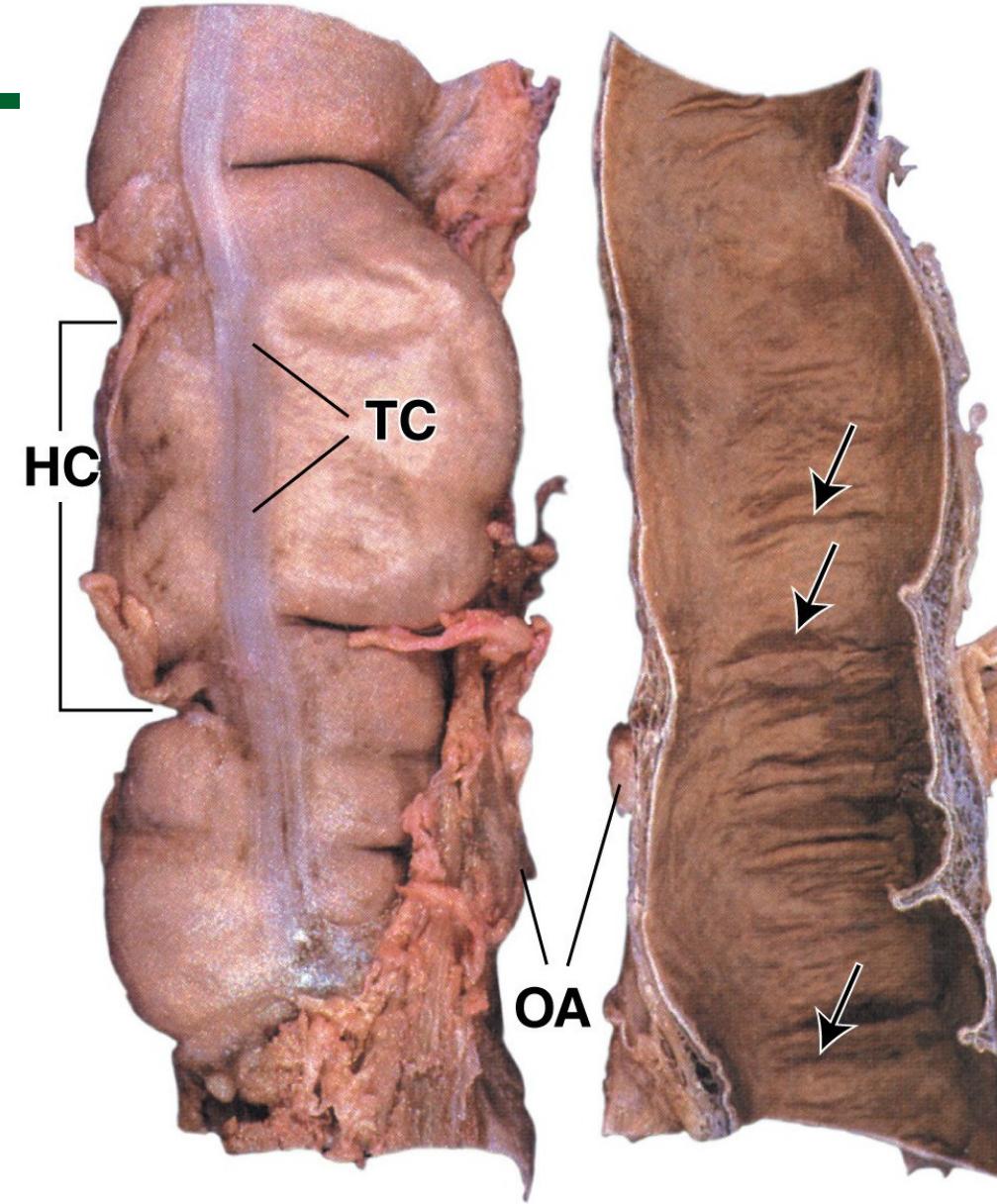
# Medical Applications

**Herniation:** outpocketing of the mucosa and submucosa of the colon can occur between the teniae coli resulting from structural defects in the colon wall or from high intraluminal pressure or constipation.

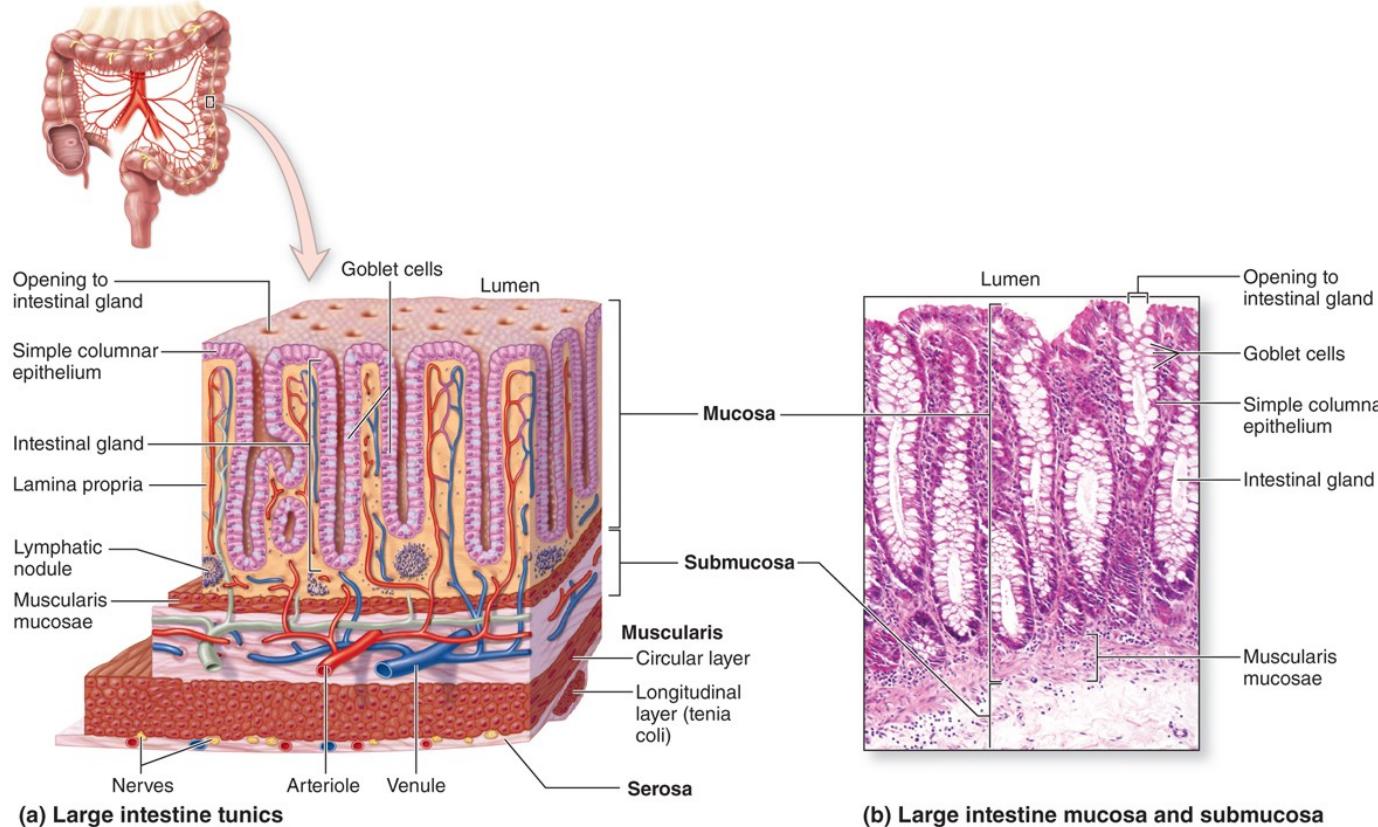
**Bacterial flora populate large intestine:** Digest cellulose and other undigested carbohydrates, help in synthesis of vitamins B and K. Fecal

**Flatus (intestinal gas):** Average person produces 500 mL per day (flatus) from 7 to 10 L of gas present but reabsorbed

Most is swallowed air, but hydrogen sulfide, indole, and skatole produce odor



# Wall of the Large Intestine

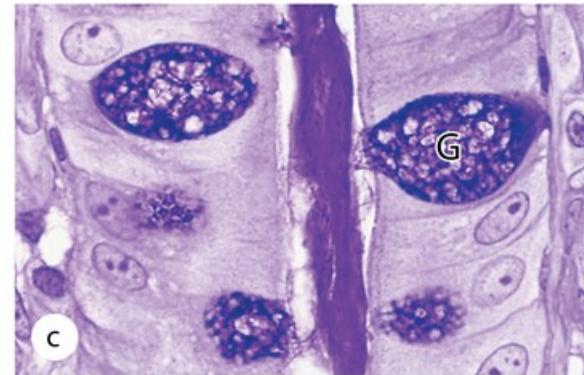
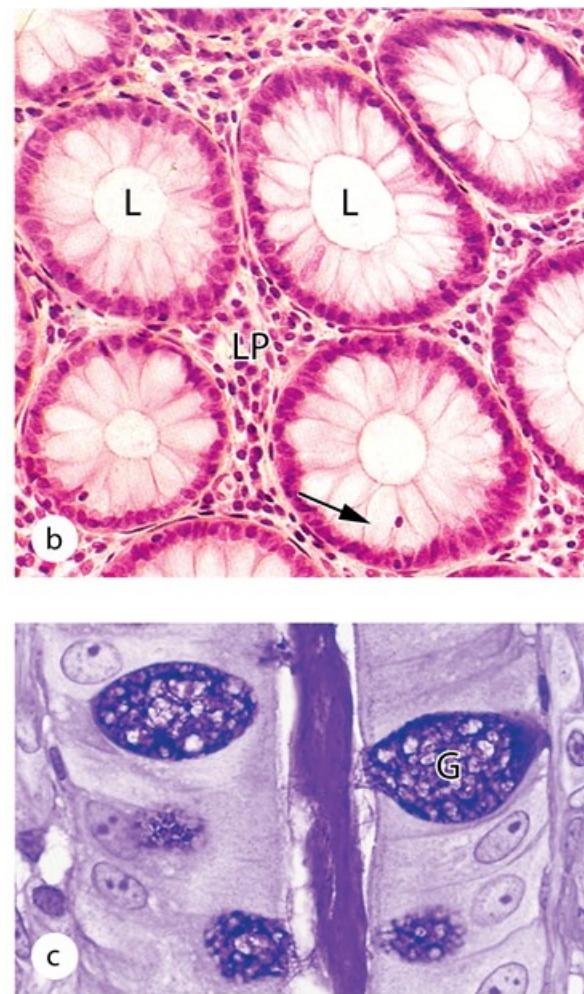


**Mucosa:** tubular **intestinal glands** extending as deep as the **muscularis mucosae** and by **lamina propria** rich in MALT

**Submucosa:** vascularized.

**Muscularis:** inner circular layer, outer longitudinal muscle: is only present in three equally spaced bands, the **teniae coli**.

# Colon mucosa



- (a) Transverse section of the colon shows the muscularis externa (**ME**), including a **tenia coli** cut transversely in the lower part of the figure, the submucosa (**S**), the mucosa (**M**) filled with **tubular intestinal glands**. Some of these glands are cut longitudinally, but most seen here are cut transversely.
- (b) Transversely cut glands are seen to consist of simple columnar epithelium surrounded by a tubular lumen (**L**) and embedded in lamina propria (**LP**) with many free lymphocytes. Lymphocytes can also be seen penetrating the epithelium (**arrow**).
- (c) Longitudinal section of one intestinal gland stained for glycoproteins shows **mucus** in the lumen and two major cell types in the epithelium: goblet cells (**G**) and the neighboring columnar cells specialized for water absorption.

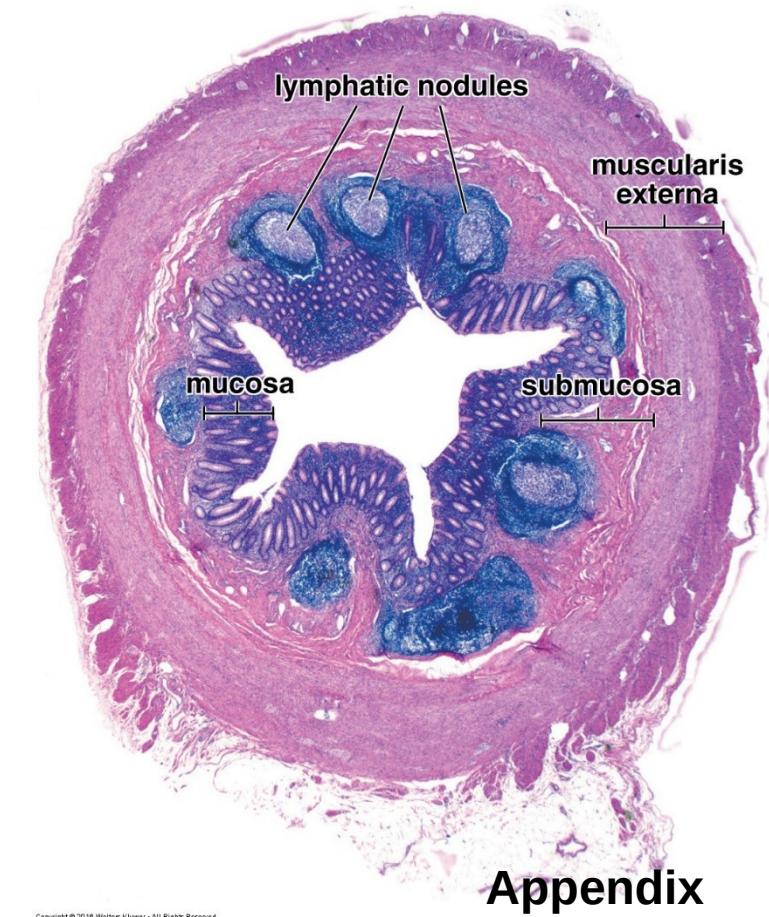
## Cecum and Appendix

**Cecum:** pouch distal to the ileocecal valve. The histology of the cecum closely resembles that of the rest of the colon.

**Appendix:** thin, finger-like extension of this cecum.

- uniform layer of longitudinal muscle in the muscularis externa
- large number of lymphatic nodules that extend into the submucosa.

**Medical Application:** Blockage of the opening between the appendix and the cecum, usually due to scarring, buildup of thick mucus, or stool that enters the lumen of the appendix from the cecum, may cause appendicitis.



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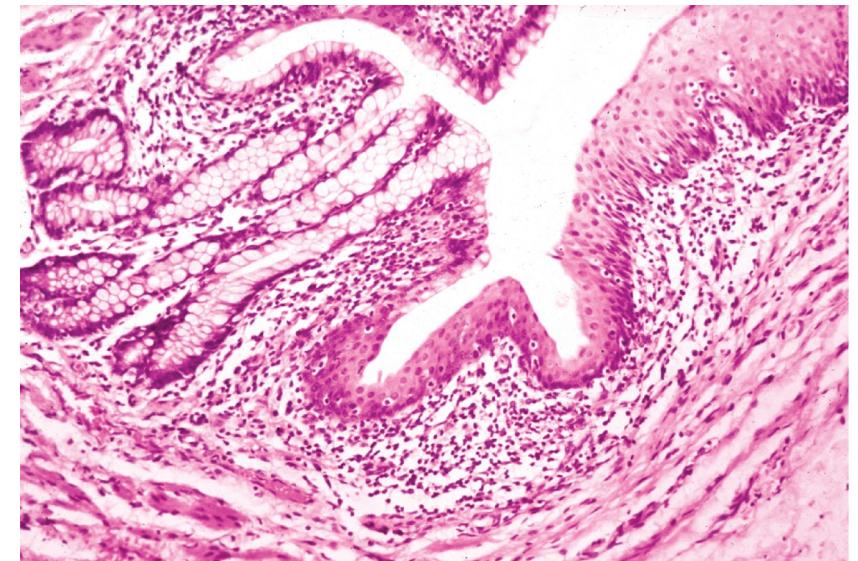
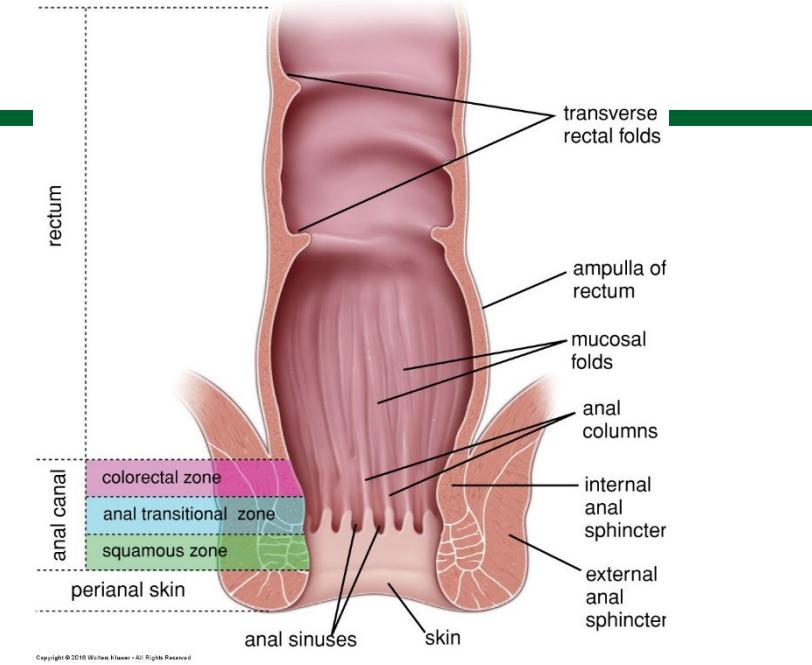
Appendix

# Rectum and Anal Canal

## Mucosa of the rectoanal junction.

The simple columnar epithelium with tubular **intestinal glands** in the rectum (left side of photo) changes abruptly to stratified squamous epithelium in the **anal canal** (right side of photo), as seen in this longitudinal section. The connective tissue of the lamina propria is seen to contain many free lymphocytes

**Hemorrhoids:** Swollen blood vessels in the mucosa or submucosa of the anal canal results from a low-fiber diet, constipation, prolonged sitting, or straining at defecation

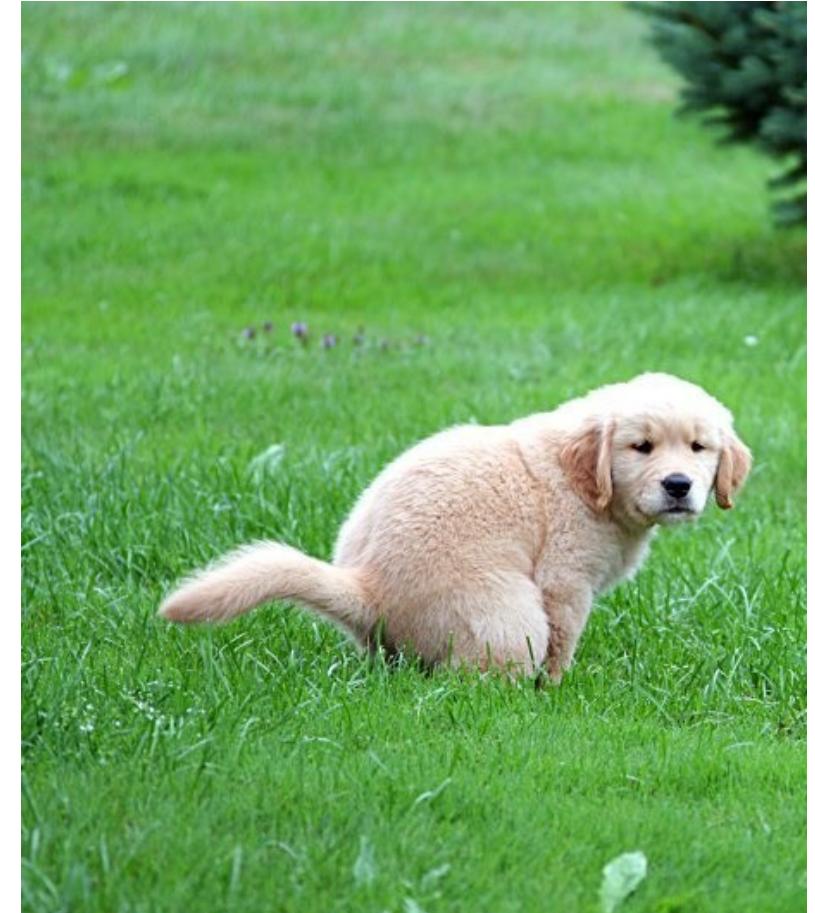


**Haustral contractions:** A form of segmentation, occurs every 30 minutes

- - This kind of colonic motility is segmentation
  - Distension of a haustrum stimulates it to contract
- Mass movements occur one to three times a day
- Stretching of rectum stimulates defecation reflexes, urge to **defecate** that is often felt soon after a meal
- Abdominal contractions (**Valsalva maneuver**) increase abdominal pressure as levator ani lifts anal canal upward
- Feces will fall away

## Defecation

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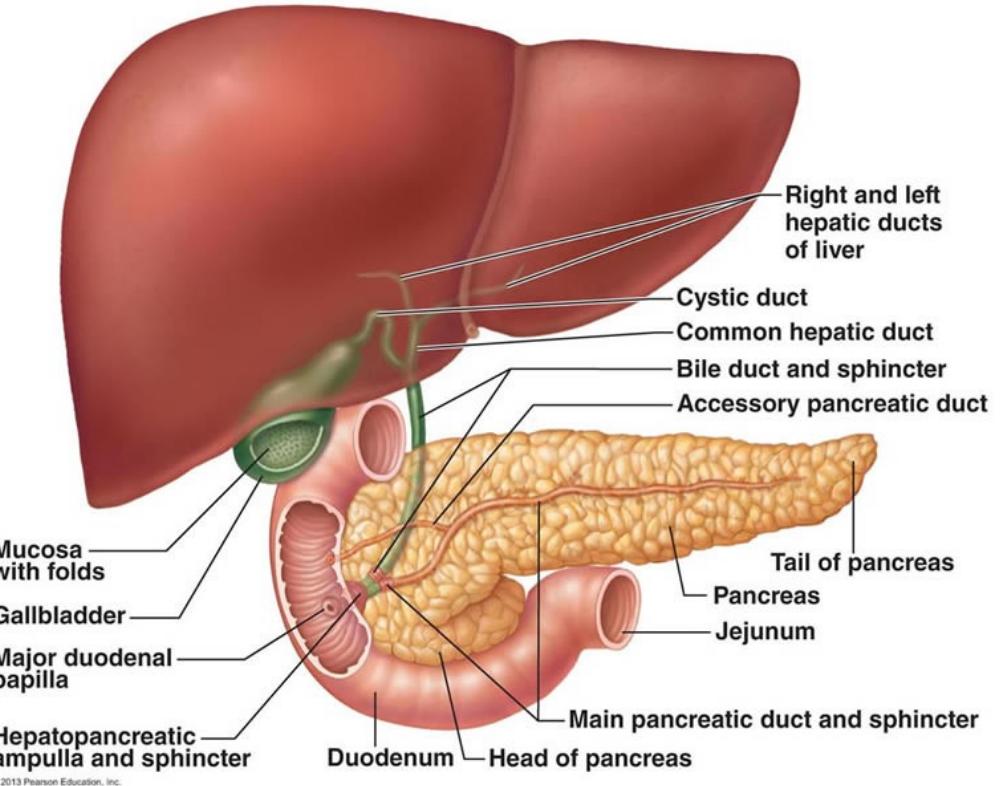
TABLE 15-2

## Summary of distinguishing digestive tract features, by region and layers.

Region and Subdivisions	Mucosa (Epithelium, Lamina Propria, Muscularis Mucosae)	Submucosa (with Submucosal Plexuses)	Muscularis (Inner Circular and Outer Longitudinal Layers, with Myenteric Plexuses Between Them)	Adventitia/Serosa
Esophagus (upper, middle, lower)	Nonkeratinized stratified squamous epithelium; cardiac glands at lower end	Small esophageal glands (mainly mucous)	Both layers striated muscle in upper region; both layers smooth muscle in lower region; smooth and striated muscle fascicles mingled in middle region	Adventitia, except at lower end with serosa
Stomach (cardia, fundus, body, pylorus)	Surface mucous cells and gastric pits leading to gastric glands with parietal and chief cells, (in the fundus and body) or to mucous cardiac glands and pyloric glands	No distinguishing features	Three indistinct layers of smooth muscle (inner oblique, middle circular, and outer longitudinal)	Serosa
Small intestine (duodenum, jejunum, ileum)	Plicae circulares; villi, with enterocytes and goblet cells, and crypts/glands with Paneth cells and stem cells; Peyer patches in ileum	Duodenal (Brunner) glands (entirely mucous); possible extensions of Peyer patches in ileum	No distinguishing features	Mainly serosa
Large intestine (cecum, colon, rectum)	Intestinal glands with goblet cells and absorptive cells	No distinguishing features	Outer longitudinal layer separated into three bands, the teniae coli	Mainly serosa, with adventitia at rectum
Anal canal	Stratified squamous epithelium; longitudinal anal columns	Venous sinuses	Inner circular layer thickened as internal sphincter	Adventitia

Organs Associated with the Digestive Tract  
Salivary Glands, Pancreas, Liver, Gallbladder, Pancreas

# BI 455 CHAPTER 16



# **Saliva and the Salivary Glands**

---

**Saliva:** starch and fat digestion, inhibits bacterial growth

**Salivary amylase:** starch digestion in the mouth

**Lingual lipase:** digests fat in stomach acid,

**Mucus:** lubricates food for swallowing

**Lysozyme:** kills bacteria

**Immunoglobulin A (IgA):** inhibits bacterial growth

**Electrolytes:**  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Cl}^-$ , phosphate, and bicarbonate



**»» MEDICAL APPLICATION** inadequate saliva production, leading to dry mouth or xerostomia, can be caused by various factors affecting the major salivary glands, such as mumps viral infection, radiation of the glands, or the normal side effect of drugs such as antihistamines .

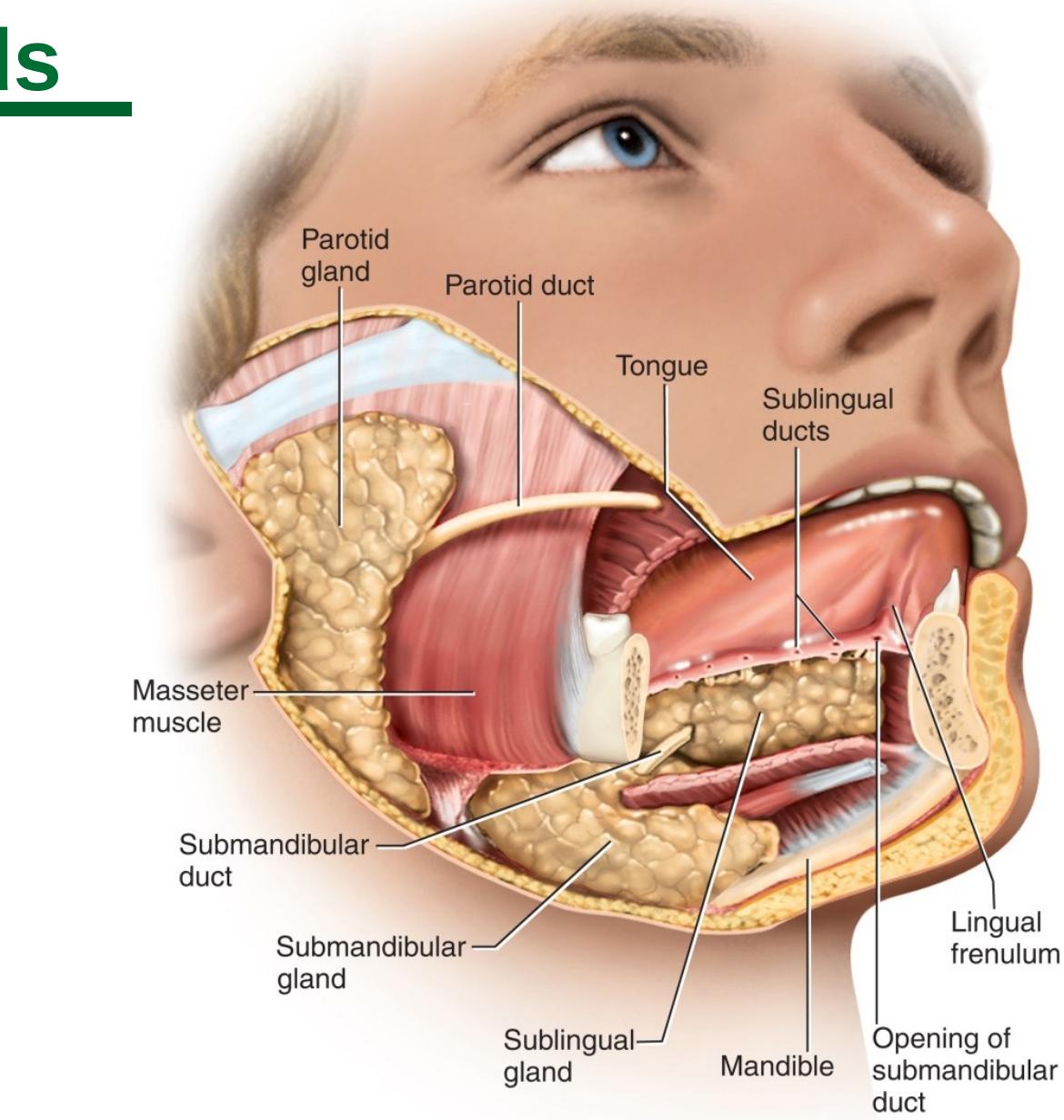
# Saliva and the Salivary Glands

**Extrinsic salivary glands:** connected to oral cavity by ducts. ~1 to 1.5 L of saliva per day

**Parotid:** Mumps is viral infection of parotid gland

**Submandibular gland:** empties near the lower central incisors

**Sublingual glands:** multiple ducts that empty posterior to submandibular duct



Compound **tubuloacinar glands** with branched ducts ending in acini

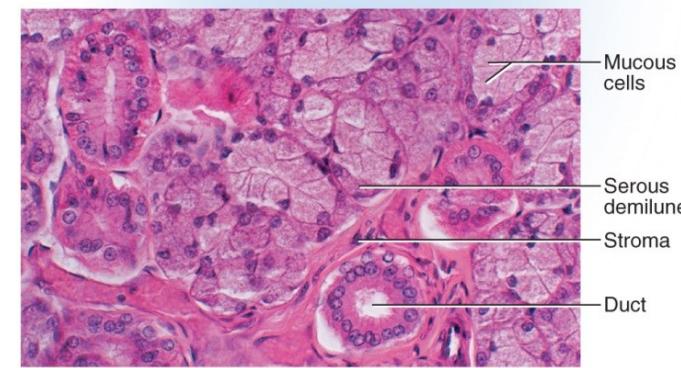
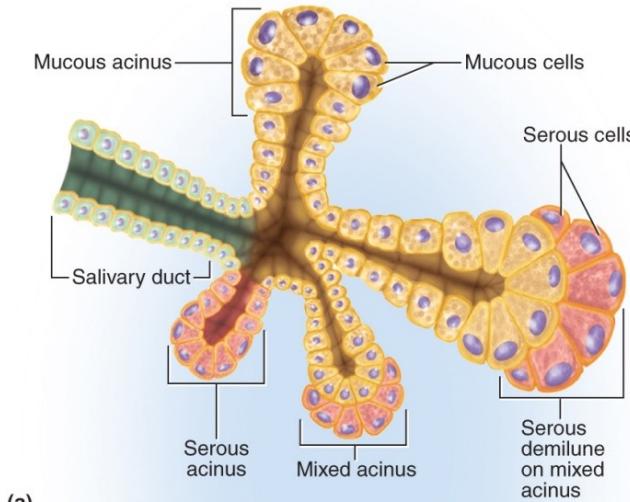
- Mucous (mucous) and serous cells (electrolytes & amylase)
- filter water and electrolytes from blood and add amylase, mucin, and lysozyme
- Salivary nuclei in the **medulla oblongata** and **pons** respond to signals generated by presence of food

### » MEDICAL APPLICATION

Excessive saliva production, or sialorrhea, is associated with the autonomic activity of nausea, inflammation within the oral cavity, and rabies viral infection.

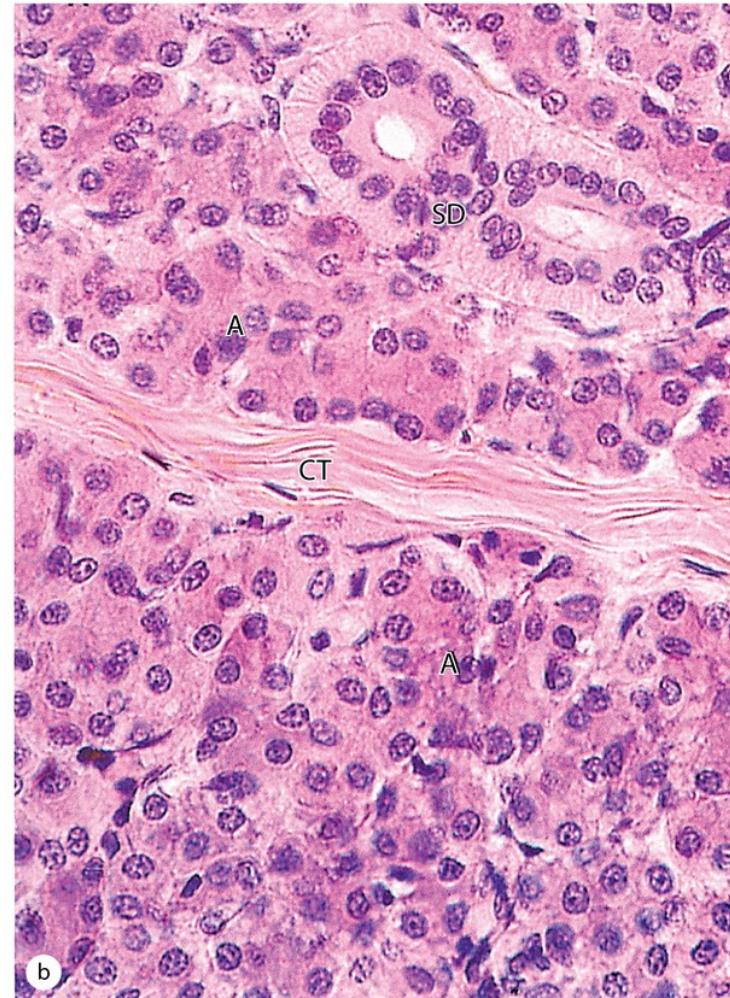
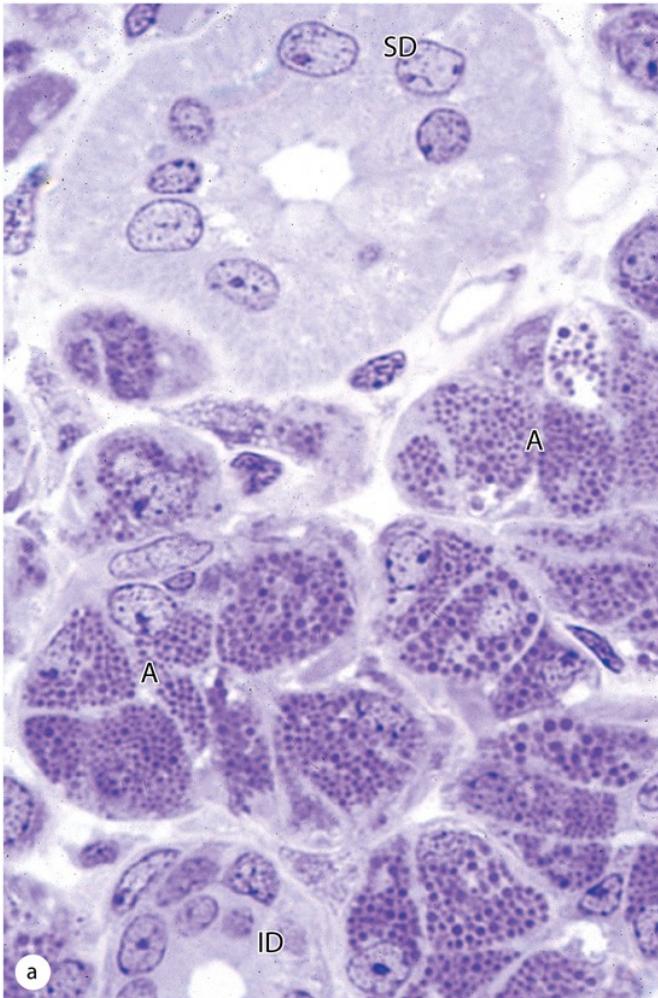
## Histology of Salivary Glands

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# Parotid gland



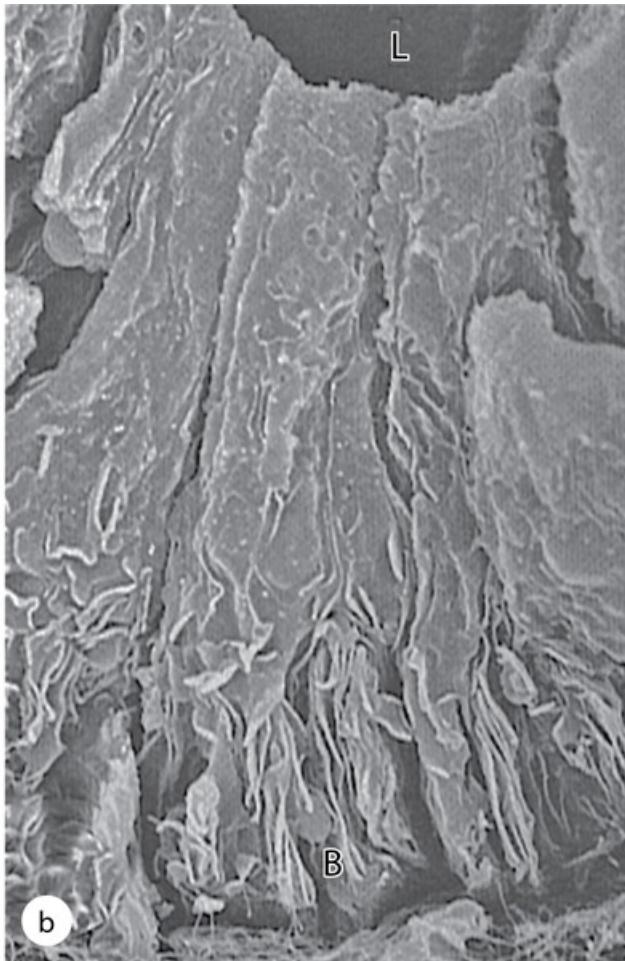
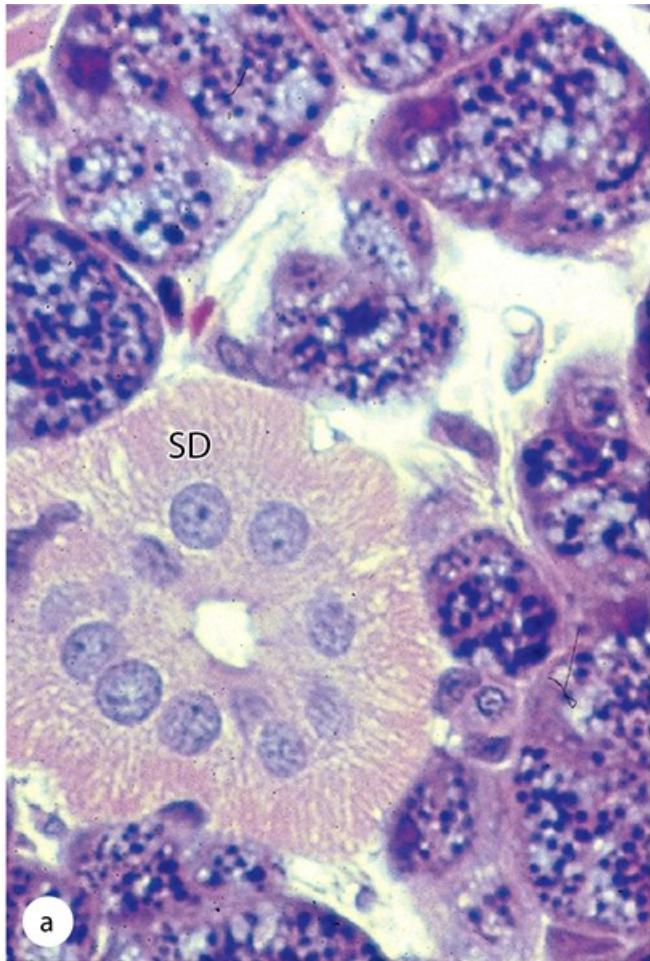
The large parotid gland consists entirely of serous acini with cells producing amylase and other proteins for storage in secretory granules.

**(a)** densely packed serous acini (**A**) with ducts show secretory granules

intercalated duct (**ID**) and striated duct (**SD**), both cut transversely.

**(b)** Striations of a duct (**SD**) are better seen here, along with a septum (**CT**) and numerous serous acini (**A**). The connective tissue often includes adipocytes.

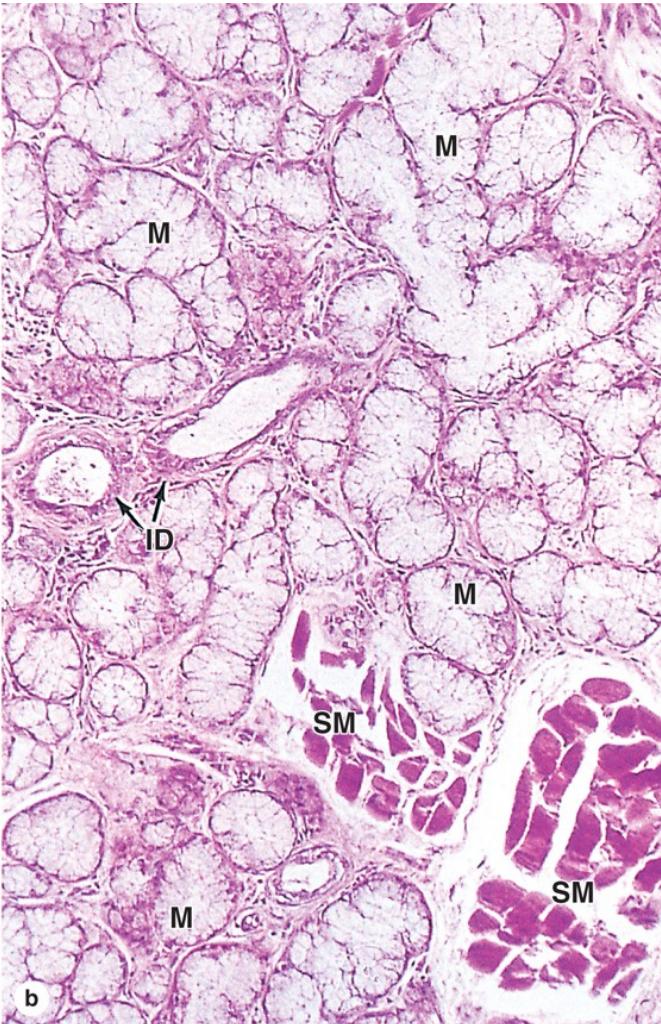
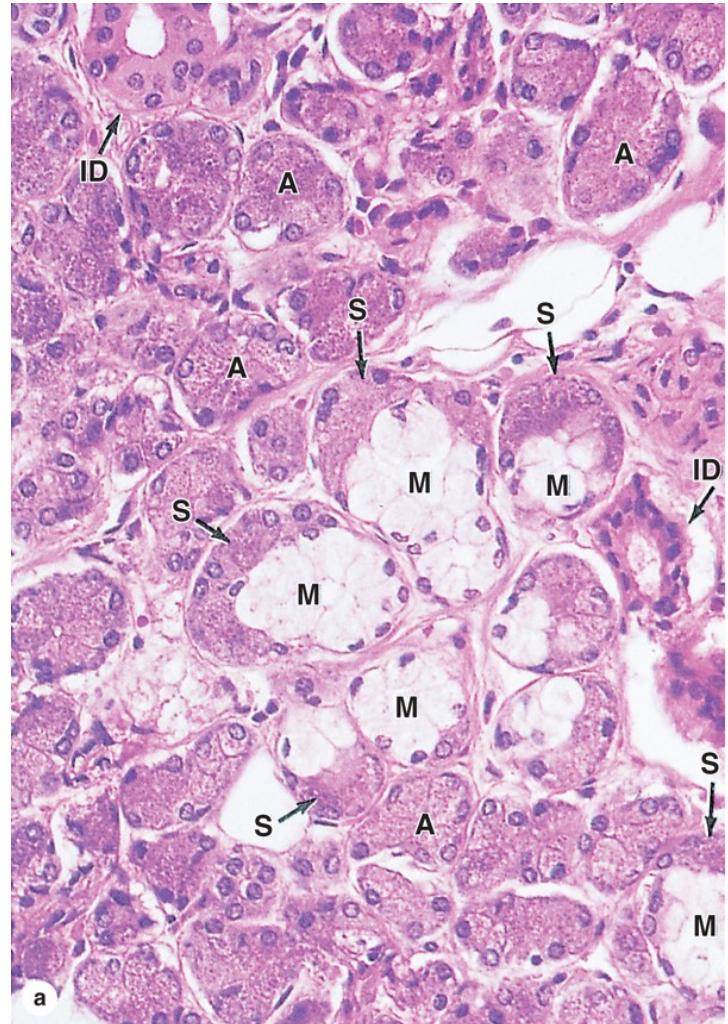
## Striated ducts



**(a)** A striated duct (**SD**) shows very faint striations in the basal half of the columnar cells, which represent mitochondria located in the folds of the lateral cell membrane.

**(b)** SEM indicates that the apical ends of the cells are joined together near the small lumen (**L**), with interdigitating folds of cell membrane best developed at the basal end (**B**).

# Submandibular gland and sublingual gland



(a) The **submandibular gland** is a mixed serous and mucous gland (serous cells predominate), and shows well-stained serous acini (A) and serous demilunes (S) and pale-staining mucous cells (M) grouped as tubules in this tubuloacinar gland. Small intralobular ducts (ID) drain each lobule.

(b) The **sublingual gland** is a mixed but largely mucous gland with a tubuloacinar arrangement of poorly stained mucous cells (M). Small intralobular ducts (ID) are seen in connective tissue, as well as small fascicles of lingual striated muscle

# The Liver Secretes Digestive Bile

## Functions

- Produces circulating plasma proteins (albumins,  $\beta$ -globulins, fibrinogen)
- Stores vitamins and iron
- Degrades drugs and toxins
- Secretes bile

**4 lobes:** right, left, quadrate, and caudate

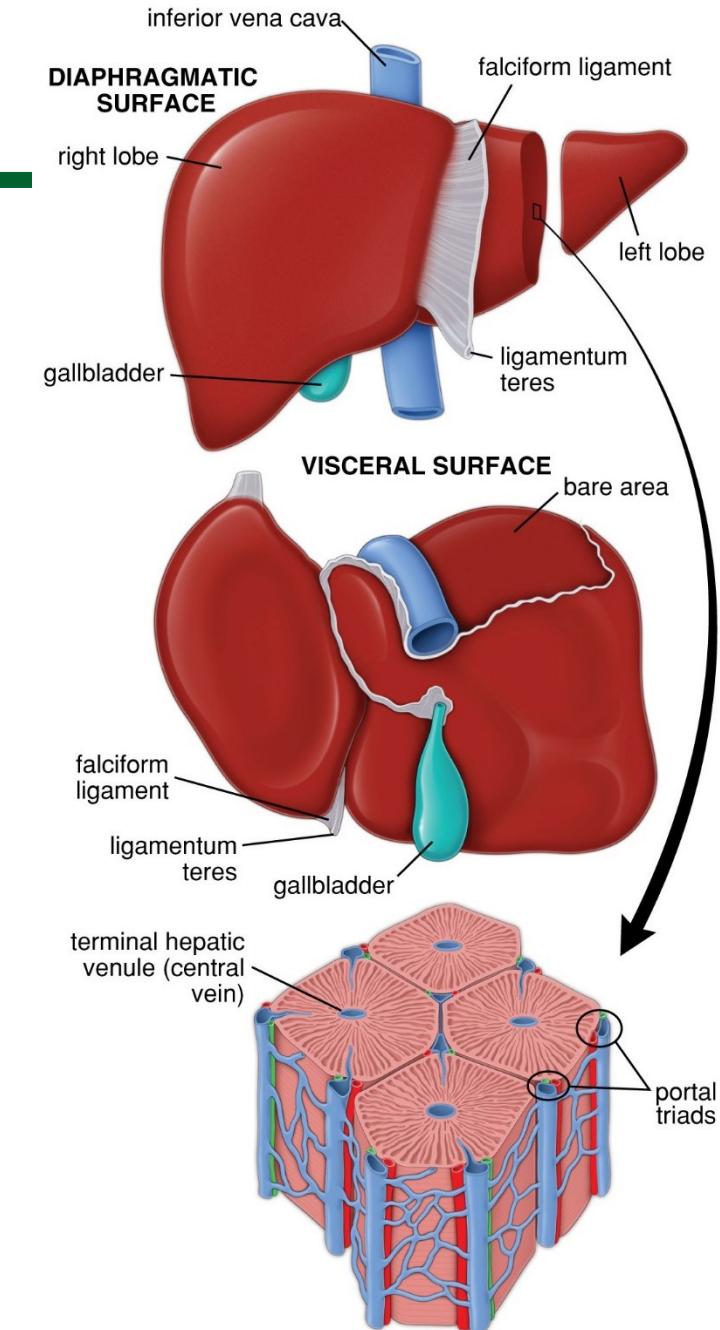
**Falciform ligament:** separates left and right lobes, suspends the liver from the diaphragm

**Round ligament (ligamentum teres):** remnant of umbilical vein, carrying blood to liver of the fetus

**Porta hepatis:** entry of hepatic portal vein and proper hepatic artery, exit of bile passages

**Gallbladder:** Stores bile

**Bile duct:** formed from union of cystic and common hepatic ducts.



# Microscopic Anatomy

**Hepatic lobules:** basic functional units

**Central vein:** passing down the core

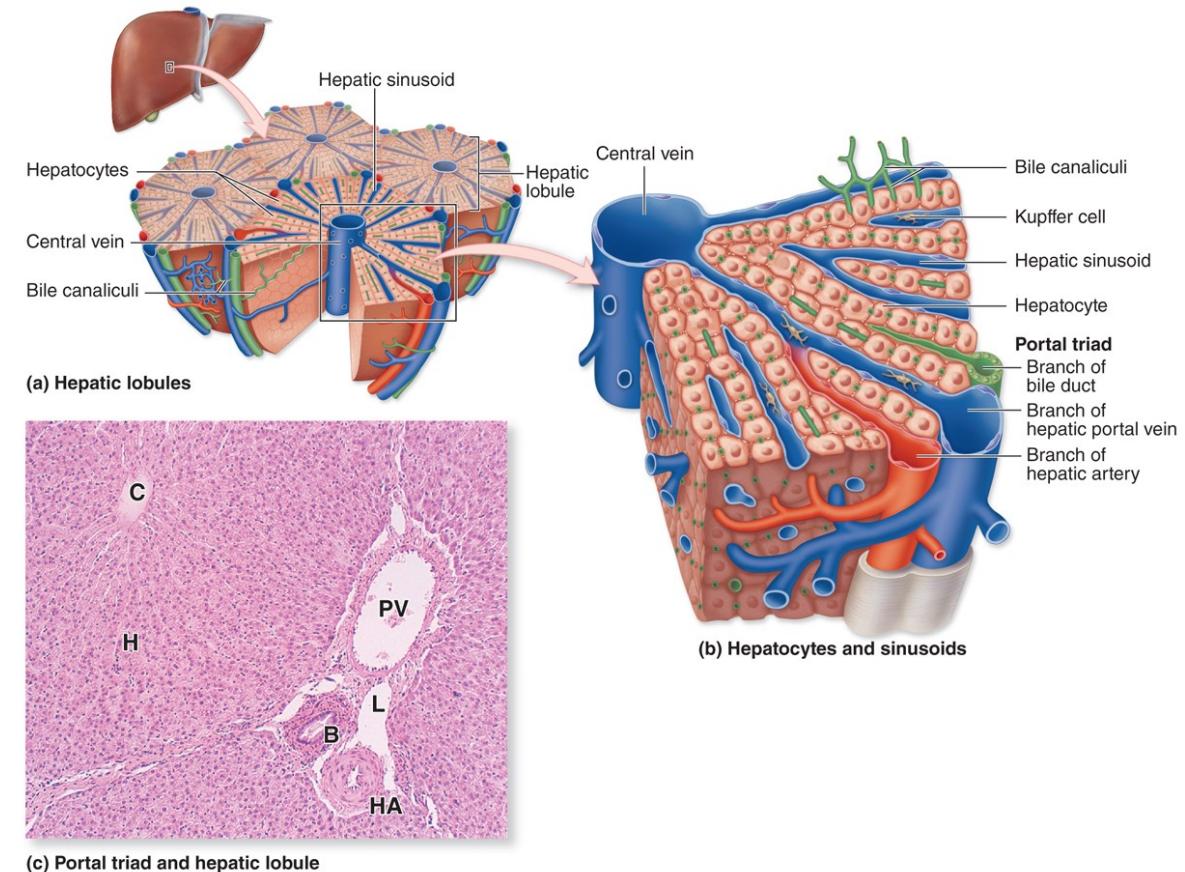
**Hepatocytes:** cuboidal cells, absorb nutrients from blood

**Hepatic sinusoids:** blood from stomach

**Hepatic macrophages (Kupffer cells):** phagocytets

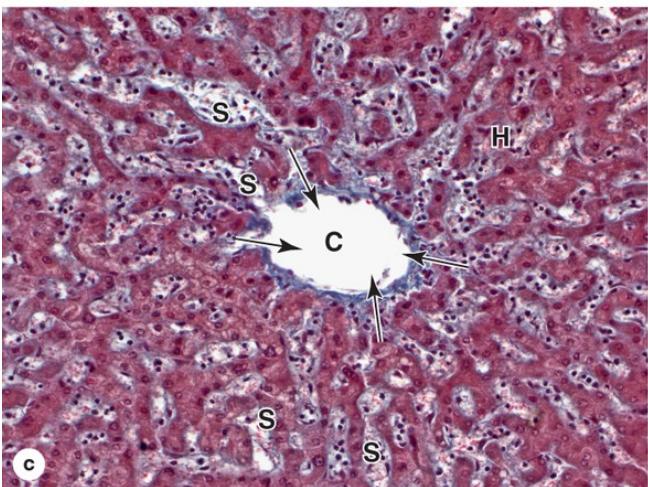
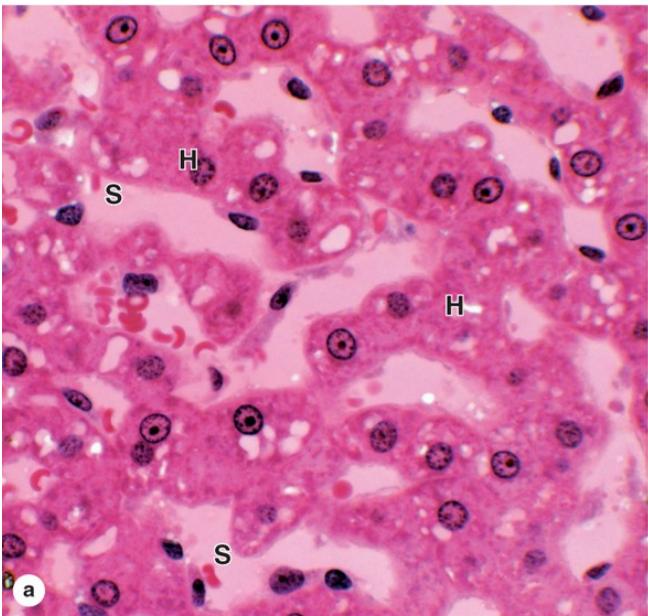
**Bile:** aids in digestion of lipids

**Bile canaliculi:** narrow channels into which the liver secretes bile



**(c)** Micrograph of a lobule shows the central vein (**C**), plates of hepatocytes (**H**), and in an adjacent portal area a small lymphatic (**L**) and components of the portal triad: a portal venule (**PV**), hepatic arteriole (**HA**), and bile ductile (**B**)

# Hepatic Lobule Microvasculature



(a) Hepatocytes (**H**) are polygonal epithelial cells, separated by venous sinusoids (**S**).

(c) hepatocytes (**H**), the central vein (**C**) of the lobule has more collagen than the smaller sinusoids (**S**) that drain into it from all directions (arrows). Mallory trichrome.

**MEDICAL APPLICATIONS:** **Cirrhosis** produces excess connective tissue that interferes with metabolic exchange between the hepatocytes and the sinusoids.

**Fatty liver disease** is a reversible condition in which large lipid droplets containing triglycerides accumulate abnormally in hepatocytes via the process called steatosis. This disorder has multiple causes, but it occurs most commonly in individuals with alcoholism or obesity. Accumulation of fat in hepatocytes may produce a progressive inflammation of the liver.

**Bile:** produced by liver

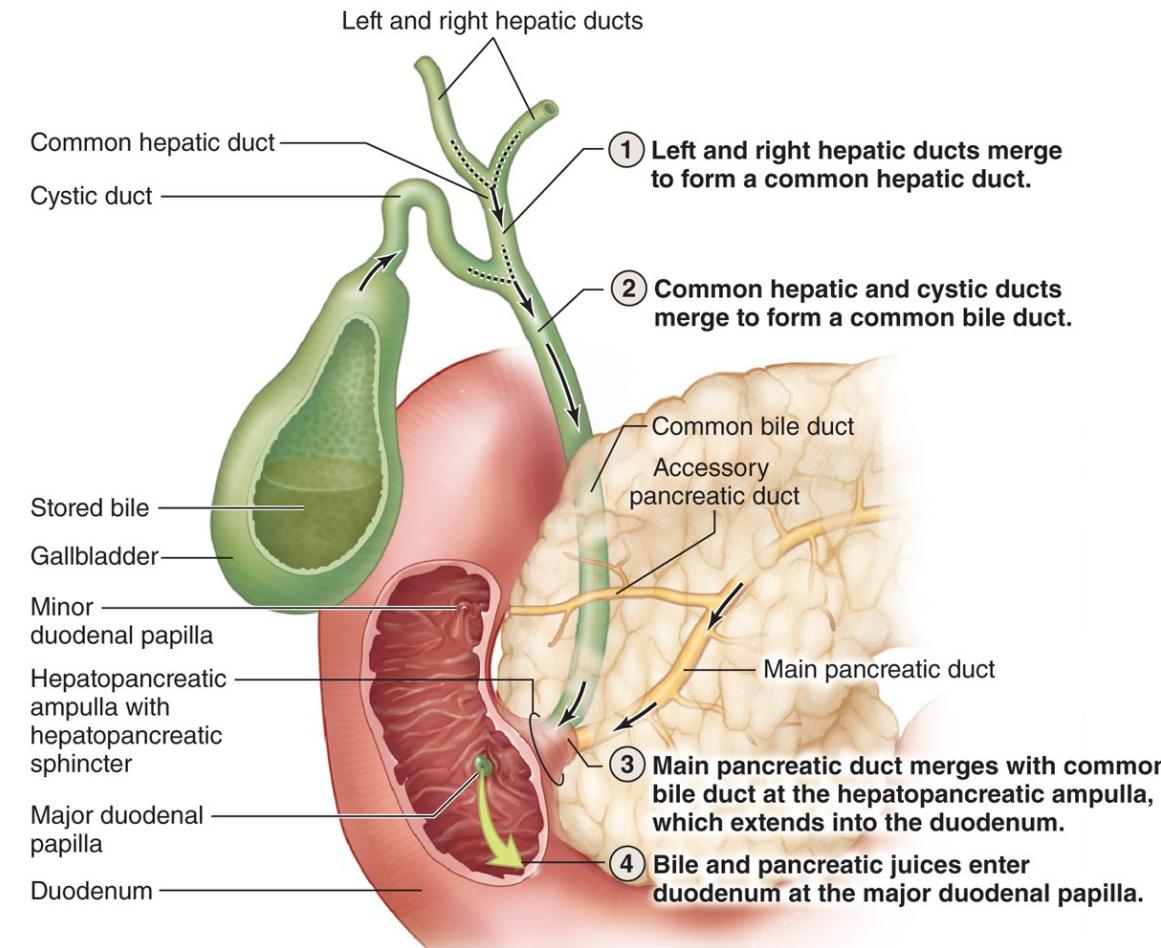
**Bile duct:** formed from union of hepatic ducts.

Bile and pancreatic juices are mixed before release into the duodenal lumen

**Medical Application:** Reabsorption of water from bile in the gallbladder is involved in the formation of **gallstones**. This disorder usually originates with bile that already contains excessive amounts of normal bile components.

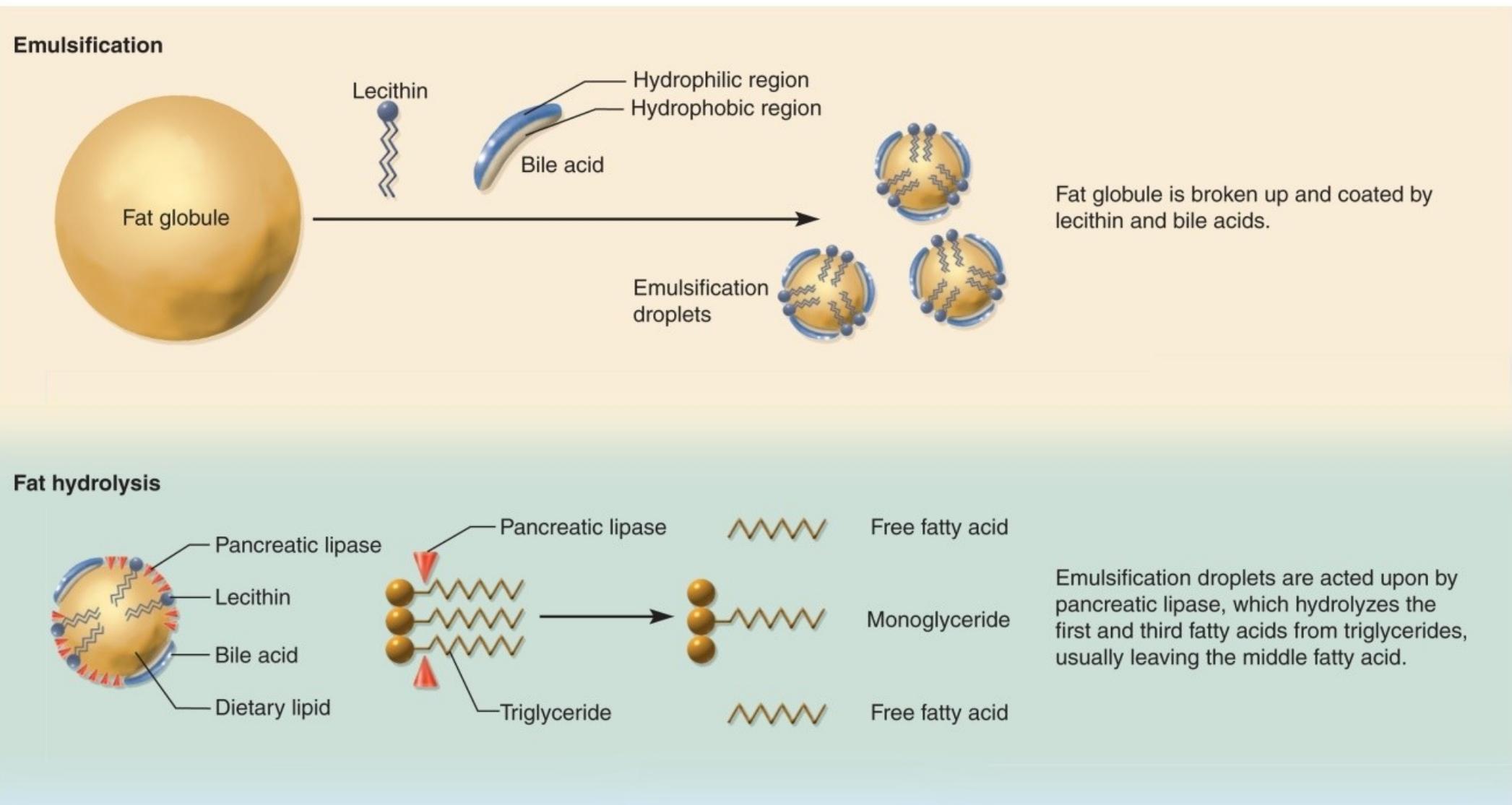
Supersaturation of cholesterol in bile can lead to the formation of cholesterol stones, the most common form.

## The Gallbladder Stores and Concentrates Bile

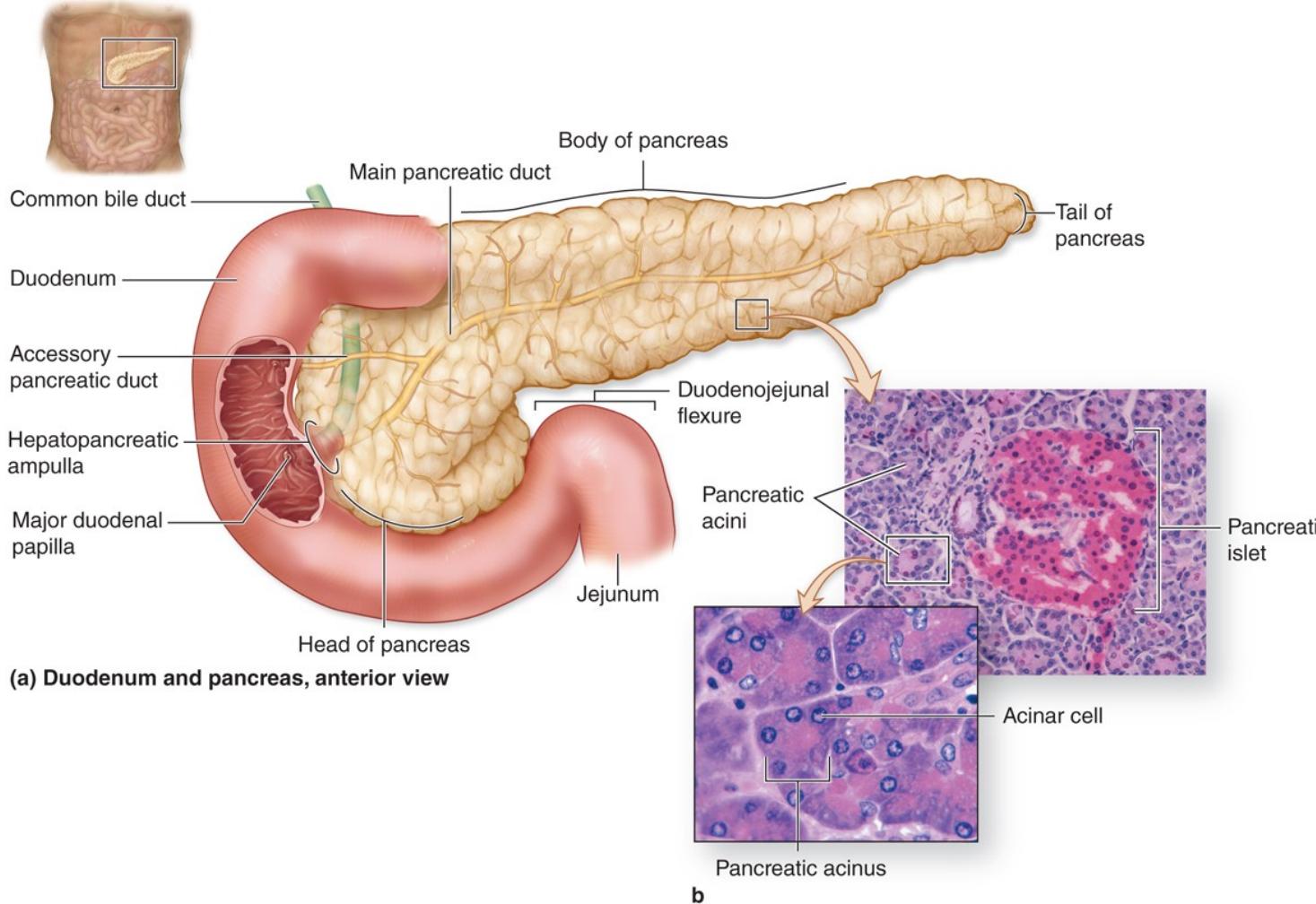


# Bile Acid Emulsifies Fat So Pancreatic Enzymes Can Access Their Substrate

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# Pancreas and duodenum



**(a)** The main regions of the pancreas are shown in relation to the two pancreatic ducts and the duodenum

**(b)** Micrographs show a pancreatic islet and several pancreatic acini

# The Pancreas is a Gland

**Endocrine:** pancreatic islets secrete insulin and glucagon

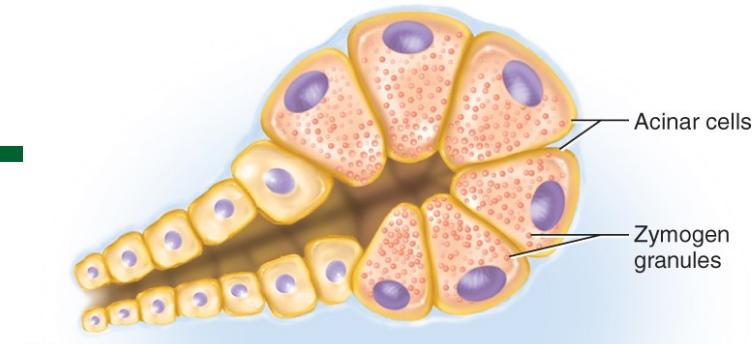
**Exocrine:** secretes 1,200 to 1,500 mL of pancreatic juice per day

**Pancreatic duct:** Joins the bile duct at the hepatopancreatic ampulla

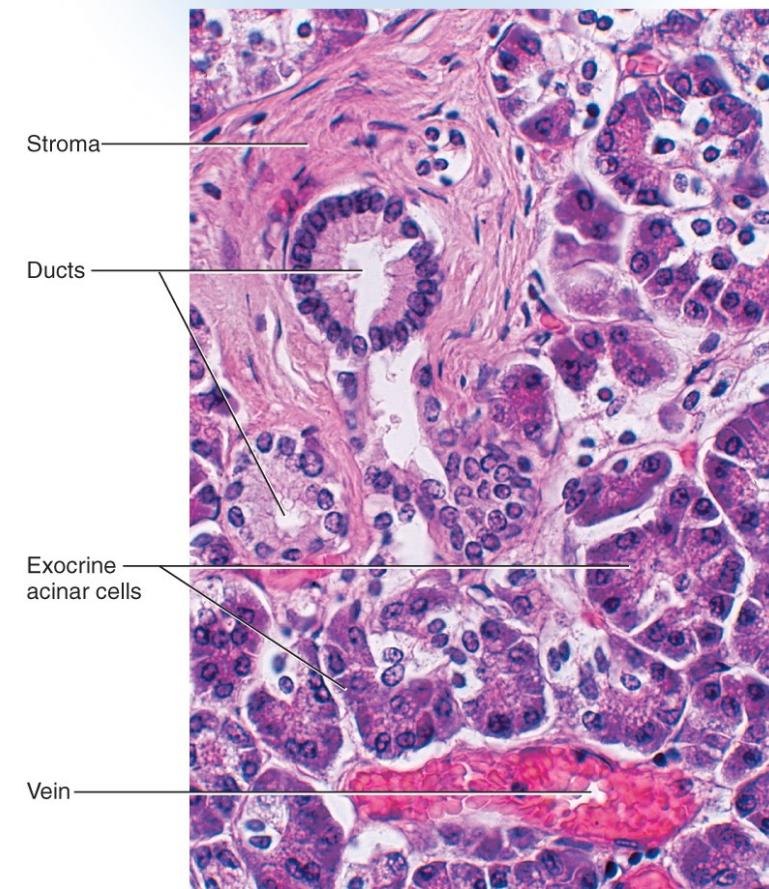
**Hepatopancreatic sphincter:** releases bile and pancreatic juice into duodenum

**Accessory pancreatic duct:** Bypasses the sphincter allowing pancreatic juice(not bile) into duodenum

**Pancreatic juice:** alkaline mixture of water, enzymes, zymogens, sodium bicarbonate, and other electrolytes



(a)



(b)

**Trypsin:** peptide cleavage

**Trypsinogen:** Converted to trypsin by enterokinase

**Chymotrypsinogen:** converted to chymotrypsin by trypsin

**Procarboxypeptidase:** converted to carboxypeptidase by trypsin

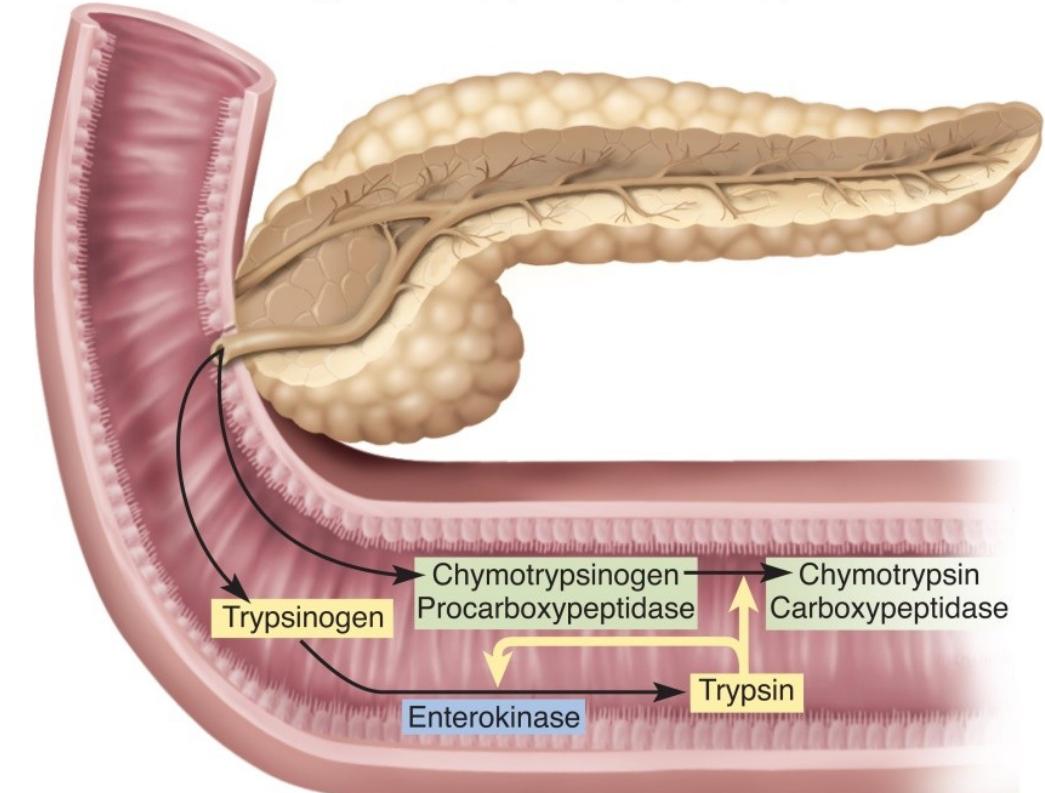
**Pancreatic amylase:** digests starch

**Pancreatic lipase:** digests fat

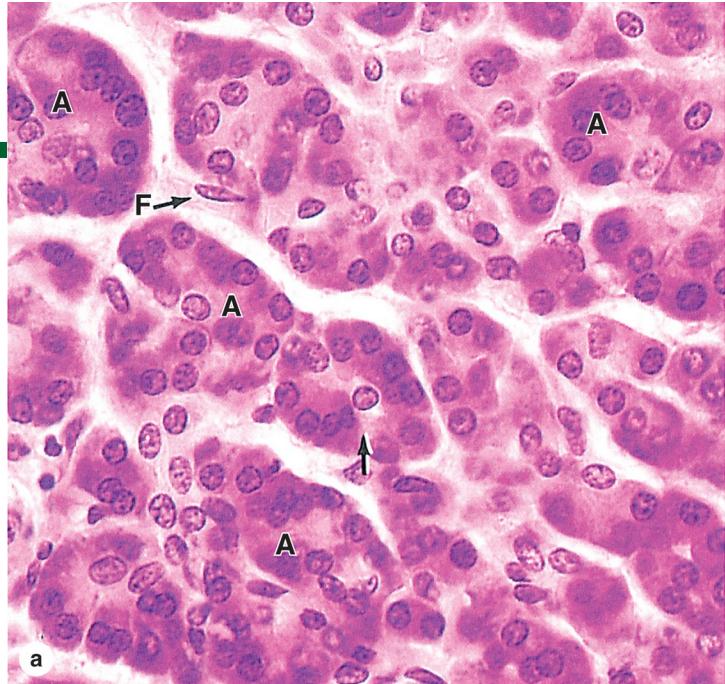
**Ribonuclease and deoxyribonuclease:** digest RNA and DNA  
Control of Release of pancreatic juice and bile

## Pancreatic Enzymes

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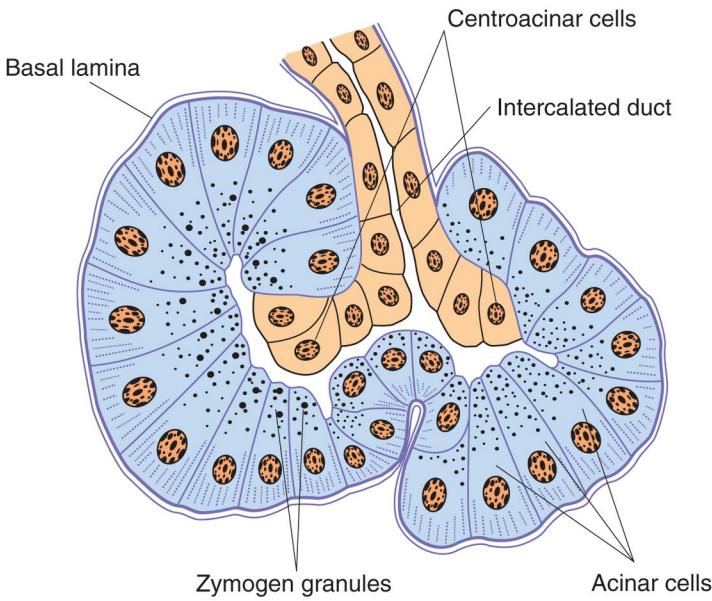


**MEDICAL APPLICATION:** In acute pancreatitis, the proenzymes may be activated and digest pancreatic tissues, leading to very serious complications. Possible causes include infection, gallstones, alcoholism, drugs, and trauma. Chronic pancreatitis can produce progressive fibrosis and loss of pancreatic function.



## Pancreatic acini

(a) Micrograph of exocrine pancreas shows the serous, enzyme-producing cells arranged in small acini (**A**) with very small lumens. Acini are surrounded by only small amounts of connective tissue with fibroblasts (**F**). Each acinus is drained by an intercalated duct with its initial cells, the centroacinar cells (**arrow**), inserted into the acinar lumen.



(b) The diagram shows the arrangement of cells more clearly. Under the influence of secretin, the **centroacinar** and **intercalated duct cells** secrete a copious  $\text{HCO}_3^-$ -rich fluid that hydrates, flushes, and alkalinizes the enzymatic secretion of the acini.