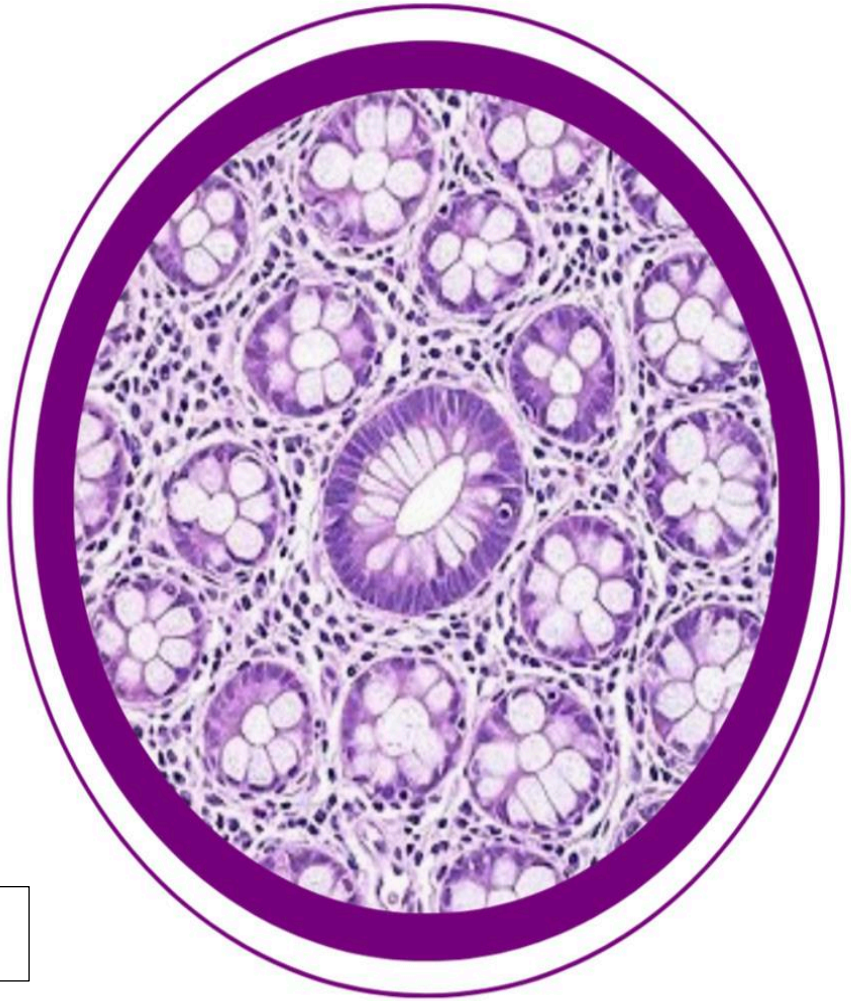
GI

HISTOLOGY

#2



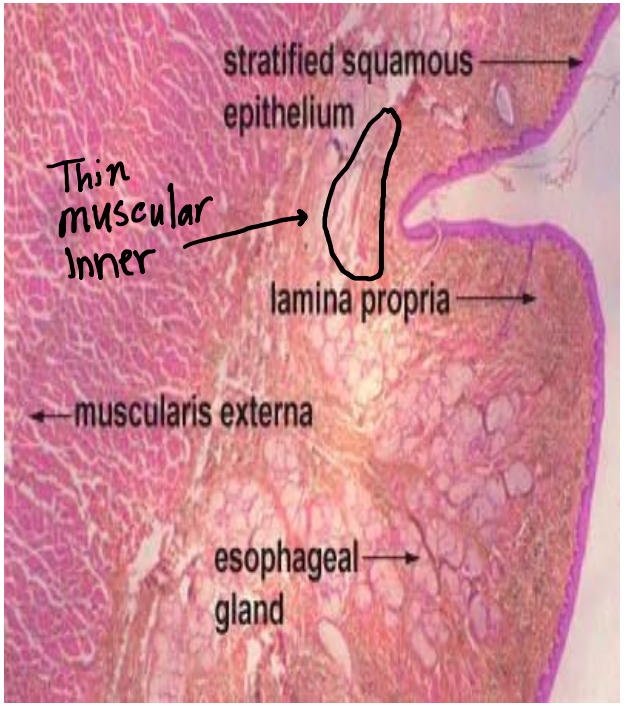
WRITER:Eman Amjad

CORRECTOR: Eman amjad

DOCTOR:Mohammad Almuhtaseb

Esophagus

- is a muscular tube whose function is to transport foodstuffs from the mouth to the stomach and to prevent the retrograde flow of gastric contents
- **It starts from 6th cervical vertebrae as continuation of pharynx, ends in cardia of stomach. Length 25 cm , but from incisors 45 cm.**
- Transport is achieved by peristaltic contractions and relaxation of the esophageal sphincters (upper and lower)
- usually controlled by reflexes and by the autonomic nervous system.

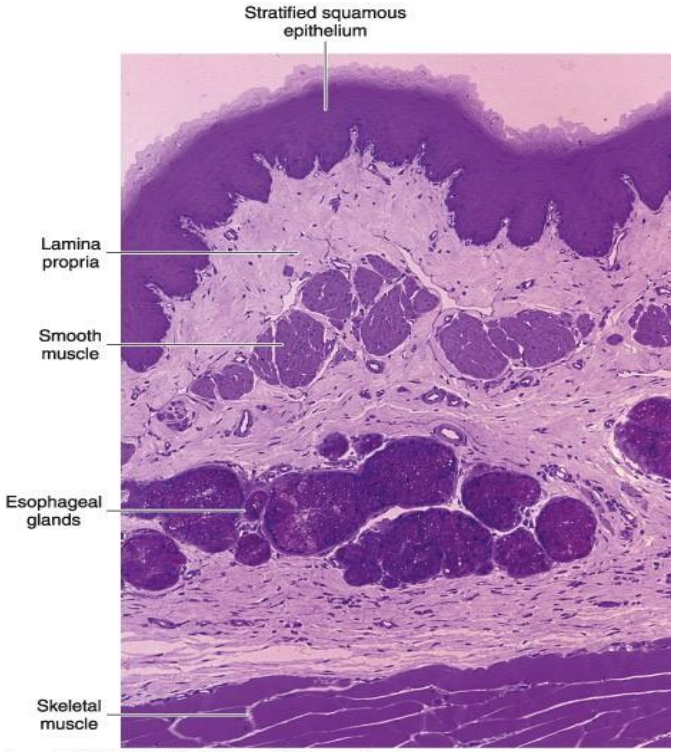


- it has the same layers as the rest of the digestive tract:

1) Mucosa: In humans the esophagus is covered by nonkeratinized stratified squamous epithelium, as oral cavity & pharynx High mitosis and fast healing after injuries in these areas.

- In the lamina propria, which is connective tissue, of the region near the stomach there are groups of glands (the **esophageal cardiac glands)** that also secrete mucus, near the stomach get prominent.
- Inner muscularis is thin, inner circular, outer longitudinal smooth muscle.

2) In the submucosa, dense connective tissue, there are groups of small mucus secreting glands, the **esophageal glands,** whose secretion facilitates the transport of foodstuffs and protects the mucosa, and Messiner's plexus.



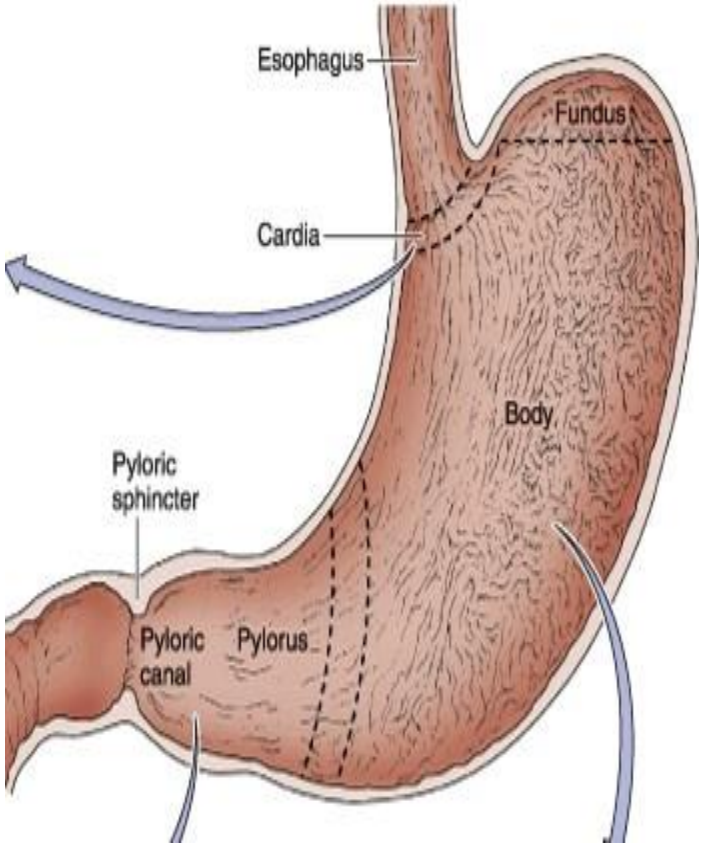
3) muscularis externa layer, that contains the myenteric or (Auerbach's) nervous plexus parasympathetic secretomotor **for glands** & peristaltic movement. At the distal end of the esophagus, the muscular layer consists of only smooth muscle cells that, close to the stomach, form the lower esophageal sphincter. In the mid portion, a mixture of striated and smooth muscle cells; and at the proximal end, only striated muscle cells.

- Upper part only skeletal muscle (somatic), second part is mixed, the last part is only smooth muscle (ANS innervation).

4) Only that portion of the esophagus (1.3 cm) that is in the peritoneal cavity is covered by serosa.The rest is covered by a layer of connective tissue, the adventitia, that blends into the surrounding tissue.

Stomach

- The stomach, like the small intestine, is a mixed exocrine– endocrine organ that digests food and secretes hormones.
- Gross inspection reveals four regions: **cardia, fundus, body,** and **pylorus**, incisura angularis between the pylorus & body of stomach.
- main functions are to continue the digestion of carbohydrates initiated in the mouth, add an acidic fluid to the ingested food, transform it by muscular activity into a viscous mass (semifluid **chyme**) through 2-4 hours it get drainage by the pyloric sphincter to small intestine. and promote the initial digestion of proteins with the enzyme **pepsin**
- It also produces a gastric lipase that digests triglycerides with the help of lingual lipase.
- the fundus and body are identical in microscopic structure
- The mucosa and submucosa of the undistended stomach lie in longitudinally directed folds known as **rugae.** When the stomach is filled with food, these folds flatten out.Fold of submucosa into mucosa.



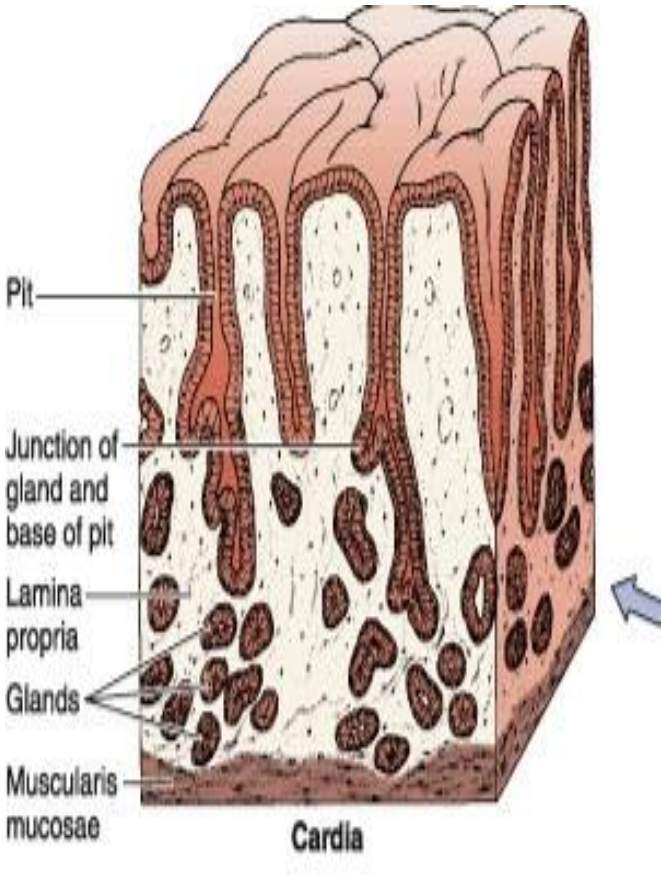
Mucosa

1) The epithelium covering the surface and lining the pits is a simple columnar epithelium without goblets cells, and all the cells secrete an alkaline mucus for protection.

2) The **lamina propria** of the stomach is composed of loose connective tissue interspersed with smooth muscle and lymphoid cells. Full of gastric glands

3) Separating the mucosa from the underlying submucosa is a layer of smooth muscle, the **muscularis mucosae.**

- The gastric mucosa consists of a **surface epithelium** that invaginates to various extents into the lamina propria, forming **gastric pits (can be seen by the magnifying glass).**
- Emptying into the gastric pits are branched, tubular glands (cardiac, gastric, and pyloric) characteristic of each region of the stomach.



4) Muscularis externa: longitudinal, circular, most inner oblique layer but absent in pylori area.
Because the pyloric sphincter is formed by the circular muscle thickenning

- numerous small circular or ovoid invaginations of the epithelial lining are observed. These are the openings of the gastric pits are the ducts of glands.

- This mucus consists primarily of water (95%), lipids, and glycoproteins, which in combination, form a hydrophobic protective gel

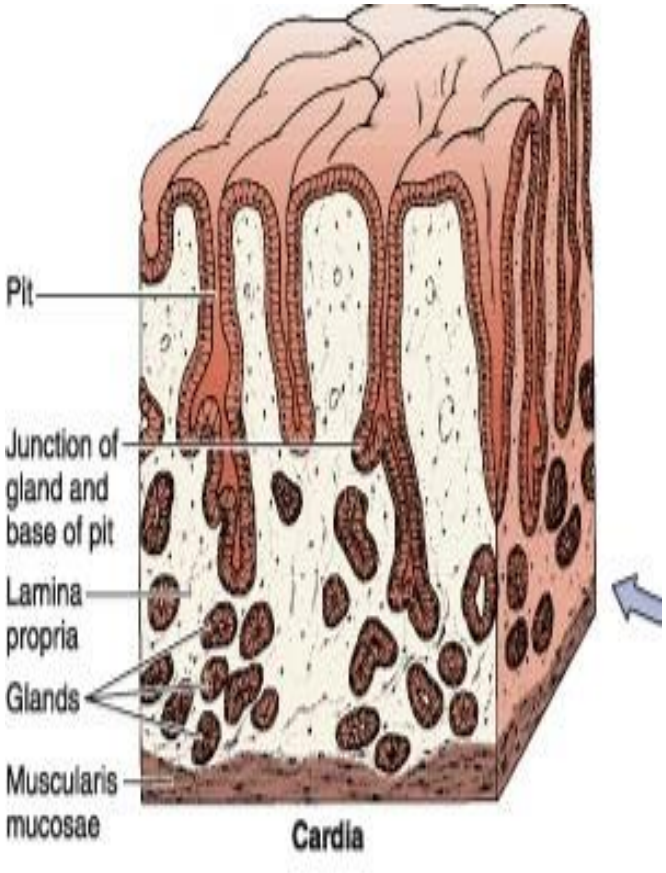
- Bicarbonate, secreted by the surface epithelial columnar cells into the mucous gel, forms a pH gradient ranging from 1 at the gastric luminal surface to 7 along the epithelial cell surface

- Surface epithelial cells also form an important line of defense due to their function in mucus production, intracellular tight junctions, and the ionic transporters that maintain intracellular pH and bicarbonate production, important for gel alkalinization.

- In differentiating between stomach's areas **we depend on:** the thickness/ extent of glands and pits through the layer & type/numerous of glands.

Cardia

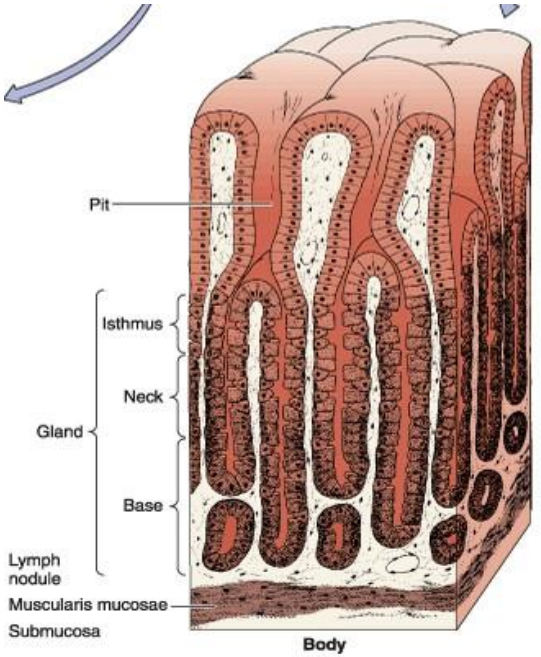
- The cardia is a narrow circular band, 1.5–3 cm in width, at the transition between the esophagus and the stomach.
- The thickness of pits is almost equal to glands' thickness.
- Its mucosa contains simple or branched tubular cardiac glands. We can find mucus cells, entero-endocrine cells, stem cells, chief and parietal cells (the last two are lesser).
- The terminal portions of these glands are frequently coiled, often with large lumens.
- Most of the secretory cells produce mucus and lysozyme (an enzyme that attacks bacterial walls), but a few parietal cells secreting H+ and Cl– (which will form HCl in the lumen) can be found.



- These glands are similar in structure to the cardiac glands of the terminal portion of the esophagus.

Fundus & Body

- The lamina propria of the fundus and body is filled with branched, tubular **gastric (fundic) glands,** three to seven of which open into the bottom of each gastric pit
- Glands are thicker, gastric pits are short & wide.
- Each gastric gland has three distinct regions: the isthmus, neck, and base. The Dr. said, “neck or isthmus is the narrow area, and body, and the base are regions”.
- The distribution of epithelial cells in gastric glands is <u>not uniform.</u>
- The **isthmus**, close to the gastric pit, contains 1) differentiating mucous cells that will migrate and replace superficial mucous cells, 2) undifferentiated stem cells**,** and 3) <u>oxyntic</u> (parietal) cells.



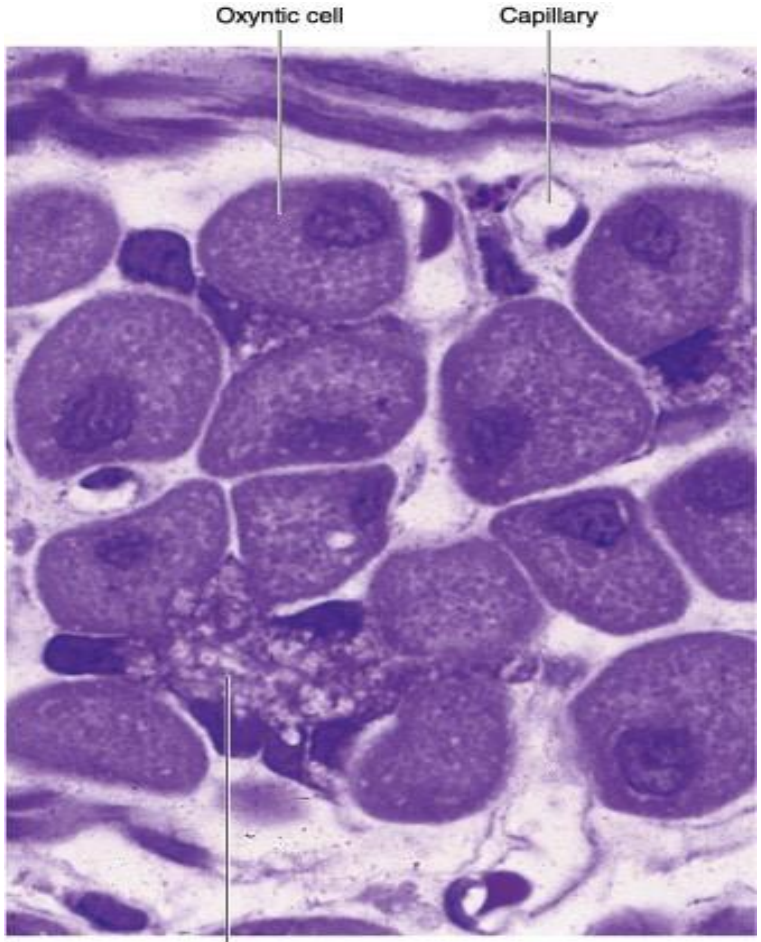
- the **neck** of the glands consists of 1) stem,2) mucous neck (different from the mucous cells in the isthmus), and 3) parietal cells. Mucous cells & parietal cells are numerous in the neck.
- the **base** of the glands primarily contains 1) parietal and 2) chief (zymogenic) cells., numerous with chief cells & 3) entero-endocrine cells.
- Enteroendocrine cells are dispersed in the neck and base of the glands.

Stem Cells

- Found in the isthmus and neck regions but few in number, stem cells are low columnar cells with oval nuclei near the bases of the cells
- These cells have a high rate of mitosis; some of them move upward to replace the pit and surface mucous cells, which have a **turnover time of 4–7 days**
- Other daughter cells migrate more deeply into the glands and differentiate into mucous neck cells and parietal, chief, and enteroendocrine cells

Mucous Neck Cells

- Mucous neck cells are present in clusters or as single cells **between** parietal cells in the necks of gastric glands
- Their mucus secretion is quite different from that of the surface epithelial mucous cells
- They are irregular in shape, with the nucleus at the base of the cell and the secretory granules near the apical surface.
- Foamy appearance because while preparing the slides the mucus dissolves.



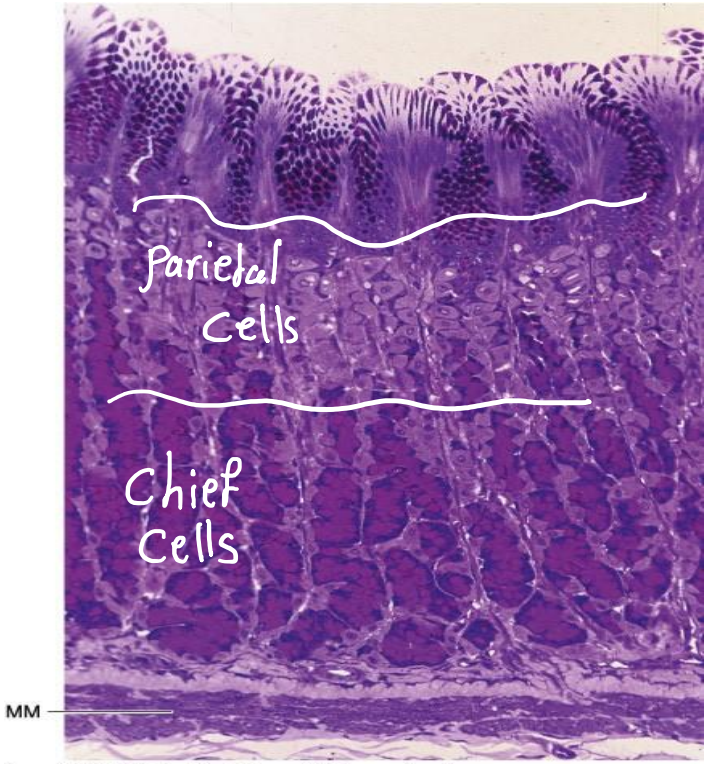
Oxyntic (Parietal) Cells

- Parietal cells are present mainly in the upper half of gastric glands; they are scarce in the base. They are acidophilus.

- They are rounded or pyramidal cells, with one centrally placed spherical nucleus and intensely eosinophilic cytoplasm, sometimes are binuclear.

1) Activated cells: The most striking features of the active secreting cell seen in the electron microscope are an abundance of mitochondria and a deep, circular invagination of the apical plasma membrane, forming the **intracellular canaliculus**
2) Resting stage: In the resting cell, a number of tubulovesicular structures can be seen in the apical region just below the plasmalemma , At this stage, the cell has few microvilli & vesicles

  - When stimulated to produce H+ and Cl–, tubulovesicles fuse with the cell membrane to form the canaliculus and more microvilli, thus providing a generous increase in the surface of the cell membrane

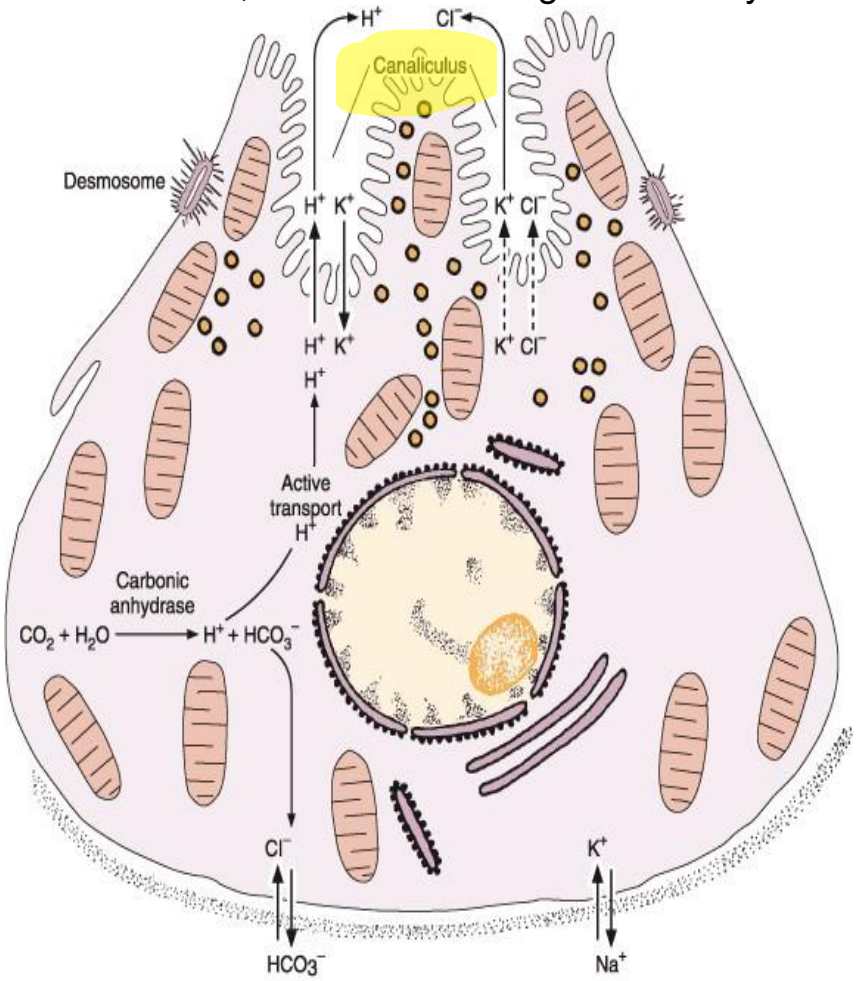


- Parietal cells secrete hydrochloric acid

- The ion H+ originates from the dissociation of the H_2CO_3 produced by the action of **carbonic**

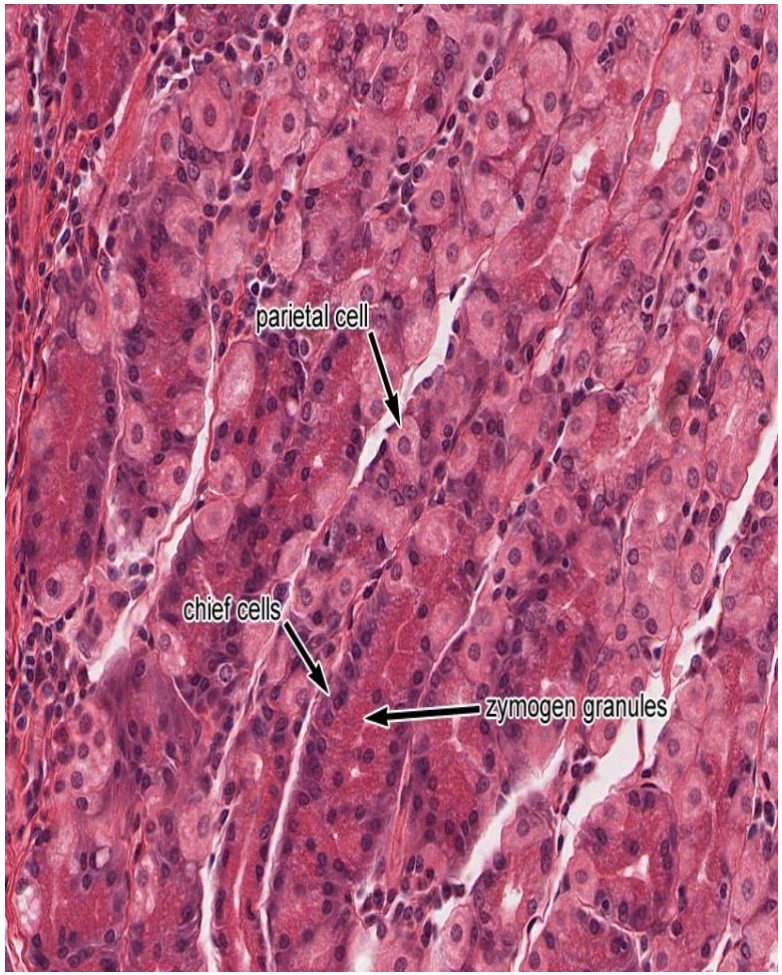
anhydrase, an enzyme abundant in oxyntic cells

- Once produced, H2CO3 dissociates in the cytoplasm into H+ and HCO32
- The active cell also secretes K+ and Cl– in the canaliculus; the K+ is exchanged for H+ by the action of the H+/K+ pump, while the Cl– forms HCl.
- The presence of abundant mitochondria in the parietal cells indicates that their metabolic processes, particularly the pumping of H+/K+, are highly energy consuming
- The secretory activity of parietal cells is initiated by various mechanisms. One mechanism is through the cholinergic nerve endings (parasympathetic stimulation).
- Histamine and a polypeptide called **gastrin,** both secreted in the gastric mucosa, act strongly to stimulate the production of hydrochloric acid.
- Gastrin also has a trophic effect on the gastric mucus stimulating growth.
- Dr. Said: “this’s biochemistry, I care for the intracellular canaliculus”.



Chief (Zymogenic) Cells

- Chief cells predominate in the lower region of the tubular glands (at the base of glands).
- characteristics of protein-synthesizing and exporting cells
- Their **basophilia** is due to the abundant rough endoplasmic reticulum and zymogen granules. The granules in their cytoplasm contain the inactive enzyme **pepsinogen.**
- The precursor pepsinogen is rapidly converted into the highly active proteolytic enzyme **pepsin** after being released into the acid environment of the stomach
- There are seven different pepsins in the human gastric juice, which are aspartate endoproteinases of relatively broad specificity active at pH <5
- In humans, chief cells also produce the enzyme **lipase.**

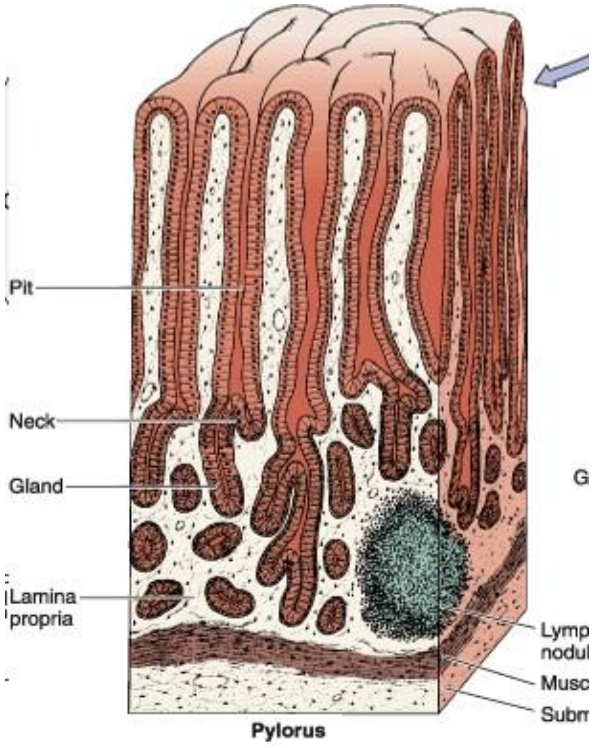


Enteroendocrine Cells

- are found in the neck and bases of gastric glands
- In the fundus of the stomach, **5-hydroxytryptamine** (serotonin) is one of the principal secretory products
- In the stomach the G—pylorus cells produces Gastrin that lead to the Stimulation of gastric acid secretion and Gastric mucosal growth
- Large nucleus. Secret the content in granules.

Pylorus

- has deep gastric pits into which the branched, tubular **pyloric glands** open.
- Long & narrow pits, no chief no parietal cells, mucus secretions mainly, lymphatic nodules. The lymphatic nodules aggregate and become obvious, but it exists in All GI tract in lamina propria.
- Compared with the glands in the cardiac region, pyloric glands have longer pits and shorter coiled secretory portions
- These glands secrete mucus as well as appreciable amounts of the enzyme lysozyme



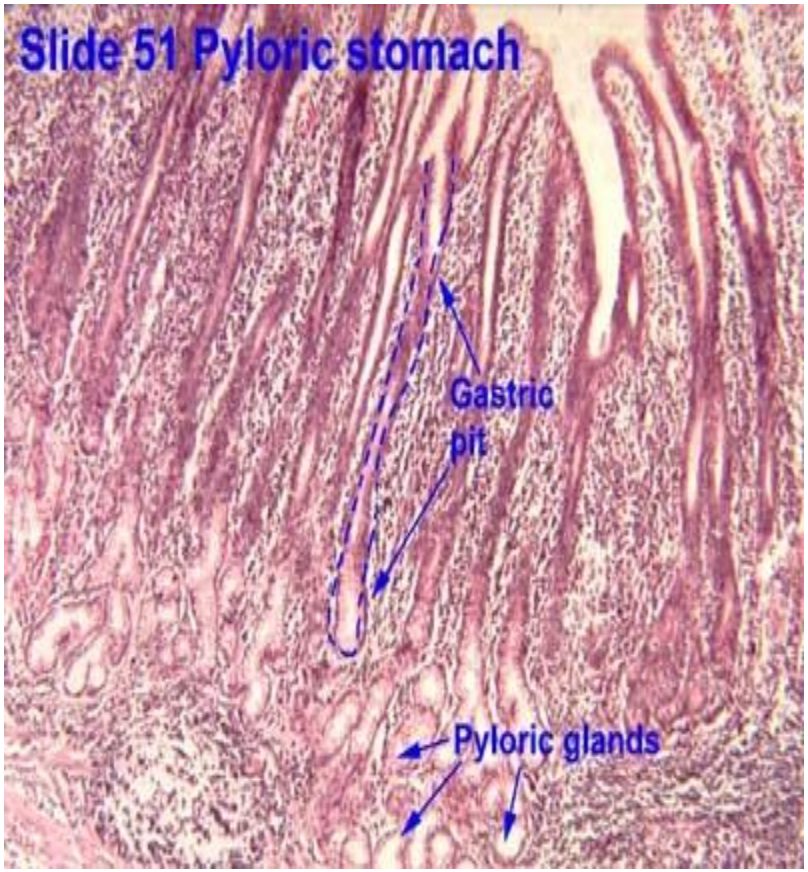
- **Gastrin (G) cells** (which release **gastrin**) are enteroendocrine cells intercalated among the mucous cells of pyloric glands

- Parasympathetic stimulation, the presence of nutrients such as amino acids and amines in the stomach, and distention of the stomach wall directly stimulate the G cell to release gastrin,

- which in turn activates the parietal cell, increasing acid secretion

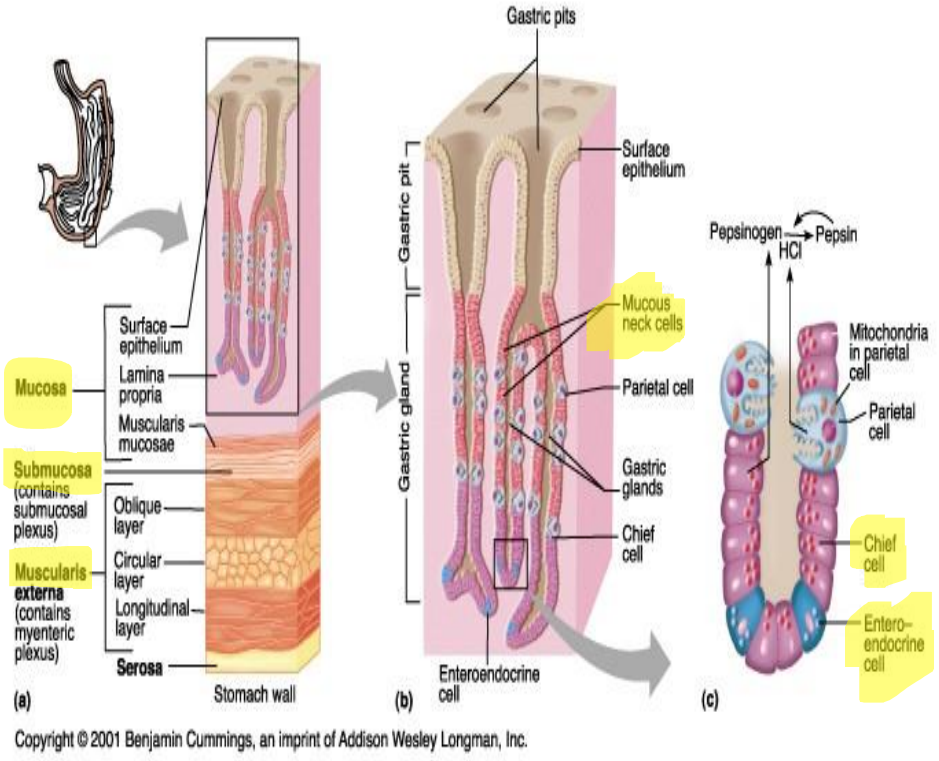
- Other enteroendocrine cells (**D cells**) secrete **somatostatin,** which inhibits the release of some other hormones, including gastrin

- Secretion of somatostatin is stimulated by HCl, counterbalancing the acid secretion.



Other layers

- The **submucosa** is composed of dense connective tissue containing blood and lymph vessels; it is infiltrated by lymphoid cells, macrophages, and mast cells.
- The **muscularis** is composed of smooth muscle fibers oriented in three main directions.
- The external layer is longitudinal, the middle layer is circular, and the internal layer is oblique
- At the pylorus, the middle layer is greatly thickened to form the **pyloric sphincter.**
- The stomach is covered by a thin **serosa.**



Small Intestine

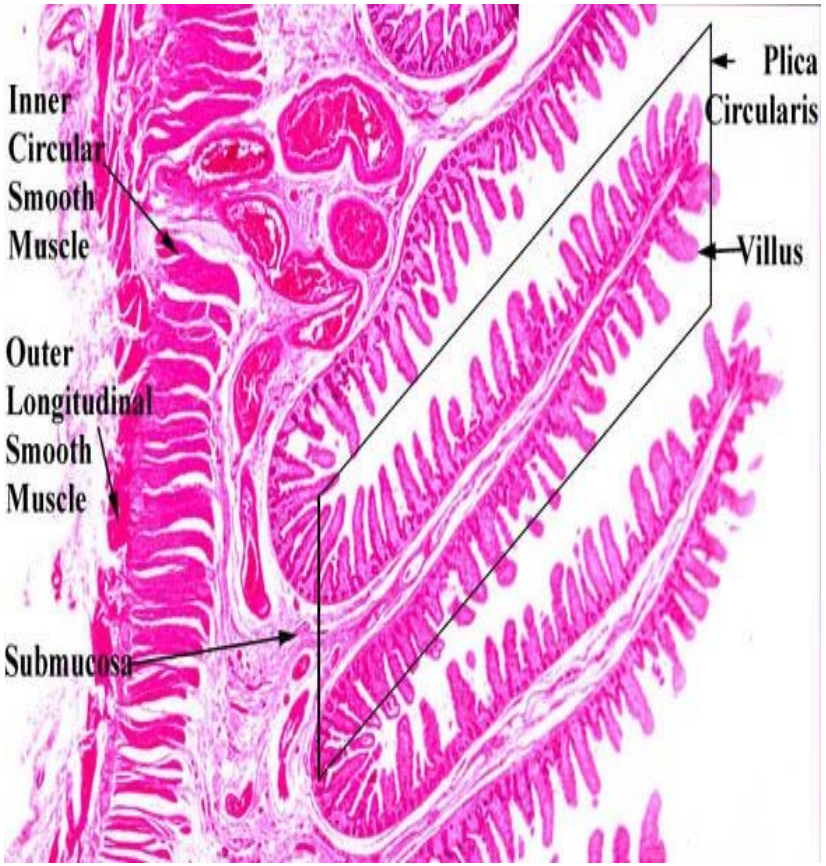
- The small intestine is the site of terminal food digestion, nutrient absorption, and endocrine secretion.
- processes of digestion are completed in the small intestine, where the nutrients (products of digestion) are absorbed by cells of the epithelial lining.
- The small intestine is relatively long—approximately 5 m—and consists of three segments: the **duodenum, jejunum,** and **ileum.**

✓ **Mainly:**

1) The lining epithelium is simple columnar with goblet cells. Goblet cells increase distally in small intestine & v.numerous in large intestine.
2) Fingerlike projections (villi) to increase surface area for absorption. **In duodenum** are leaf like projections.
3) **In jejunum**, the submucosa fold gets into mucosa & form the plicae circulares.
4) **In duodenum**, on the surface there's more prominent microvilli (brush surface)
5) **In ileum**, lymphatic nodules (peyer's patches) are prominent.

Mucous Membrane

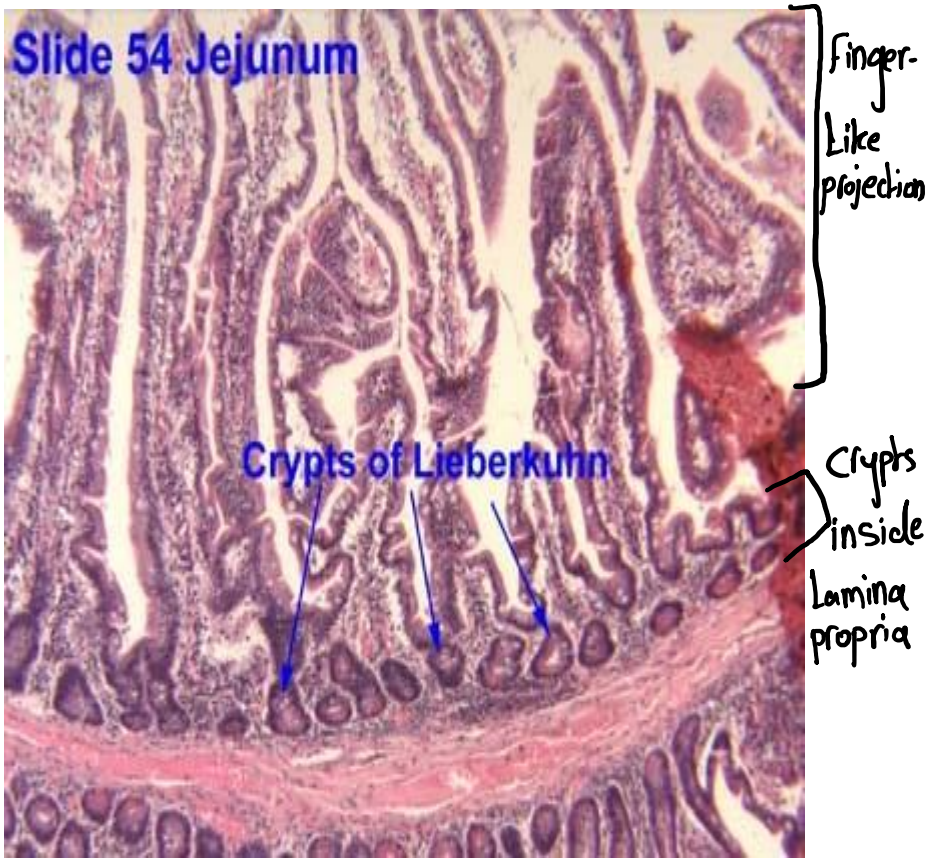
- the lining of the small intestine shows a series of permanent folds, **plicae circulares (Kerckring's valves),**
- consisting of mucosa and submucosa and having a semilunar, circular, or spiral form
- The plicae are most developed in, and consequently a characteristic of, the jejunum.
- They do not constitute a significant feature of the duodenum and ileum, although they are frequently present.
- **Intestinal villi** are 0.5- to 1.5-mm-long outgrowths of the mucosa (epithelium plus lamina propria inside the villi) projecting into the lumen of the small intestine
- In the duodenum they are leaf shaped, gradually assuming fingerlike shapes as they reach the ileum

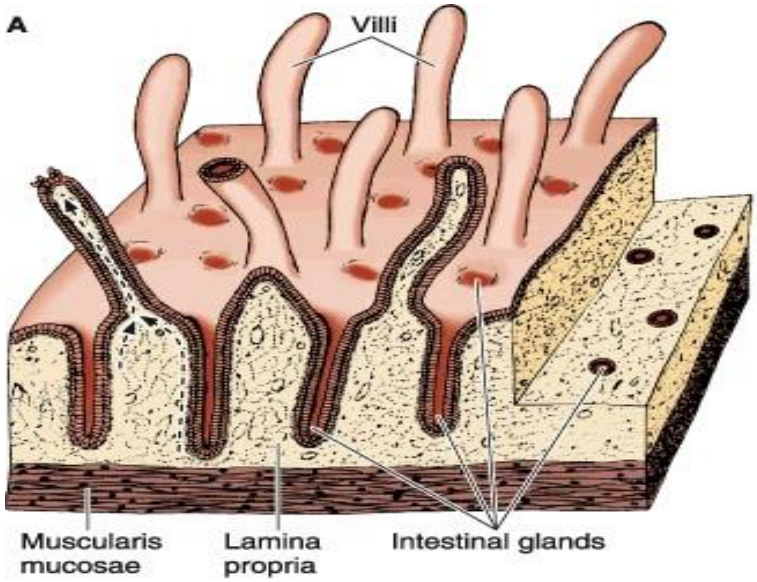


- Between the villi are small openings of simple tubular glands called **intestinal glands** (also called **crypts**), or **glands of Lieberkühn.**

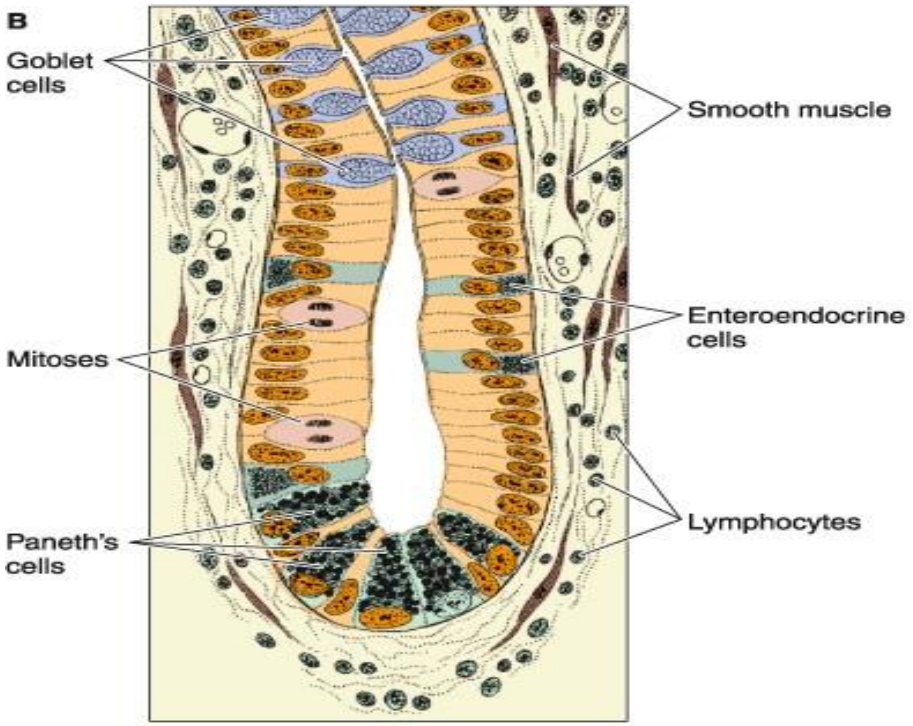
- The epithelium of the villi is continuous with that of the glands (simple columnar with goblet cells).

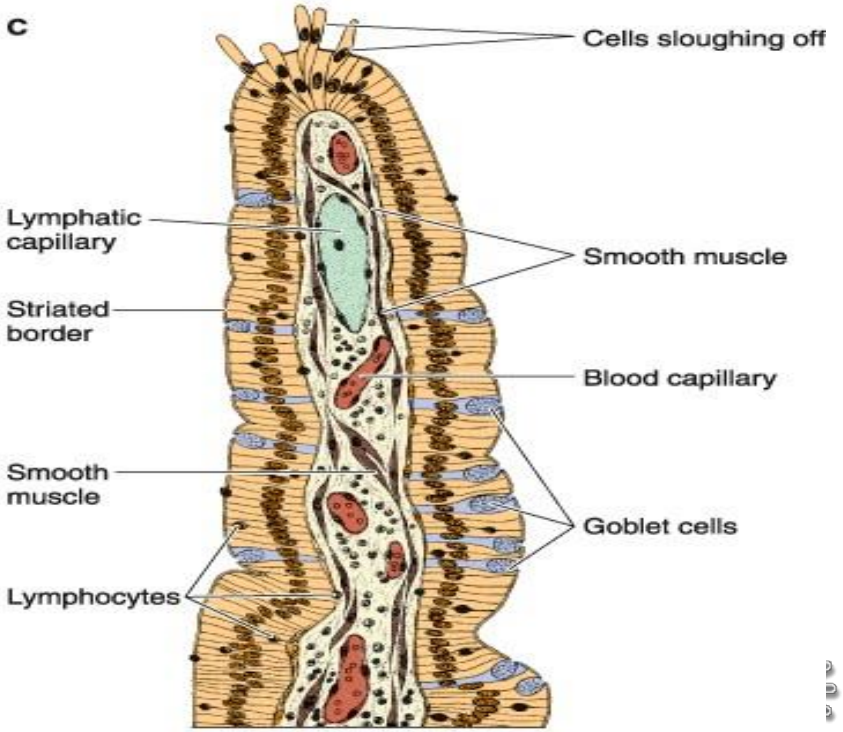
- The intestinal glands contain stem cells, some absorptive cells, goblet cells, Paneth's cells in base of Lieberkhun crypts, and enteroendocrine cells.

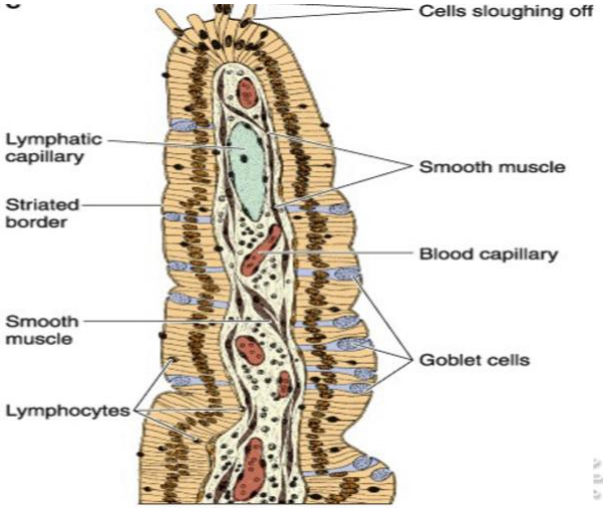




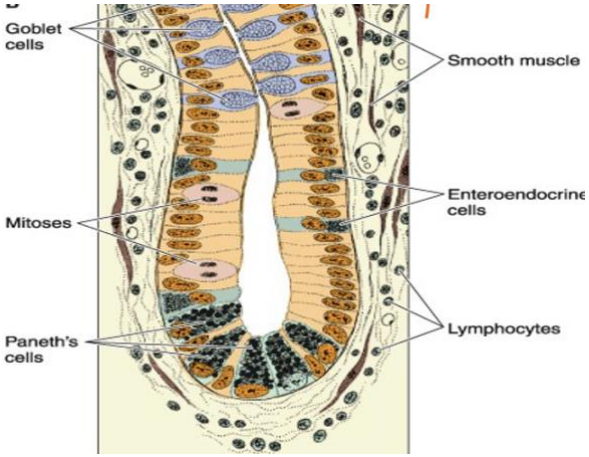
The villi & gland are together as your fingers. The upper half is villi & lower half is gland.





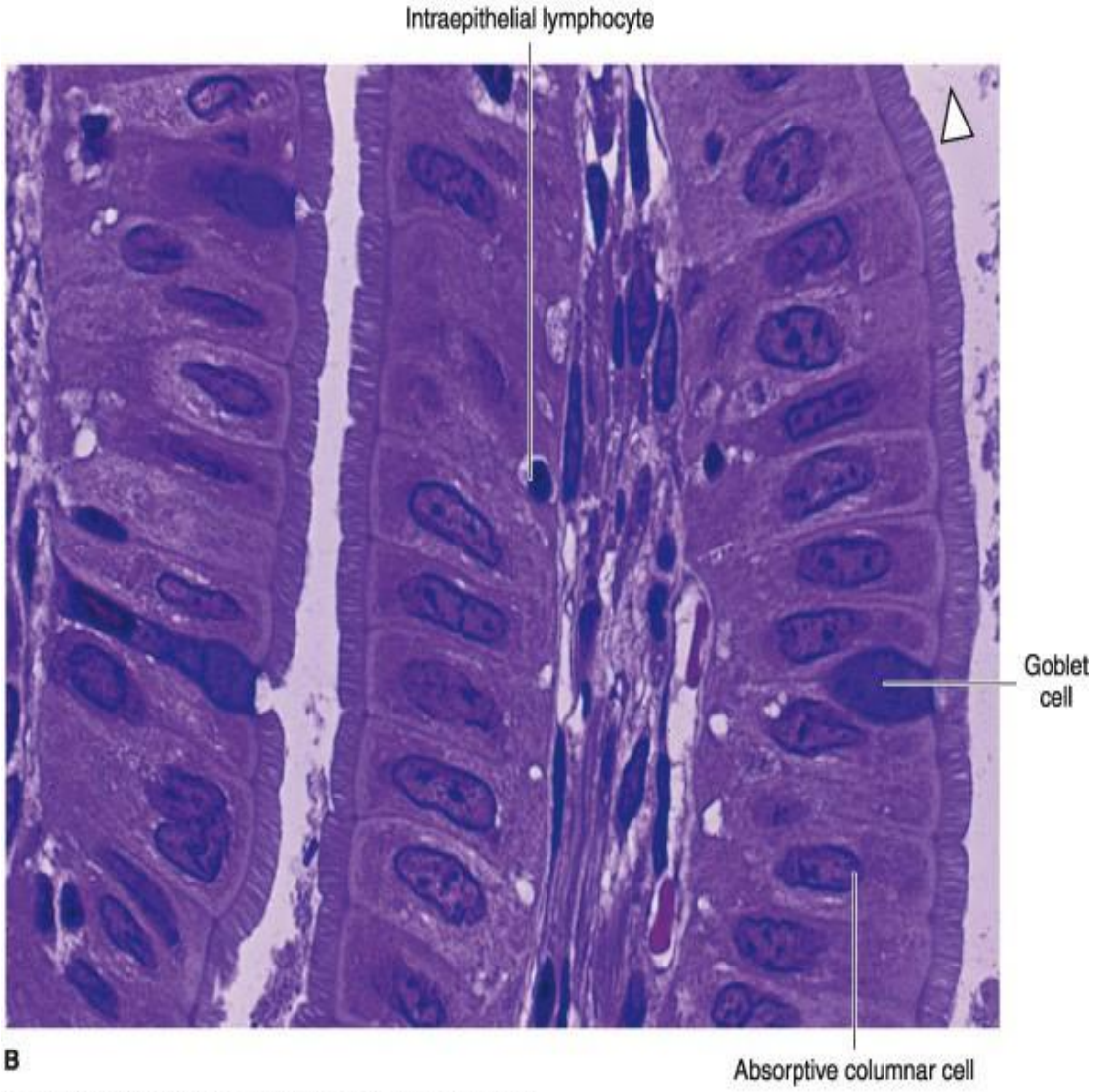


- **Villi** contains goblets cells, inside you can see lamina propria with muscles
- Lamina propria is loose Connective tissue, which mean it contains fibroblast cells, macrophages….
- Contain **Lacteal**, which is blind lymphatic vessels for fat absorption.



- **Glands**, contain goblet cells, in the wall smooth muscles, lining simple columnar
- **At the base,** we find Paneth's cells **that secrete** lysozymes enzymes (antibacterial), prominent in jejunum

- **Absorptive cells** or **enterocytes** are tall columnar cells, each with an oval nucleus in the basal half of the cell
- At the apex of each cell is a homogeneous layer called the **striated (brush) border** (microvilli)
- When viewed with the electron microscope, the striated border is seen to be a layer of densely packed **microvilli**
- Each absorptive cell is estimated to have an average of 3000 microvilli, and 1 mm2 of mucosa contains about 200 million of these structures



- Each microvillus is a cylindrical protrusion of the apical cytoplasm that is approximately 1 m tall by 0.1 m in diameter

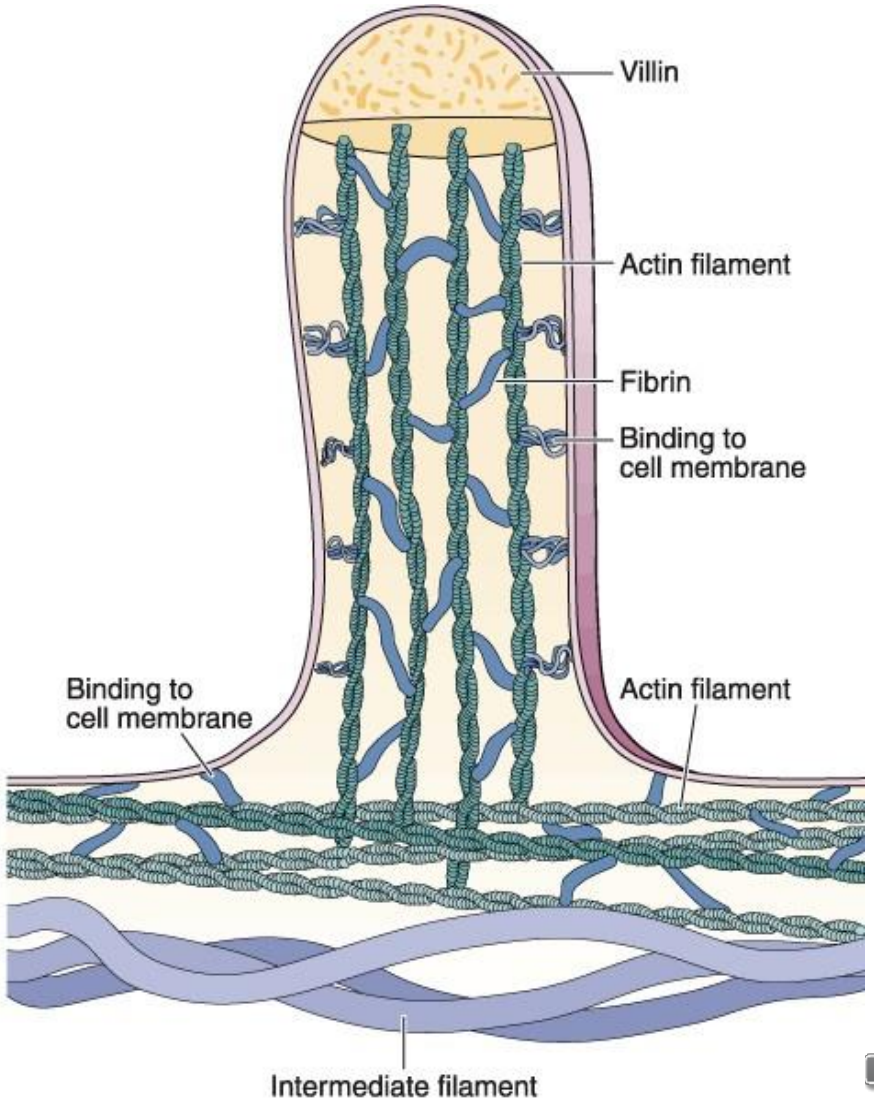
- consists of the cell membrane enclosing a core of actin microfilaments associated with other cytoskeletal proteins

- Microvilli have the important physiological function of increasing the area of contact between the intestinal surface and the nutrients.

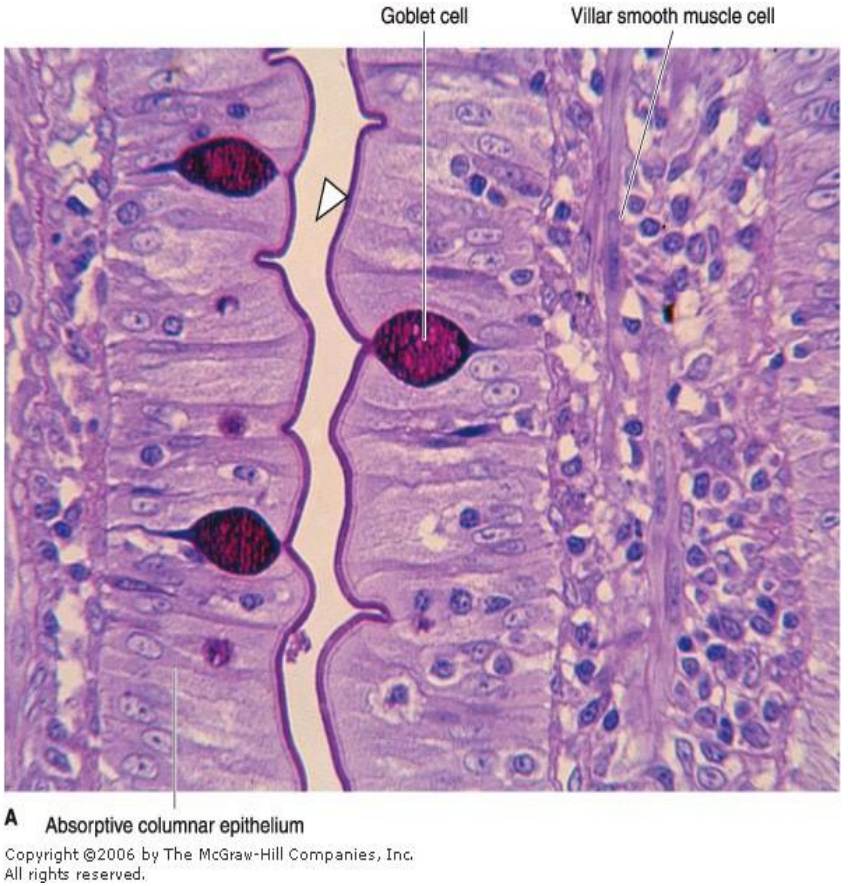
- **Note: The presence of plicae circulares, villi, and microvilli greatly increases the surface of the intestinal lining**

- It has been calculated that plicae increase the intestinal surface **3-fold**, the villi increase it **10-fold,** and the microvilli increase it **20fold**.

- Together, these processes are responsible for a 600-fold increase in the intestinal surface, resulting in a total area of 200 m2

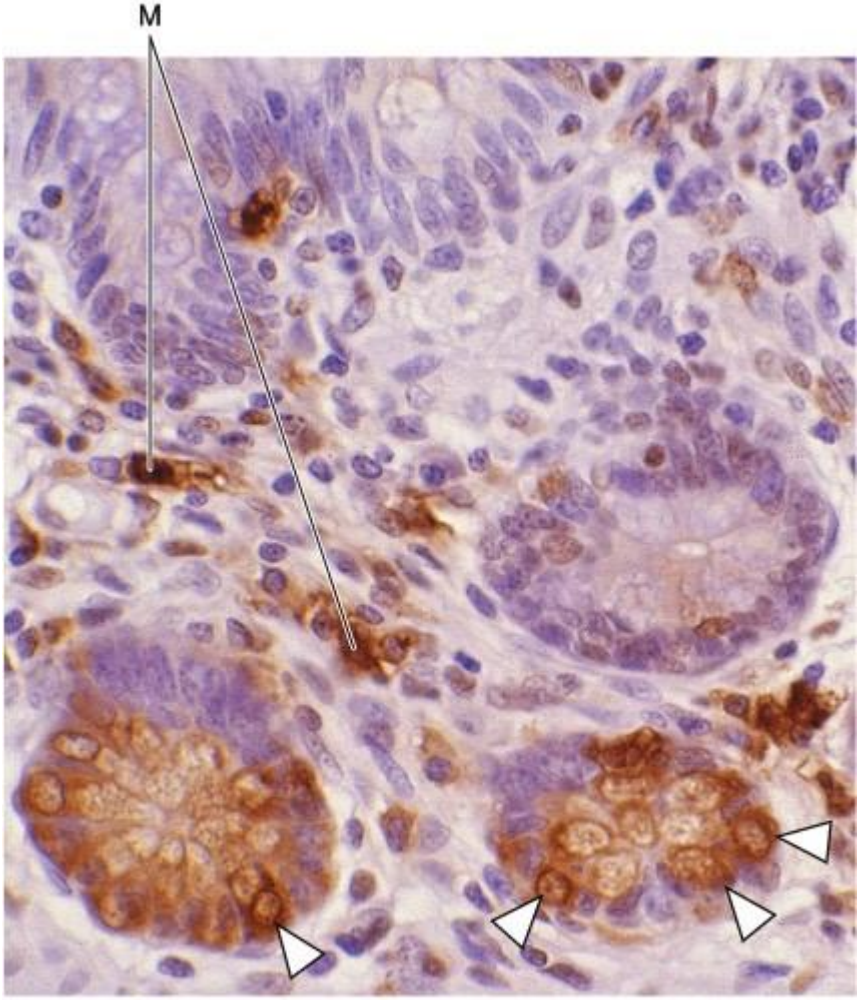


- **Goblet cells** are interspersed between the absorptive cells
- They are less abundant in the duodenum and increase in number as they approach the ileum
- These cells produce acid glycoproteins of the mucin type to form mucus, whose main function is to protect and lubricate the lining of the intestine. Absorption & lubrication mucos.



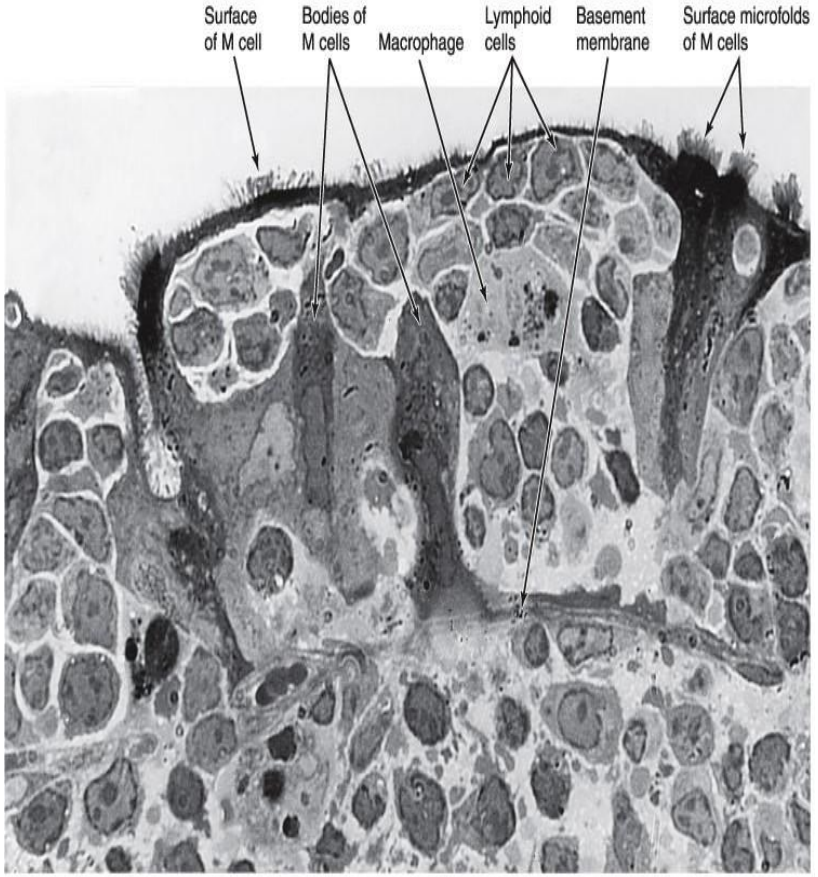
Paneth's cells

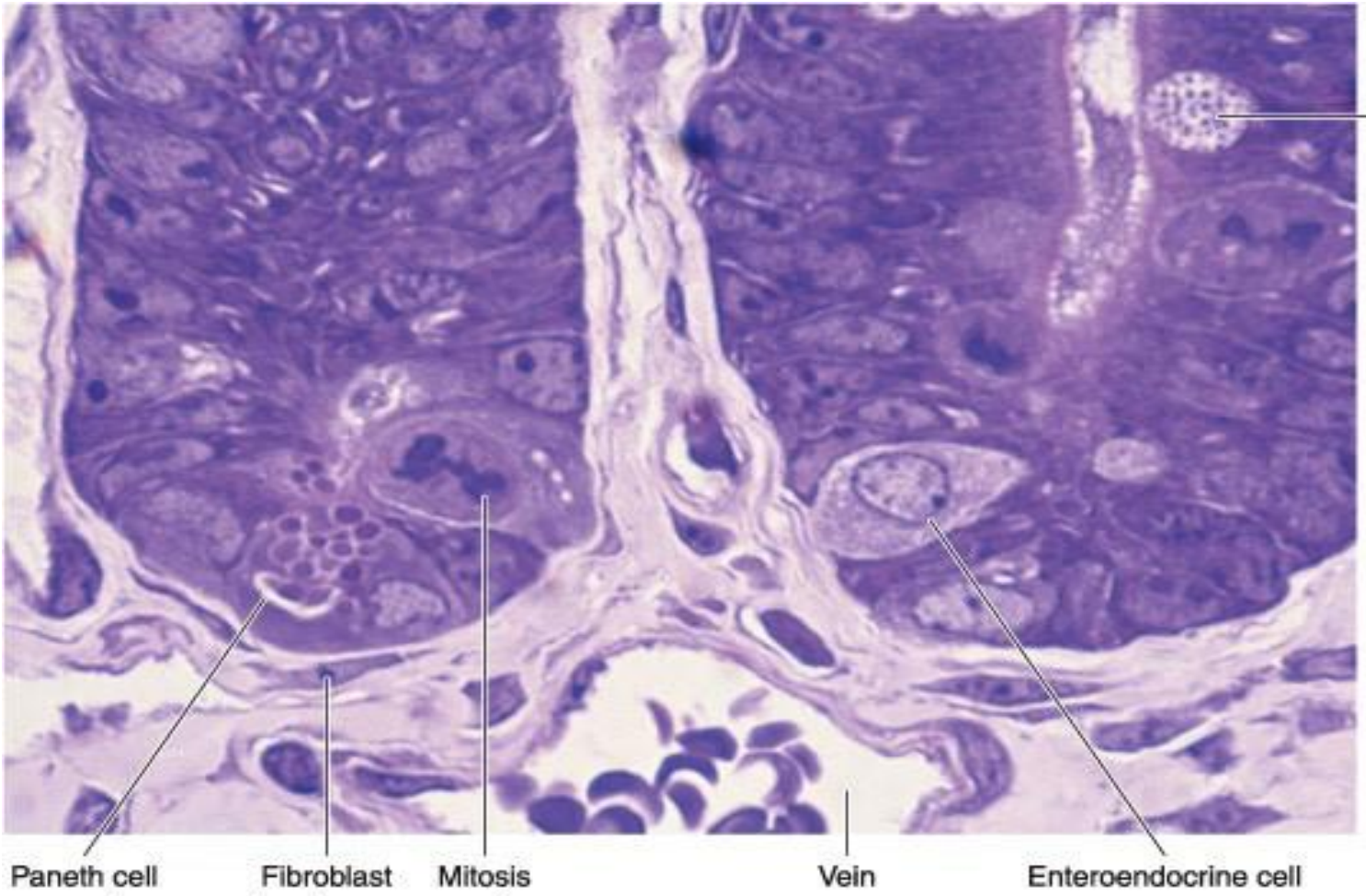
- in the basal portion of the intestinal glands are exocrine cells with secretory granules in their apical cytoplasm.
- lysozyme—an enzyme that digests the cell walls of some bacteria— was detected in the large eosinophilic secretory granules of these cells
- Lysozyme has antibacterial activity and **may play a role in controlling the intestinal flora**.



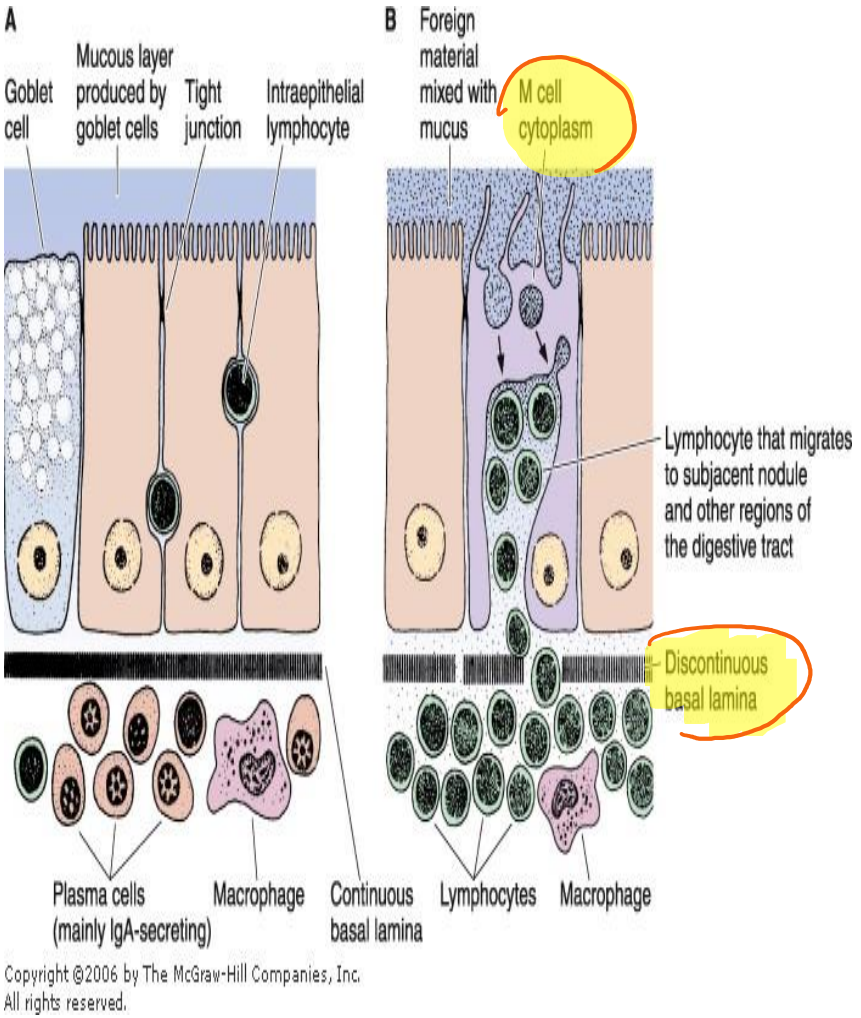
M (microfold) cells

- are specialized **epithelial cells** overlying the lymphoid follicles of Peyer's patches, prominent in ileum.
- the presence of numerous basal membrane invaginations that form pits containing many intraepithelial lymphocytes and antigenpresenting cells (macrophages).
- M cells can endocytose antigens and transport them to the underlying macrophages and lymphoid cells, which then migrate to other compartments of the lymphoid system (nodes),
- M cells represent an important link in the intestinal immunological system
- basement membrane under M cells is **discontinuous, facilitating transit between the lamina propria and M cells,** for the passage of lymphocytes & macrophages and inter the M cells, which reach the surface for engulfing bacteria

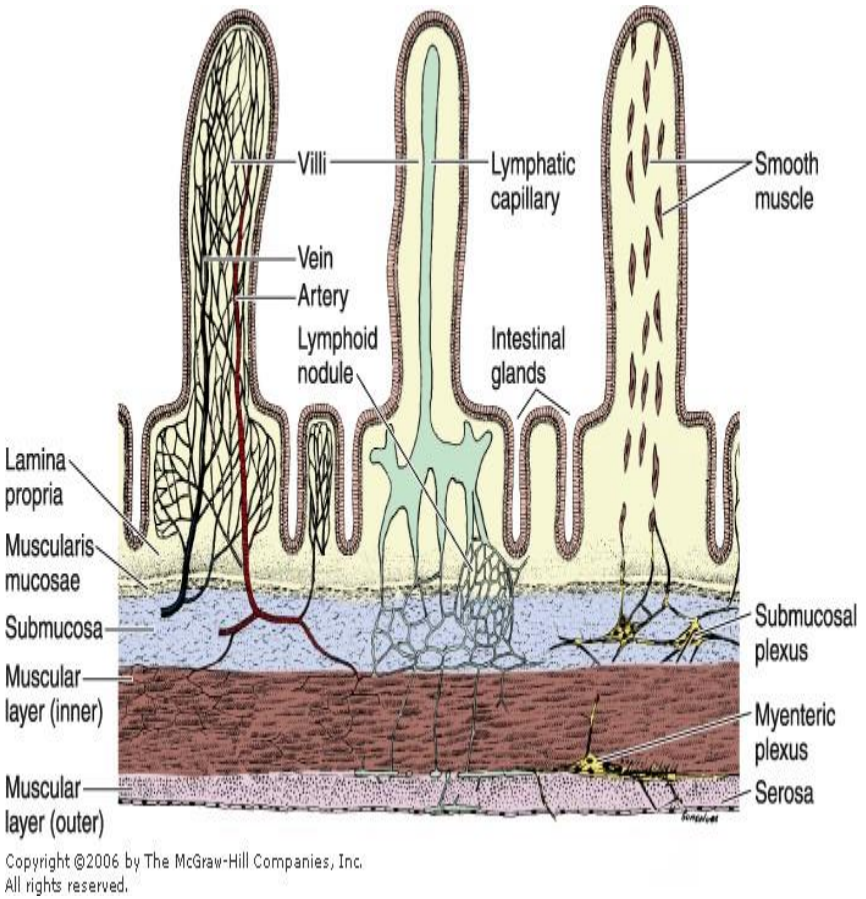




- The very large mucosal surface of the gastrointestinal tract is exposed to many potentially invasive microorganisms
- Secretory immunoglobulins of the IgA are the first line of defense
- Another protective device is the intercellular tight junctions that make the epithelial cells a barrier to the penetration of microorganisms.
- In addition the gastrointestinal tract contains antibody-secreting plasma cells, macrophages, and a very large number of lymphocytes
- located in both the mucosa and the submucosa. Together, these cells are called the gut-associated lymphoid tissue (GALT).

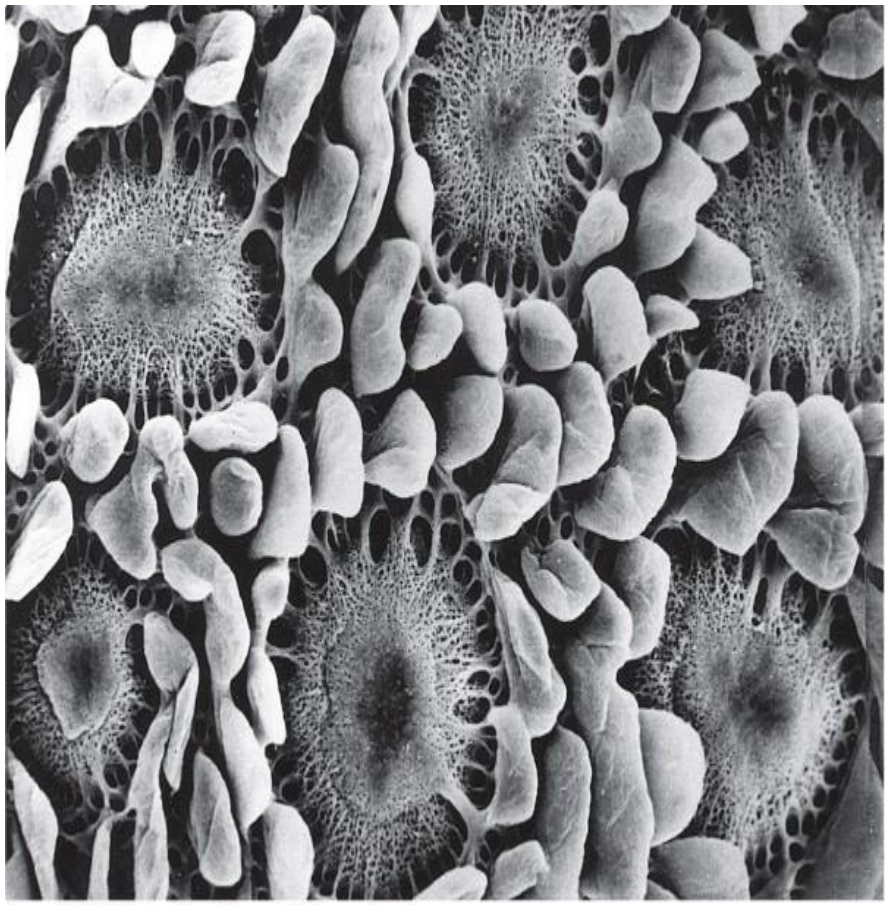


- The lamina propria of the small intestine is composed of loose connective tissue with blood and lymph vessels, nerve fibers, and smooth muscle cells.
- The lamina propria penetrates the core of the intestinal villi
- smooth muscle cells are responsible for the rhythmic movements of the villi, which are important for absorption



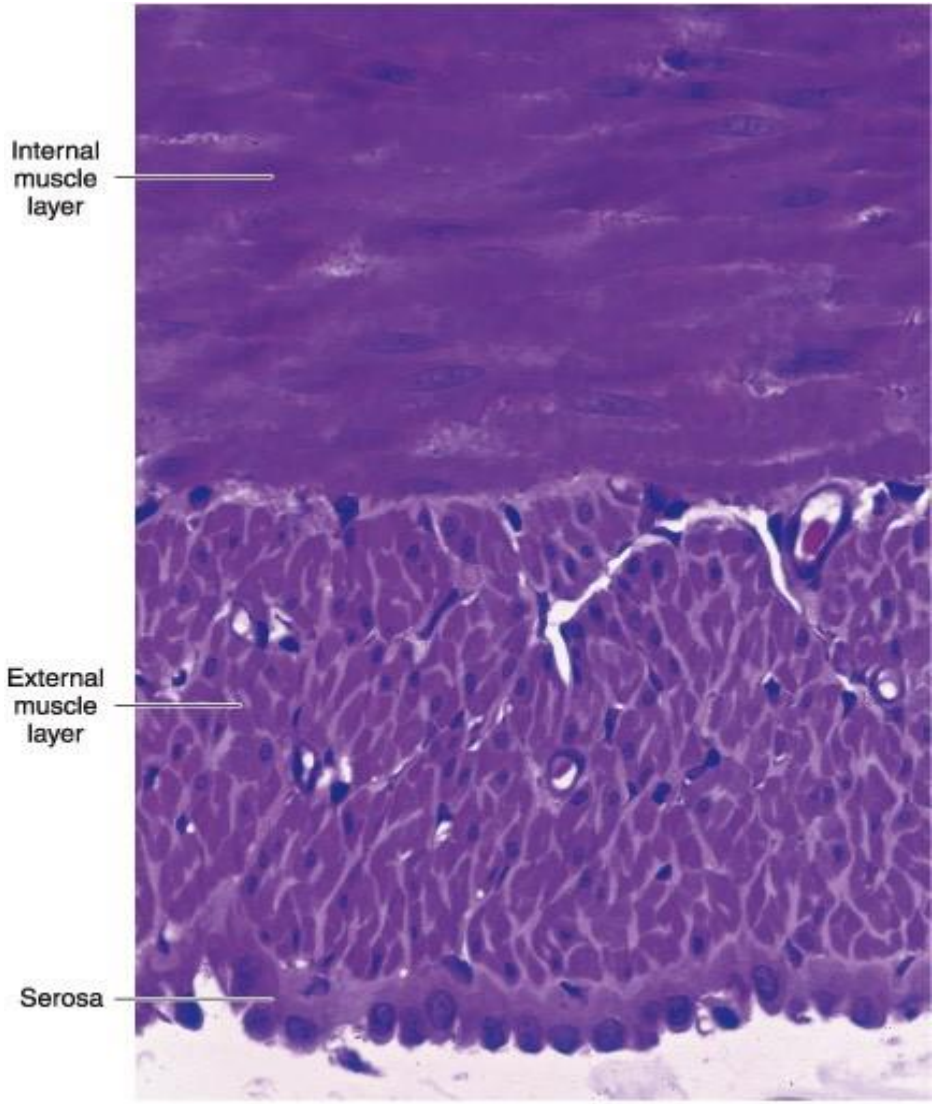
- In the initial portion of the duodenum (this pic)the **submucosa** contains clusters of ramified, coiled tubular glands that open into the intestinal glands. These are the **duodenal** (or **Brunner's) glands**
- The product of secretion of the glands is distinctly alkaline (pH 8.1–9.3),
- acting to protect the duodenal mucous membrane from the effects of the acid gastric juice and to bring the intestinal contents to the optimum pH for pancreatic enzyme action.

- The lamina propria and the submucosa of the small intestine contain aggregates of lymphoid nodules known as **Peyer's patches,** an important component of the GALT (Gut associated lymphatic tissue)



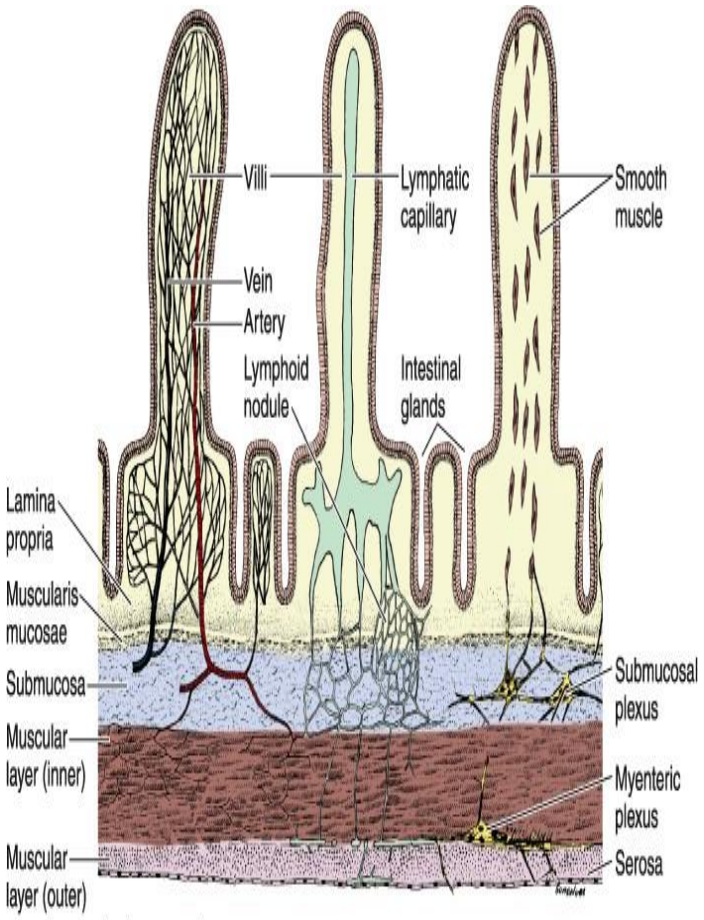
- Each patch consists of 10–200 nodules and is visible to the naked eye as an oval area on the antimesenteric side of the intestine
- There are about 30 patches in humans, **most of them in the ileum**
- each Peyer's patch appears as a dome-shaped area devoid of villi
- Instead of absorptive cells, its covering epithelium consists of **M cells**

- The muscularis mucosa is well developed in the intestines, composed of an internal circular layer and an external longitudinal layer, in between myenteric plexus for the secretion & motility.



Vessels & Nerves

- The blood vessels that nourish the intestine and remove absorbed products of digestion penetrate the muscularis and form a large plexus in the submucosa
- From the submucosa, branches extend through the muscularis mucosae and lamina propria and into the villi.
- Each villus receives, according to its size, one or more branchesthat form a capillary network just below its epithelium
- At the tips of the villi, one or more venules arise from these capillaries and run in the opposite direction, reaching the veins of the submucosal plexus
- **These capillaries (lacteals),** although larger than the blood capillaries, are difficult to observe because their walls are so close together that they appear to be collapsed
- Lacteals run to the region of lamina propria above the muscularis mucosae, where they form a plexus. From there they are directed to the submucosa, where they surround lymphoid nodules
- Lacteals anastomose repeatedly and leave the intestine along with the blood vessels.
- They are especially important for the absorption of lipids, because blood circulation does not easily accept the lipoproteins produced by the absorptive cells during this process



- important for intestinal function is the rhythmic movement of the villi
- This movement is the result of the contraction of smooth muscle cells running vertically between the muscularis mucosae and the tip of the villi
- These contractions occur at the rate of several strokes per minute and have a pumping action on the villi that propels the lymph to the mesenteric lymphatics.

- The innervation of the intestines is formed by both an **intrinsic component** and an **extrinsic component**

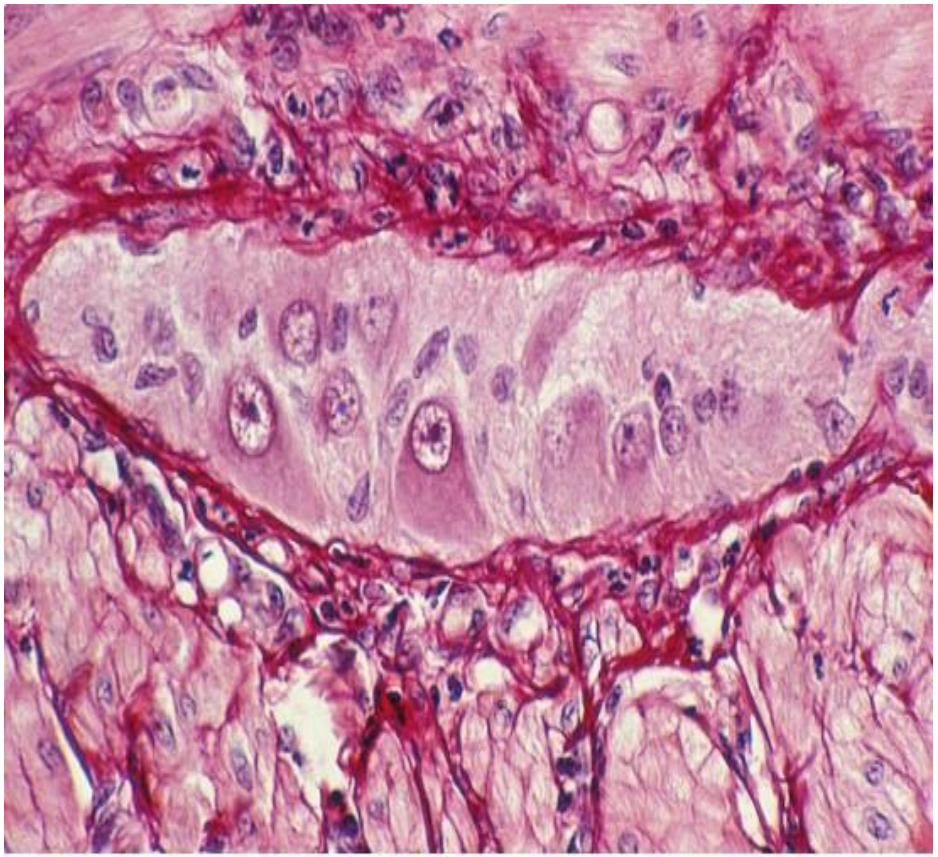
- The intrinsic component comprises groups of neurons that form the **myenteric (Auerbach's) nerve plexus** between the outer longitudinal and inner circular layers of the muscularis. It's parasympathetic & called enteric plexus

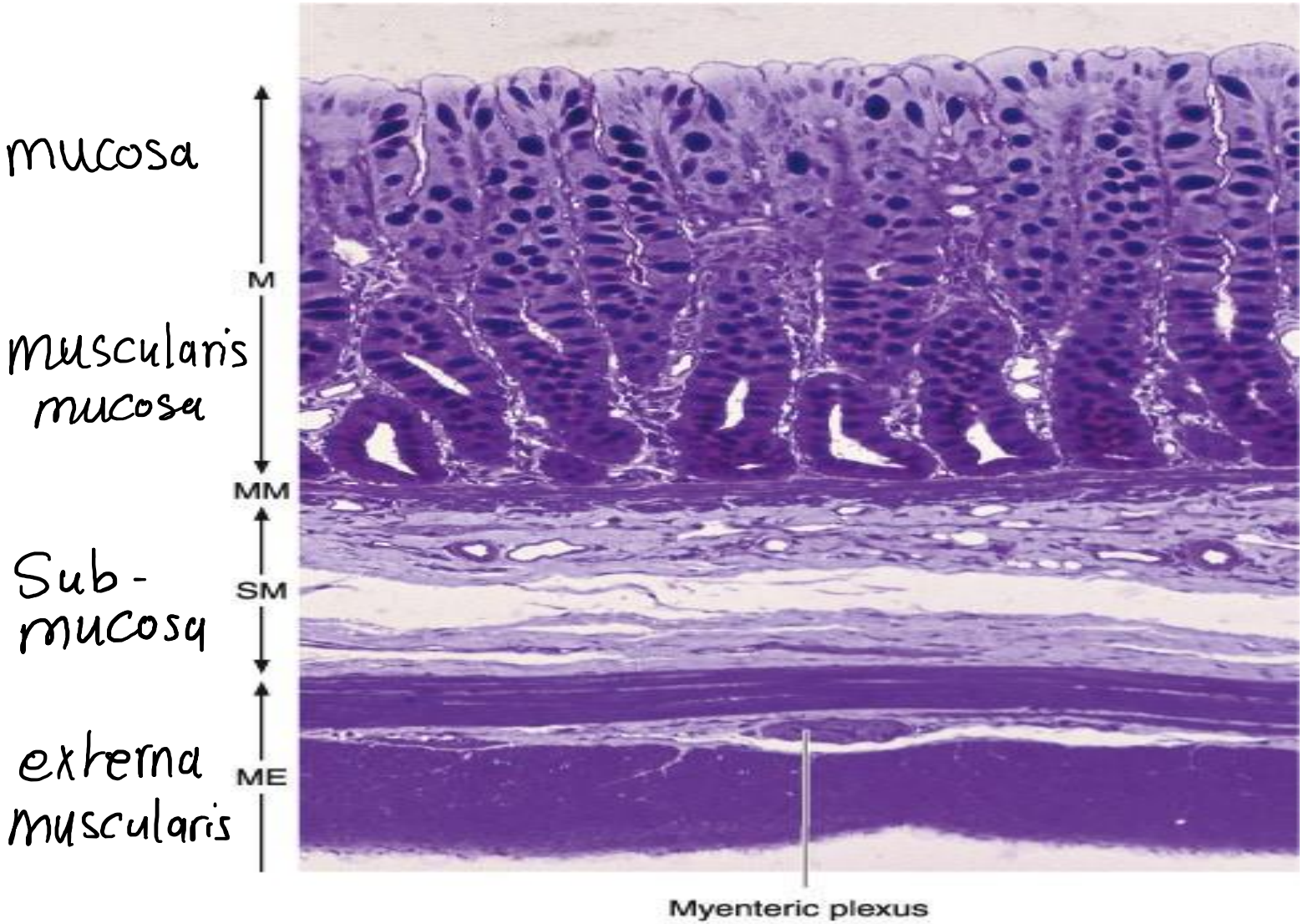
- and the **submucosal (Meissner's) plexus** in the submucosa

- The plexuses contain some sensory neurons that receive information from nerve endings near the epithelial layer and in the smooth muscle layer

- regarding the composition of the intestinal content (chemoreceptors) and the degree of expansion of the intestinal wall (mechanoreceptors)

- The other nerve cells are effectors and innervate the muscle layers and hormonesecreting cells





- The intrinsic innervation formed by these plexuses is responsible for the intestinal contractions that occur in the total absence of the extrinsic innervation.

- The extrinsic innervation is formed by parasympathetic cholinergic nerve fibers that stimulate the activity of the intestinal smooth muscle

- and by sympathetic adrenergic nerve fibers that depress intestinal smooth muscle activity.

- It distribution along with blood supply.

إِنّي رَأَيتُ وُقوفَ الماءِ يُفسِدُهُ إِن ساحَ طابَ وَإِن لَم يَجرِ لَم يَطِبِ

وَالأُسدُ لَولا فِراقُ الأَرضِ ما افتَرَسَت وَالسَهمُ لَولا فِراقُ القَوسِ لَم يصِبِ

وَالشَمسُ لَو وَقَفَت في الفُلكِ دائِمَةً لَمَلَّها الناسُ مِن عجمٍ وَمِن عَرَبِ

Extra for summary from Junqueira's book

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

Digestive Tract SUMMARY OF KEY POINTS

Oral Cavity

- The **oral cavity** is lined primarily by **mucosa** with **nonkeratinized stratified squamous epithelium**, with **keratinized stratified squamous epithelium** on the **hard palate** and **gingiva**.
- The dorsal surface mucosa of the tongue has projecting **lingual papillae** of four types: **filiform** papillae with keratinized epithelium and nonkeratinized **foliate**, **fungiform**, and large **vallate** papillae.
- All lingual papillae, except the filiform type, have epithelial **taste buds** on their sides, with chemosensory **gustatory cells** with synapses to basal sensory innervation, **support cells**, and an apical **taste pore**.
- Each tooth has **enamel** covering its **crown** and **neck** and a vascularized, innervated central **pulp cavity** within the **dentin** that makes up the **roots** and extends into the neck.
- Enamel calcifies as parallel **enamel rods** in a process guided by the protein **amelogenin** after secretion from columnar epithelial cells called **ameloblasts** in the **enamel organ** of the embryonic **tooth bud**.
- **Predentin** is secreted as elongated **dentinal tubules** from tall **odontoblasts**, which line the pulp cavity and persist in the fully formed tooth, with apical **odontoblast processes** extending between the tubules.
- The **periodontium** of each tooth consists of a thin layer of bone-like **cementum** surrounding dentin of the roots and the **periodontal ligament** binding the cementum to **alveolar bone** on the jaw socket.

Layers of the Digestive Tract

- From the esophagus to the rectum, the digestive tract has **four major layers**: a lining **mucosa**, a **submucosa**, a **muscularis**, and an outermost **adventitia** or mesothelium-covered **serosa**.
- The **mucosa** varies regionally along the tract but always consists of a lining **epithelium** on a **lamina propria** of loose connective tissue and smooth muscle fibers extending from **muscularis mucosae** layer.

Esophagus

- The mucosa of the **esophagus** has **nonkeratinized stratified squamous epithelium**; its muscularis is striated at its superior end with smooth muscle at its inferior end, with mixed fiber types in the middle.
- Most of the outer layer of the esophagus is **adventitia**, merging with other tissues of the mediastinum.
- At the **esophagogastric junction**, stratified squamous epithelium changes abruptly to **simple columnar epithelium** invaginating into the lamina propria as many branched tubular glands.

Stomach

- The **stomach** has four major regions: the superior **cardia** and inferior **pylorus**, which are rather similar histologically, and the intervening **fundus** and **body**, which are also similar.
- The mucosa of the stomach fundus and body is penetrated by numerous **gastric pits**, which are lined like the stomach lumen with **surface mucous cells** and which lead into branching **gastric glands**.
- The surface mucous cells secrete a thick layer of **viscous mucus with bicarbonate ions**, which protects these cells and the underlying lamina propria.
- The **gastric glands** are lined by epithelium with four **major cell types**, as well as their pluripotent **stem cells** that are located in the narrow neck regions of these glands:
  - **Mucous neck cells** include immature precursors of the surface mucous cells but produce less alkaline mucus while migrating up into the gastric pits.
  - **Parietal cells** are large cells with many mitochondria and **large intracellular canaliculi** for production of **HCl** in the gastric secretion; they also secrete **intrinsic factor** for vitamin B_{12} uptake.
  - **Chief (zymogenic) cells**, clustered mainly in the lower half of the gastric glands, secrete the protein **pepsinogen** that is activated by the low pH in the lumen to form the major protease **pepsin**.
  - **Enteroendocrine cells** are scattered epithelial cells of the **diffuse neuroendocrine system**, which release **peptide hormones** to regulate activities of neighboring tissues during food digestion.
- The mucosa of the stomach cardiac and pyloric regions has branching **cardial and pyloric glands**, which consist almost entirely of columnar **mucous cells**, lacking parietal and chief cells.

Small Intestine

- The **small intestine** has three regions: the **duodenum** with large mucous glands in the submucosa called **duodenal glands**; the **jejunum**; and the **ileum** with the large mucosal and submucosal **Peyer patches**.
- In all regions of small intestine the mucosa has millions of projecting **villi**, with simple columnar epithelium over cores of lamina propria, and intervening simple tubular **intestinal glands** (or crypts).
- Stem cells in these glands produce the columnar epithelial cells of villi, mainly **goblet cells** and **enterocytes** for nutrient absorption, as well as defensin-producing **Paneth cells** deep in the glands.
- **Sugars** and **amino acids** produced by final steps of digesting carbohydrates and polypeptides in the **glycocalyx** undergo transcytosis through **enterocytes** for uptake by **capillaries**.
- Products of **lipid** digestion associate with bile salts, are taken up by enterocytes, and are converted to **triglycerides** and **lipoproteins** for release as **chylomicrons** and uptake by a lymphatic called a **lacteal** in the core of each villus.
- **Smooth muscle** of the **lamina propria** and **muscularis mucosae**, under the control of the autonomic **submucosal (Meissner) plexus**, moves the villi and helps propel lymph through the lacteals.
- **Smooth muscle** in the **inner circular layer** and the **outer longitudinal layer** of the muscularis, under the control of the autonomic **myenteric (Auerbach) plexus**, produces strong **peristalsis**.

Large Intestine

- The **large intestine** has three major regions: the short **cecum**, with the appendix; the long **colon**, with its ascending, transverse, descending, and sigmoid portions; and the **rectum**.
- Along its entire length, the mucosa of the large intestine has millions of short simple tubular **intestinal glands**, lined by lubricant **goblet cells** and **absorptive cells** for the uptake of water and electrolytes.
- The **muscularis** of the colon has its outer longitudinal layer subdivided into three bands of smooth muscle called **teniae coli**, which act in the peristaltic movement of feces to the rectum.

Anal Canal

- At the **anal canal** the simple columnar epithelium lining the rectum shifts abruptly to **stratified squamous epithelium** of the skin at the **anus**.
- Near the anus the circular layer of the rectum's muscularis forms the **internal anal sphincter**, with further control exerted by **striated muscle** of the **external anal sphincter**.