Digestive Tract

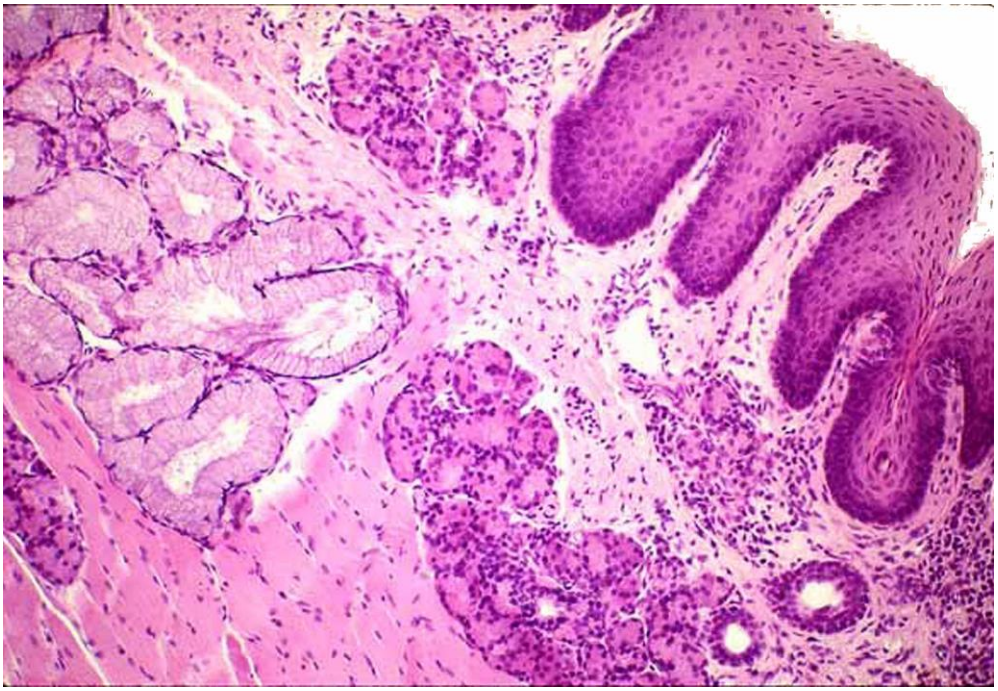
The digestive system consists of the digestive tract, oral cavity, esophagus, stomach, small and large intestines, rectum, and anus and its associated glands salivary glands, liver, and pancreas. Its function is to obtain the molecules necessary for the maintenance, growth, and energy needs of the body from ingested food. Large molecules such as proteins, fats, complex carbohydrates, and nucleic acids are broken down into small molecules that are easily absorbed through the lining of the digestive tract, mostly in the small intestine. Water, vitamins, and minerals are also absorbed from ingested food. In addition, the inner layer of the digestive tract is a protective barrier between the content of the tract's lumen and the internal milieu of the body.

The first step in the complex process known as digestion occurs in the mouth, where food is moistened by saliva and ground by the teeth into smaller pieces; saliva also initiates the digestion of carbohydrates. Digestion continues in the stomach and small intestine, where the food transformed into its basic components (eg, amino acids, monosaccharides, free fatty acids, monoglycerides) is absorbed. Water absorption occurs in the large intestine, causing the undigested contents to become semisolid.

The Oral Cavity

The oral cavity is lined with stratified squamous epithelium, keratinized or nonkeratinized, depending on the region. The keratin layer protects the oral mucosa from damage during masticatory function and is present mostly in the gingiva (gum) and hard palate. The lamina propria in these regions has several papillae and rests directly on bony tissue. Nonkeratinized squamous epithelium covers the soft palate, lips, cheeks, and the floor of the mouth. The lamina propria has papillae, similar to those in the dermis of the skin, and is continuous with a submucosa containing diffuse small salivary glands. In the lips, a transition from the oral nonkeratinized epithelium to the keratinized epithelium of the skin can be observed.

The soft palate has a core of skeletal muscle, numerous mucous glands, and lymphoid nodules in its submucosa.



Section of Oral mucosa

General Structure of the Digestive Tract

The entire gastrointestinal tract presents certain common structural characteristics. It is a hollow tube composed of a lumen whose diameter varies, surrounded by a wall made up of four principal layers: the ***mucosa, submucosa, muscularis, and serosa***.

The mucosa comprises an *epithelial lining*; a *lamina propria* of loose connective tissue rich in blood and lymph vessels and smooth muscle cells, sometimes also containing glands and lymphoid tissue; and the *muscularis mucosae*, usually consisting of a thin inner circular layer and an outer longitudinal layer of smooth muscle cells separating the mucosa from the submucosa. The mucosa is frequently called a mucous membrane.

The submucosa is composed of dense connective tissue with many blood and lymph vessels and a submucosal (also called **Meissner's**) nerve plexus. It may also contain glands and lymphoid tissue.

The muscularis contains smooth muscle cells that are spirally oriented and divided into two sublayers according to the main direction the muscle cells follow. In the internal sublayer (close to the lumen), the orientation is generally circular; in the external sublayer, it is mostly longitudinal. The muscularis also contains the myenteric (or **Auerbach's**) nerve plexus, which lies between the two muscle sublayers, and blood and lymph vessels in the connective tissue between the muscle sublayers.

The serosa is a thin layer of loose connective tissue, rich in blood and lymph vessels and adipose tissue, and a simple squamous covering epithelium (mesothelium). In the

abdominal cavity, the serosa is continuous with the mesenteries (thin membranes covered by mesothelium on both sides), which support the intestines, and with the peritoneum, a serous membrane that lines the cavity wall. In places where the digestive organ is bound to other organs or structures, however, the serosa is replaced by a thick adventitia, consisting of connective tissue containing vessels and nerves, without the mesothelium.

The main functions of the epithelial lining of the digestive tract are to provide a selectively permeable barrier between the contents of the tract and the tissues of the body, to facilitate the transport and digestion of food, to promote the absorption of the products of this digestion, and to produce hormones that affect the activity of the digestive system. Cells in this layer produce mucus for lubrication and protection.

The abundant lymphoid nodules in the lamina propria and the submucosal layer protect the organism (in association with the epithelium) from bacterial invasion. The necessity for this immunological support is obvious, because the entire digestive tract—with the exception of the oral cavity, esophagus, and anal canal—is lined with a simple thin, vulnerable epithelium. The lamina propria, located just below the epithelium, is a zone rich in macrophages and lymphoid cells, some of which actively produce antibodies. These antibodies are mainly immunoglobulin A (IgA) and are bound to a secretory protein produced by the epithelial cells of the intestinal lining and secreted into the intestinal lumen. This complex protects against viral and bacterial invasion.

The muscularis mucosae promotes the movement of the mucosa independent of other movements of the digestive tract, increasing its contact with the food. The contractions of the muscularis, generated and coordinated by nerve plexuses, propel and mix the food in the digestive tract. These plexuses are composed mainly of nerve cell aggregates (multipolar visceral neurons) that form small parasympathetic ganglia. A rich network of pre- and postganglionic fibers of the autonomic nervous system and some visceral sensory fibers in these ganglia permit communication between them. The number of these ganglia along the digestive tract is variable; they are more numerous in regions of greatest motility.

Tongue

The tongue is a mass of striated muscle covered by a mucous membrane whose structure varies according to the region. The muscle fibers cross one another in three planes; they are grouped in bundles, usually separated by connective tissue. Because the connective tissue of the lamina propria penetrates the spaces between the muscular bundles, the mucous membrane is strongly adherent to the muscle. The mucous membrane is smooth on the lower (ventral) surface of the tongue. The tongue's dorsal surface is irregular, covered anteriorly by a great number of small eminences called papillae. The posterior one-third of the dorsal surface of the tongue is separated from

the anterior two-thirds by a V-shaped boundary. Behind this boundary, the surface of the tongue shows small bulges composed mainly of two types of small lymphoid aggregations: small collections of lymphoid nodules and the lingual tonsils, where lymphoid nodules aggregate around invaginations (crypts) of the mucous membrane.

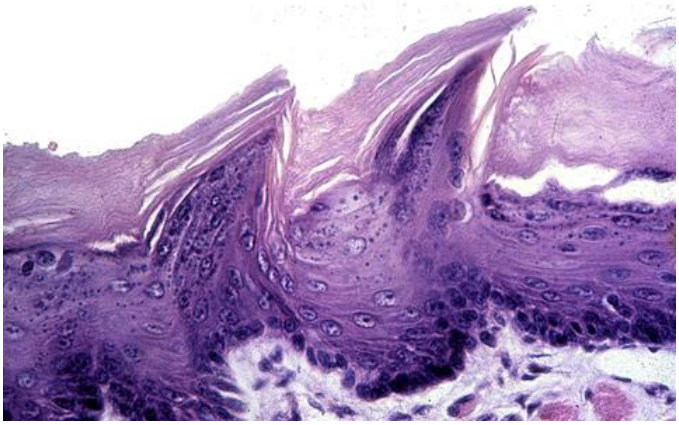
Papillae

Papillae are elevations of the oral epithelium and lamina propria that assume various forms and functions. There are four types:

1-Filiform Papillae

Filiform papillae have an elongated conical shape; they are quite numerous and are present over the entire surface of the tongue. Their epithelium, which does not contain taste buds, is keratinized.

Filiform Papillae



2-Fungiform Papillae

Fungiform papillae resemble mushrooms in that they have a narrow stalk and a smooth-surfaced, dilated upper part. These papillae, which contain scattered taste buds on their upper surfaces, are irregularly interspersed among the filiform papillae.

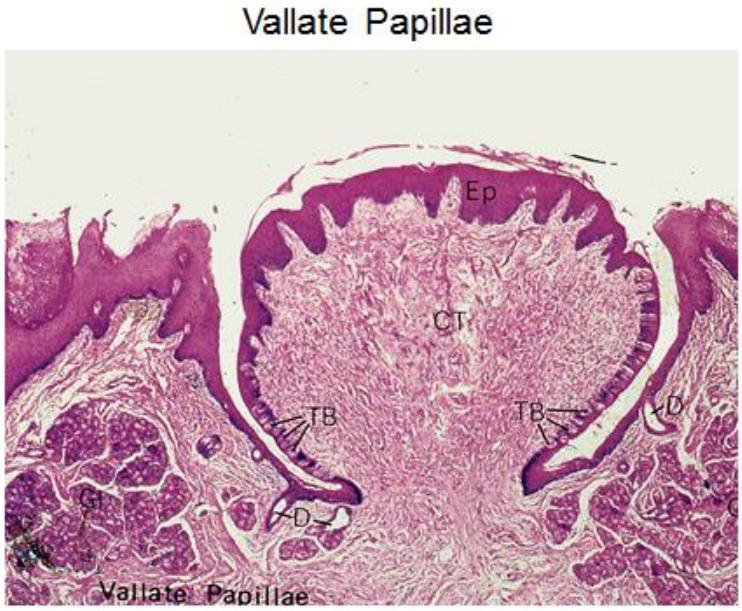
3-Foliate Papillae

Foliate papillae are poorly developed in humans. They consist of two or more parallel ridges and furrows on the dorsolateral surface of the tongue and contain many taste buds.

4-Circumvallate Papillae

Circumvallate papillae are 7–12 extremely large circular papillae whose flattened surfaces extend above the other papillae. They are distributed in the V region in the

posterior portion of the tongue. Numerous serous (von Ebner's) glands drain their contents into the deep groove that encircles the periphery of each papilla. This moatlike arrangement provides a continuous flow of fluid over the great number of taste buds present along the sides of these papillae. The glands also secrete a lipase that probably prevents the formation of a hydrophobic layer over the taste buds that would hinder their function. This flow of secretions is important in removing food particles from the vicinity of the taste buds so that they can receive and process new gustatory stimuli. Along with this local role, lingual lipase is active in the stomach and can digest up to 30% of dietary triglycerides. Other small mucous salivary glands dispersed throughout the lining of the oral cavity act in the same way as the serous glands associated with this type of papilla to prepare the taste buds in other parts of the oral cavity, such as the anterior portion of the tongue, to respond to taste stimuli.



There are at least four qualities in human taste perception: saltiness, sourness, sweetness, and bitterness. All qualities can be elicited from all the regions of the tongue that contain taste buds, specialized structures that contain the taste cells, the detectors of tastants (substances capable of eliciting taste). Taste buds are onion-shaped structures, each one containing 50–100 cells. The bud rests in the basal lamina, and in its apical portion the taste cells project microvilli that poke through an opening called the taste pore. Most of the cells are actually the taste cells, while others have a supportive function, secreting an amorphous material that surrounds the microvilli in the taste pore. Undifferentiated basal cells are responsible for the replacement of all the cell types. Tastants dissolved in saliva contact the taste cells through the pore, interacting with taste receptors (sweet and bitter tastes) or ion channels (salty and sour tastes) on the surface of the cells. The result is a depolarization of the taste cells, leading to the release of neurotransmitters that will, in turn, stimulate afferent nerve fibers connected to the taste cells. This information will be processed by central gustatory neurons. It is believed that each tasting stimulus generates a unique pattern of activity across a large

set of neurons, which explains taste discrimination. The receptors for bitter tastants, recently identified, belong to a family estimated to have 40–80 members. In the near future other families of taste receptors will certainly be identified as well.

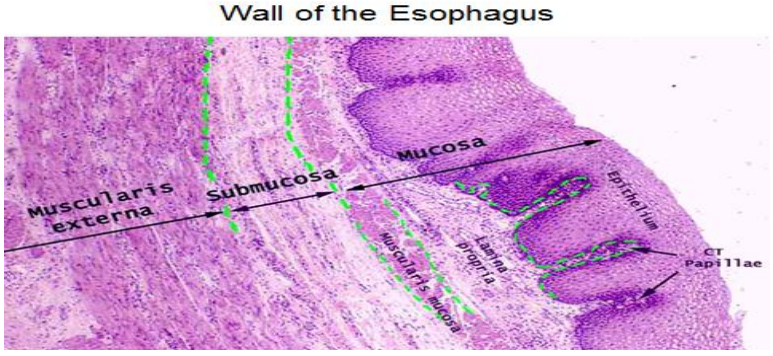
Pharynx

The pharynx, a transitional space between the oral cavity and the respiratory and digestive systems, forms an area of communication between the nasal region and the larynx. The pharynx is lined by stratified nonkeratinized squamous epithelium in the region continuous with the esophagus and by ciliated pseudostratified columnar epithelium containing goblet cells in the regions close to the nasal cavity.

The pharynx contains the tonsils. The mucosa of the pharynx also has many small mucous salivary glands in its lamina propria, composed of dense connective tissue. The constrictor and longitudinal muscles of the pharynx are located outside this layer.

Esophagus

The part of the gastrointestinal tract called the 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. 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. In humans the esophagus is covered by nonkeratinized stratified squamous epithelium. In general, it has the same layers as the rest of the digestive tract. In the submucosa are groups of small mucus-secreting glands, the esophageal glands, whose secretion facilitates the transport of foodstuffs and protects the mucosa. In the lamina propria of the region near the stomach are groups of glands, the esophageal cardiac glands, that also secrete mucus. 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. Only that portion of the esophagus 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. It is a dilated segment of the digestive tract whose 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 (chyme), 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. Gross inspection reveals four regions: cardia, fundus, body, and pylorus. Because the fundus and body are identical in microscopic structure, only three histological regions are recognized. 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.

Mucosa

The gastric mucosa consists of a surface epithelium that invaginates to various extents into the lamina propria, forming ***gastric pits***. Emptying into the gastric pits are branched, tubular glands (***cardiac, gastric, and pyloric***) characteristic of each region of the stomach. The lamina propria of the stomach is composed of loose connective tissue interspersed with smooth muscle and lymphoid cells. Separating the mucosa from the underlying submucosa is a layer of smooth muscle, the muscularis mucosae.

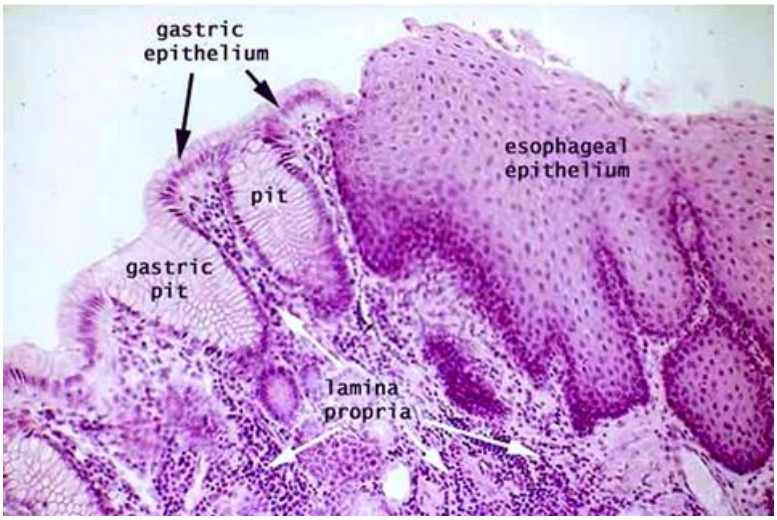
When the luminal surface of the stomach is viewed under low magnification, numerous small circular or ovoid invaginations of the epithelial lining are observed. These are the openings of the gastric pits. The epithelium covering the surface and lining the pits is a simple columnar epithelium, and all the cells secrete an alkaline mucus. This mucus consists primarily of water (95%), lipids, and glycoproteins, which, in combination, form a hydrophobic protective gel. Bicarbonate, secreted by the surface epithelial cells into the mucous gel, forms a pH gradient ranging from 1 at the gastric luminal surface to 7 along the epithelial cell surface.

The mucus firmly adherent to the epithelial surface is very effective in protection, while the superficial luminal mucous layer is more soluble, partially digested by pepsin and mixed with the luminal contents. 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. A third (but not less important) line of defense is a rich submucosal circulatory bed, which provides bicarbonate, micronutrients, and oxygen to mucosal cells, while removing toxic metabolic products. This factor also favors the healing of superficial wounds in a process called mucosal restitution. Like the hydrochloric acid, pepsin, lipases (lingual and gastric), and bile must also be considered as endogenous aggressors to the epithelial lining.

Cardia

The cardia is a narrow circular band, 1.5–3 cm in width, at the transition between the esophagus and the stomach. Its mucosa contains simple or branched tubular cardiac glands. 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.

Stomach – Esophagus Junction



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. Each gastric gland has three distinct regions: the isthmus, neck, and base. The distribution of epithelial cells in gastric glands is not uniform. The isthmus, close to the gastric pit, contains differentiating mucous cells that will migrate and replace superficial mucous cells, undifferentiated stem cells, and oxyntic (parietal) cells; the neck of the glands consists of stem, mucous neck (different from the mucous cells in the isthmus), and parietal cells; the base of the glands primarily contains parietal and chief (zymogenic) cells. Enteroendocrine cells are dispersed in the neck and base of the glands.

1- 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. These cells are replaced much more slowly than surface mucous cells.

2- 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.

3- Oxyntic (Parietal) Cells

Parietal cells are present mainly in the upper half of gastric glands; they are scarce in the base. They are rounded or pyramidal cells, with one centrally placed spherical nucleus and intensely eosinophilic cytoplasm. The most striking features of the active secreting cell seen in the electron microscope are an abundance of mitochondria (eosinophilic) and a deep, circular invagination of the apical plasma membrane, forming the intracellular canaliculus. 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. 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.

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 mucosa, stimulating growth.

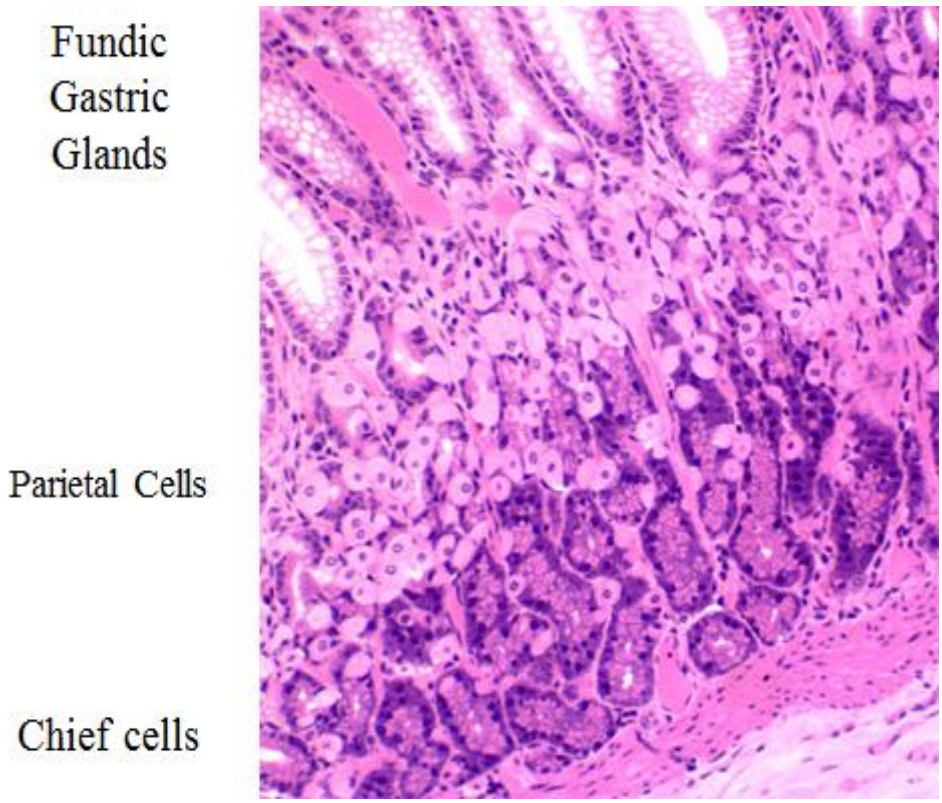
4- Chief (Zymogenic) Cells

Chief cells predominate in the lower region of the tubular glands and have all the characteristics of protein-synthesizing and -exporting cells. Their basophilia is due to the abundant rough endoplasmic reticulum. 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.

5- Enteroendocrine Cells

Enteroendocrine cells, discussed more extensively below, 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. Other products of enteroendocrine cells in the gastrointestinal tract are listed in Table.



Principal Enteroendocrine Cells in the Gastrointestinal Tract. للاطلاع		
Cell Type and Location	**Hormone Produced**	**Major Action**
G—pylorus	**Gastrin**	**Stimulation of gastric acid secretion**
		Gastric mucosal growth
S—small intestine	**Secretin**	**Pancreatic and biliary bicarbonate and water secretion**
K—small intestine	**Gast ic inhibitory polypeptide**	**Inhibition of gastric acid secretion**
		Stimulation of insulin release
L—small intestine	**Glucagon-like peptide 1 (GLP-1)**	**Inhibition of gastric acid secretion**
		Stimulation of insulinrelease
I—small intestine	**Cholecystokinin**	**Pancreatic enzyme secretion, gallbladder contraction**
D—gut	**Somatostatin**	**Inhibition of endocrine, exocrine, and neuro transmitter secretion**
Mo—small intestine	**Motilin**	**Increased gut motility**
EC—digestive tract	**Serotonin, substance P**	**Increased gut motility**
D_1—digestive tract	**Vasoactive intestinal polypeptide**	**Ion and water secretion, increased gut motility**

Pylorus

The pylorus (from Latin, meaning gatekeeper) has deep gastric pits into which the branched, tubular pyloric glands open. 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 of the Stomach

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. The 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. These segments have many characteristics in common and will be discussed together.

Mucous Membrane

Viewed with the naked eye, 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) 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 inappropriately called crypts), or glands of ***Lieberkühn***.

The epithelium of the villi is continuous with that of the glands. ***The intestinal glands contain stem cells, some absorptive cells, goblet cells, Paneth's cells, and enteroendocrine cells.***

1- 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. When viewed with the electron microscope, the striated border is seen to be a layer of densely packed microvilli. Each microvillus is a cylindrical protrusion of the apical cytoplasm that is approximately 1 m tall by 0.1 m in diameter and consists of the cell membrane enclosing a core of actin microfilaments associated with other cytoskeletal proteins. Each absorptive cell is estimated to have an average of 3000 microvilli, and 1 mm^2 of mucosa contains about 200 million of these structures. Microvilli have the important physiological function of increasing the area of contact between the intestinal surface and the nutrients. The presence of plicae, villi, and microvilli greatly increases the surface of the intestinal lining—an important characteristic in an organ in which absorption occurs so intensely. It has been calculated that plicae increase the intestinal surface 3-fold, the villi increase it 10-fold, and the microvilli increase it 20-fold. Together, these processes are responsible for a 600-fold increase in the intestinal surface, resulting in a total area of 200 m^2.

2-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 that are hydrated and cross-linked to form mucus, whose main function is to protect and lubricate the lining of the intestine.

3-Paneth's cells in the basal portion of the intestinal glands are exocrine cells with secretory granules in their apical cytoplasm. Researchers using immunocytochemical methods have detected lysozyme—an enzyme that digests the cell walls of some bacteria—in the large eosinophilic secretory granules of these cells. Lysozyme has antibacterial activity and may play a role in controlling the intestinal flora.

4-M (microfold) cells are specialized epithelial cells overlying the lymphoid follicles of Peyer's patches (discussed later). These cells are characterized by the presence of numerous basal membrane invaginations that form pits containing many intraepithelial lymphocytes and antigen-presenting 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), where immune responses to foreign antigens are initiated. M cells represent an important link in the intestinal immunological system. The basement membrane under M cells is discontinuous, facilitating transit between the lamina propria and M cells.

5-Endocrine Cells of the Intestine. In addition to the cells discussed above, the intestine

contains some widely distributed cells with characteristics of the diffuse neuroendocrine system.

Upon stimulation these cells release their secretory granules by exocytosis, and the hormones may then exert paracrine (local) or endocrine (blood-borne) effects. Polypeptide-secreting cells of the digestive tract fall into two classes: the open type, in which the apex of the cell presents microvilli and contacts the lumen of the organ ; and the closed type, in which the cellular apex is covered by other epithelial cells. In the small intestine, endocrine cells of the open type are more slender than the neighboring absorptive cells, possessing irregular microvilli in the apical surface and small secretory granules in the cytoplasm. It has been suggested that in the open type, the chemical contents of the digestive tract (ie, certain nutrients, pH) might act on its microvilli and thereby influence secretion of these cells. Although the picture of gastrointestinal endocrinology is still incomplete, the activity of the digestive system is clearly controlled by the nervous system and is modulated by a complex system of locally produced peptide hormones.

Lamina Propria to Serosa

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, taking along blood and lymph vessels, nerves, connective tissue, and smooth muscle cells. The smooth muscle cells are responsible for the rhythmic movements of the villi, which are important for absorption.

The muscularis mucosae does not present any peculiarities in this organ. In the initial portion of the duodenum the submucosa contains clusters of ramified, coiled tubular glands that open into the intestinal glands. These are the duodenal (or Brunner's) glands. Their cells are of the mucous type. 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.

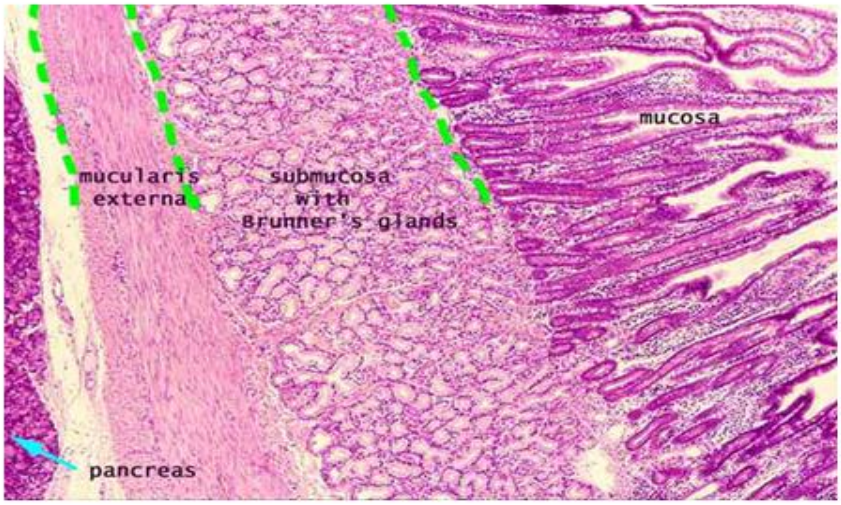
The lamina propria and the submucosa of the small intestine contain aggregates of lymphoid nodules known as Peyer's patches, an important component of the GALT. Each patch consists of 10–200 nodules and is visible to the naked eye as an oval area on the antimesenteric side of the intestine. There are about 30 patches in humans, most of them in the ileum. When viewed from the luminal surface, 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 is well developed in the intestines, composed of an internal

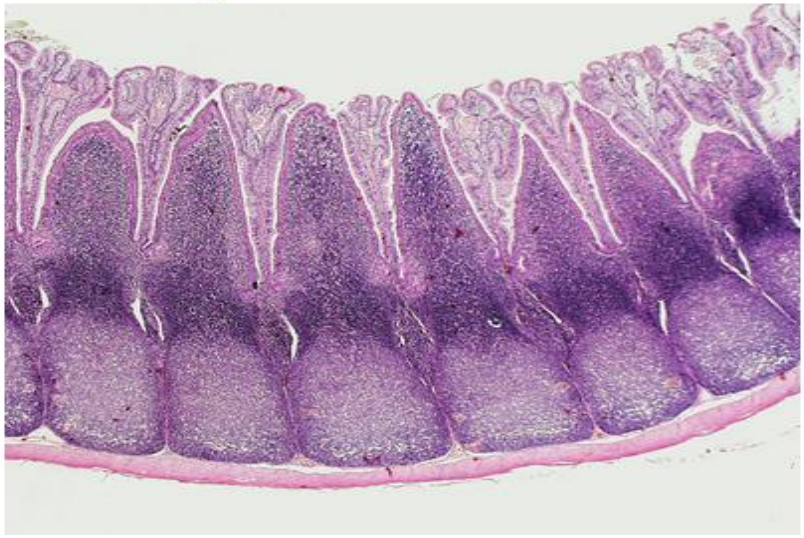
circular layer and an external longitudinal layer. The appearance of the smooth muscle cells in these layers in histological sections will depend on the plane of the section (transverse or longitudinal).

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 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), respectively. The other nerve cells are effectors and innervate the muscle layers and hormone-secreting 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.

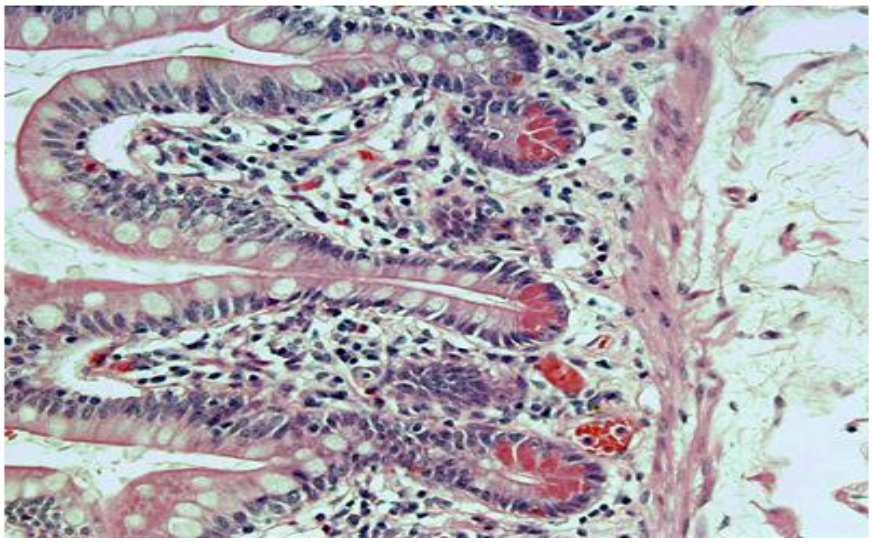
Duodenum



Ileum – Peyer's Patches in the Submucosa



Paneth Cells at the base of the Crypts



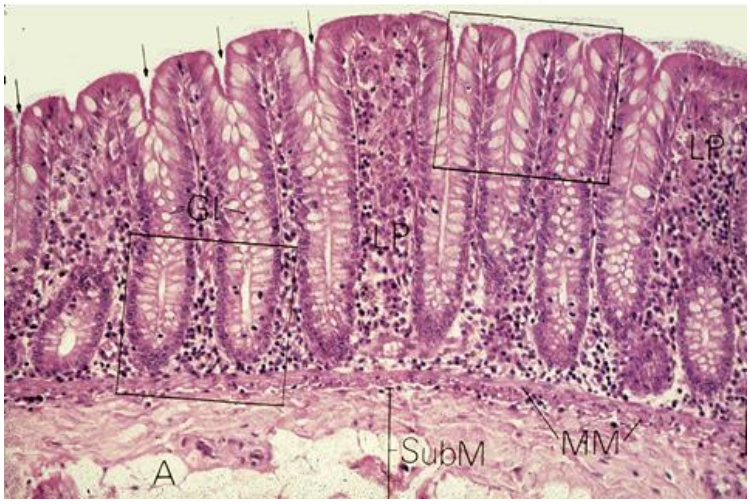
Large Intestine

The large intestine consists of a mucosal membrane with no folds except in its distal (rectal) portion. *No villi are present in this portion of the intestine*. The intestinal glands are long and characterized by a great abundance of goblet and absorptive cells and a small number of enteroendocrine cells. The absorptive cells are columnar and have short, irregular microvilli. The large intestine is well suited to its main functions: absorption of water, formation of the fecal mass, and production of mucus. Mucus is a highly hydrated gel that not only lubricates the intestinal surface but also covers bacteria and particulate matter. The absorption of water is passive, following the active transport of sodium out of the basal surfaces of the epithelial cells.

The lamina propria is rich in lymphoid cells and in nodules that frequently extend into the submucosa. This richness in lymphoid tissue (GALT) is related to the abundant bacterial population of the large intestine. The muscularis comprises longitudinal and circular strands. This layer differs from that of the small intestine, because fibers of the outer longitudinal layer congregate in three thick longitudinal bands called teniae coli. In the intraperitoneal portions of the colon, the serous layer is characterized by small, pendulous protuberances composed of adipose tissue—the appendices epiploicae.

In the anal region, the mucous membrane forms a series of longitudinal folds, the rectal columns of Morgagni. About 2 cm above the anal opening, the intestinal mucosa is replaced by stratified squamous epithelium. In this region, the lamina propria contains a plexus of large veins that, when excessively dilated and varicose, produces hemorrhoids.

Colon Mucus Membrane by LM



Cell Renewal in the Gastrointestinal Tract

The epithelial cells of the entire gastrointestinal tract are constantly being cast off and replaced with new ones formed through mitosis of stem cells. ***These stem*** cells are located in the basal layer of the esophageal epithelium, the neck of gastric glands, the lower half of the intestinal glands, and the bottom third of the crypts of the large intestine. From this proliferative zone in each region, cells move to the maturation area, where they undergo structural and enzymatic maturation, providing the functional cell population of each region. In the small intestine the cells die by apoptosis in the tip of the villi or are sloughed off by mechanical action during function.

Appendix

The appendix is an evagination of the cecum; it is characterized by a relatively small,

narrow, and irregular lumen that is caused by the presence of abundant lymphoid follicles in its wall. Although its general structure is similar to that of the large intestine, it contains fewer and shorter intestinal glands and has no teniae coli.

Because the appendix is closed ended, it has a very small volume capacity and frequently becomes a site of inflammation (appendicitis). Frequent causes of appendicitis are luminal obstruction (by a fecalith, enlarged lymphoid follicles associated with viral infection, tumors, worms) and ulceration of the mucosa. The inflammation can progress to the point of perforation of this structure, with consequent infection of the peritoneal cavity.