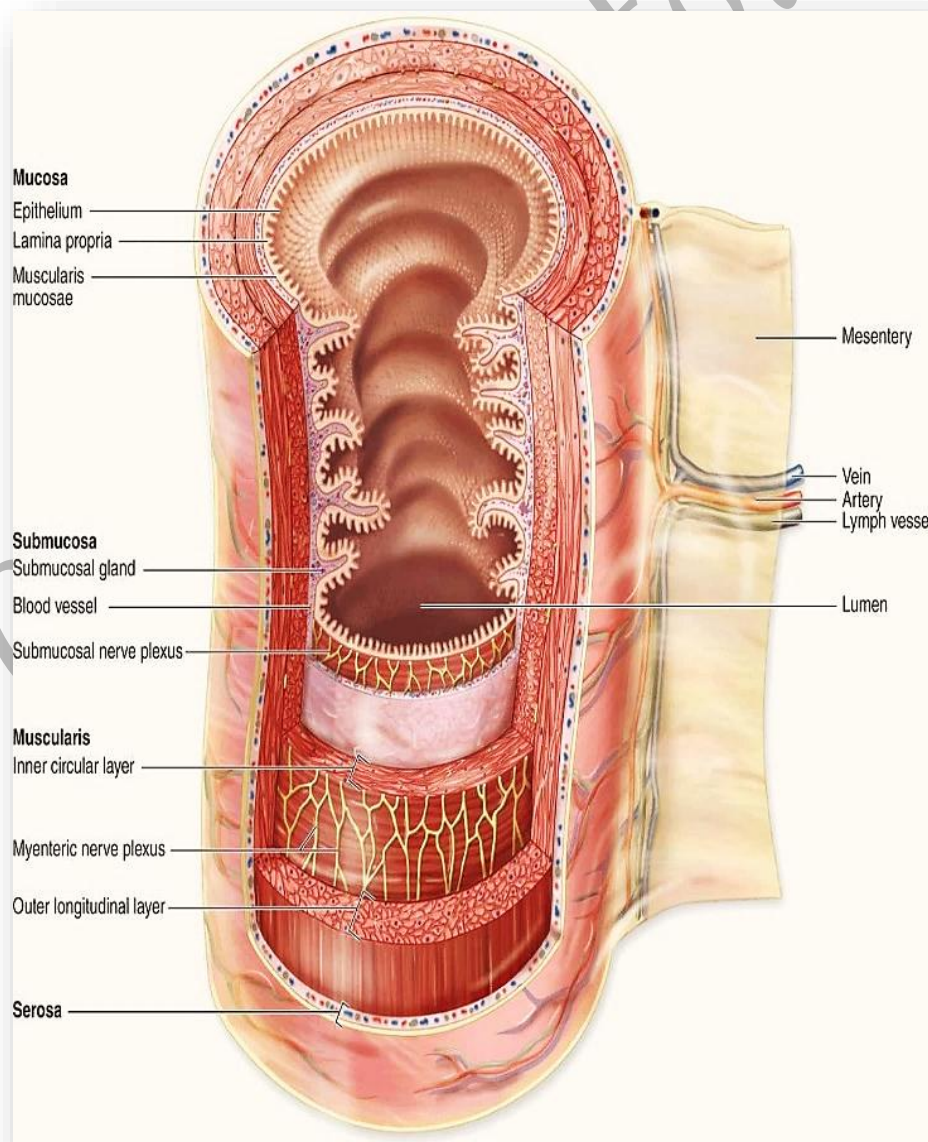


## Digestive System

The digestive system consists of the digestive tract— oral cavity, esophagus, stomach, small and large intestines, and anus—and its associated glands— salivary glands, liver, and pancreas. Also called the gastrointestinal tract or alimentary canal, its function is to obtain from ingested food the molecules necessary for the maintenance, growth, and energy needs of the body.

During digestion proteins, complex carbohydrates, nucleic acids, and fats are broken down into their small molecule subunits that are easily absorbed through the small intestine lining. Most water and electrolytes are absorbed in the large intestine.

It consists of a hollow tube of varying diameter, composed of a **mucosa**, **submucosa**, **muscularis externa**, and **serosa** (or adventitia).



**Structures within the digestive tract allow the following:**

- 1) ingestion, or introduction of food and liquid into the oral cavity.
- 2) Mastication, or chewing, which divides solid food into digestible pieces.
- 3) Motility, muscular movements of materials through the tract.
- 4) Secretion of lubricating and protective mucus, digestive enzymes, acidic and alkaline fluids, and bile.
- 5) Hormone release for local control of motility and secretion.
- 6) Chemical digestion or enzymatic degradation of large macromolecules in food to smaller molecules and their subunits.
- 7) Absorption of the small molecules and water into the blood and lymph.
- 8) Elimination of indigestible, unabsorbed components of food.

***General structure of the digestive tract***

The digestive tract is a hollow tube with a lumen of variable diameter and a wall made up of **four** main layers:

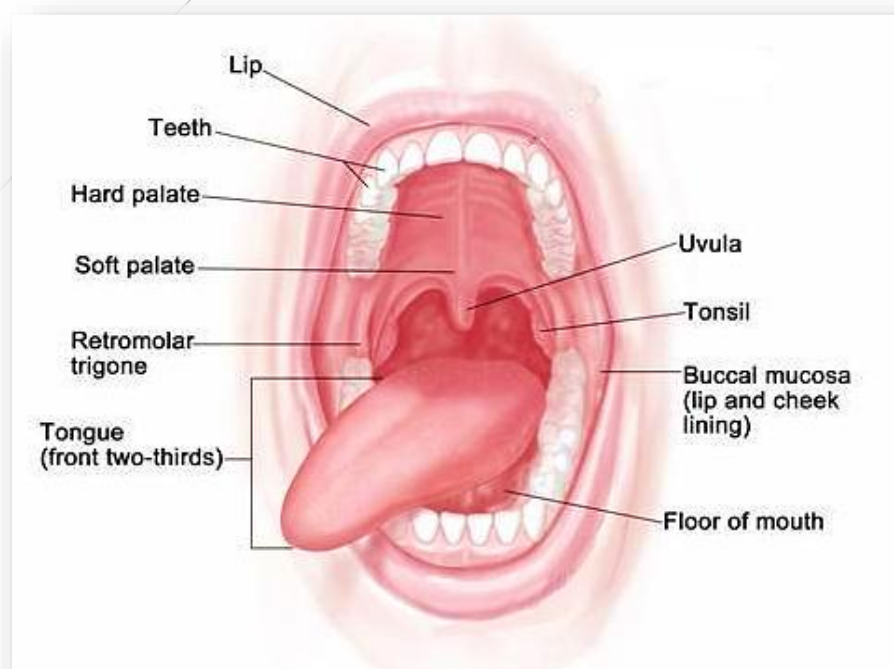
- 1) **The mucosa** consists of an epithelial lining; an underlying lamina propria of loose connective tissue rich in blood vessels, lymphatics, lymphocytes, smooth muscle cells, and often containing small glands; and a thin layer of smooth muscle called the muscularis mucosae separating mucosa from submucosa and allowing local movements of the mucosa. The mucosa is also frequently called a mucous membrane.
- 2) **The submucosa** contains denser connective tissue with larger blood and lymph vessels and the submucosal (Meissner) plexus of autonomic nerves. It may also contain glands and significant lymphoid tissue.
- 3) **The thick muscularis** (or muscularis externa) is composed of smooth muscle cells organized as two or more sublayers. In the internal sublayer (closer to the lumen), the fiber orientation is generally circular; in the external sublayer it is longitudinal. The connective tissue between the muscle sublayers contains blood and lymph vessels, as well as the myenteric (Auerbach) nerve plexus of many autonomic neurons aggregated into small ganglia and interconnected by pre- and postganglionic nerve fibers. This and the submucosal plexus together comprise the enteric nervous system of the digestive tract. Contractions of the muscularis, which mix and propel the luminal contents forward, are generated and coordinated by the myenteric plexus.

**4) The serosa** is a thin layer of loose connective tissue, rich in blood vessels, lymphatics, and adipose tissue, with a simple squamous covering epithelium or mesothelium. In the abdominal cavity, the serosa is continuous with mesenteries, thin membranes covered by mesothelium on both sides that support the intestines. Mesenteries are continuous with the peritoneum, a serous membrane that lines that cavity. In places where the digestive tract is not suspended in a cavity but bound directly to adjacent structures, such as in the esophagus, the serosa is replaced by a thick adventitia, a connective tissue layer that merges with the surrounding tissues and lacks mesothelium.

## *Oral cavity*

The oral cavity is lined with stratified squamous epithelium, which may be keratinized, partially keratinized, or nonkeratinized depending on the location.

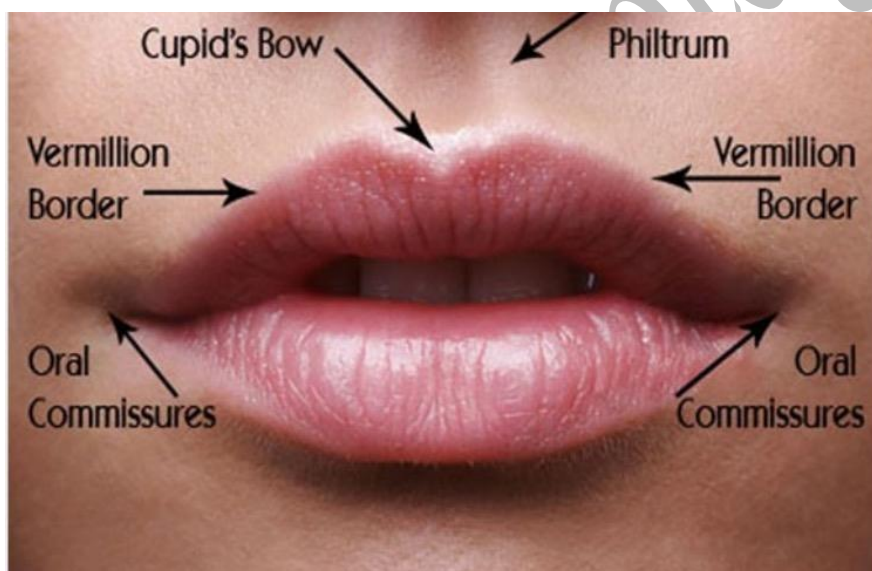
The keratinized cell layers resist damage from abrasion and are best developed in the masticatory mucosa on the **gingiva** (gum) and **hard palate**. The lamina propria in these regions rests directly on the **periosteum** of underlying bone. Nonkeratinized squamous epithelium predominates in the lining mucosa over the **soft palate**, **cheeks**, the **floor of the mouth**, and the **pharynx**, the **posterior region** of the oral cavity leading to the esophagus. Lining mucosa overlies a thick submucosa containing many minor **salivary glands**, which secrete continuously to keep the mucosal surface wet, and diffuse lymphoid tissue.



## Lips

Lips, soft pliable anatomical structures that form the mouth margin of most vertebrates, composed of a surface epidermis (skin), connective tissue, and (in typical mammals) a muscle layer.

In man the outer skin contains hair, sweat glands, and sebaceous (oil) glands. The edges of the lips are covered with reddish skin, sometimes called the **vermillion border**, and abundantly provided with sensitive nerve endings. The reddish skin is a transition layer between the outer, hair-bearing tissue and the inner mucous membrane. The interior surface of the lips is lined with a moist mucous membrane. In newborn infants the inner surface is much thicker, with sebaceous glands and minute projections called papillae.



## Tongue

The tongue is a mass of **striated muscle** covered by mucosa, which manipulates ingested material during mastication and swallowing. The muscle fibers are oriented in all directions, allowing a high level of mobility. Connective tissue between the small fascicles of muscle is penetrated by the lamina propria, which makes the mucous membrane strongly adherent to the muscular core. The lower surface of the tongue is smooth, with typical lining mucosa. The dorsal surface is irregular, having hundreds of small protruding papillae of various types on its anterior two-thirds and the massed lingual tonsils on the posterior third, or root of the tongue. The papillary and tonsillar areas of



the lingual surface are separated by a V-shaped groove called the **sulcus terminalis**.

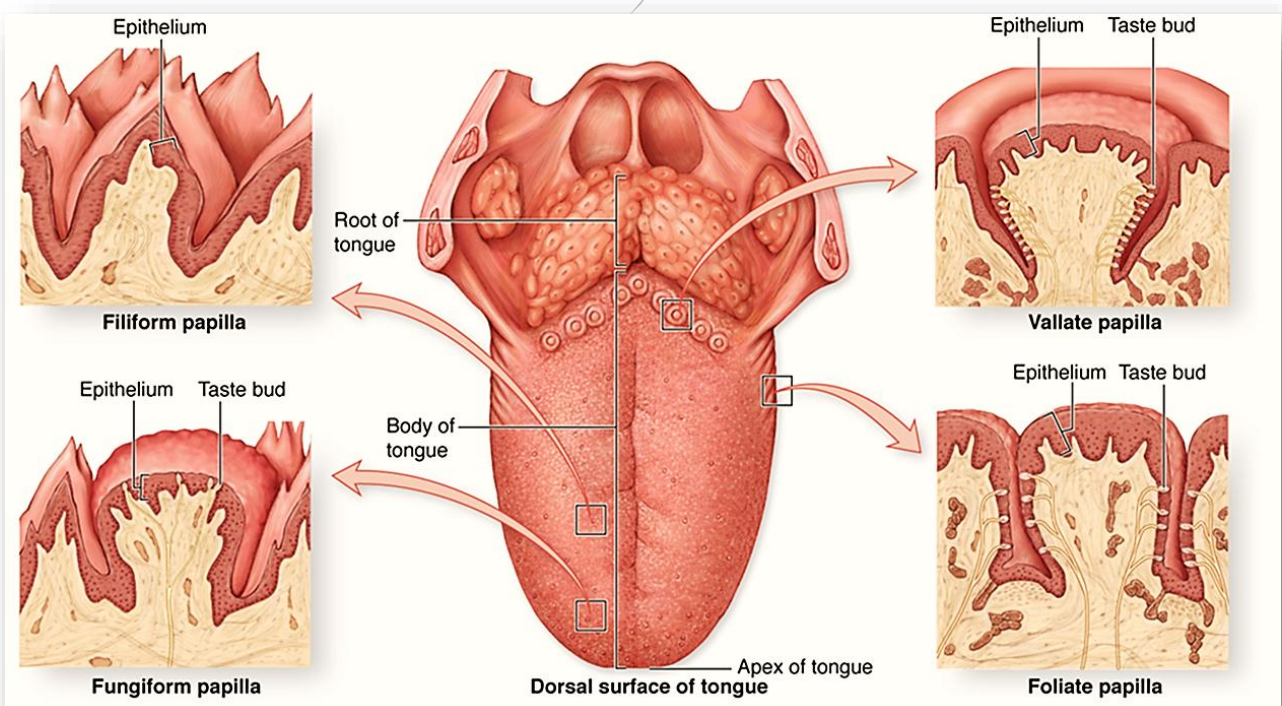
The lingual papillae are elevations of the mucous membrane that assume various forms and functions. There are **four** types:

**1) Filiform papillae** are very numerous, have an elongated conical shape, and are heavily keratinized, which gives their surface a gray or whitish appearance. They provide a rough surface that facilitates movement of food during chewing.

**2) Fungiform papillae** are much less numerous, lightly keratinized, and interspersed among the filiform papillae. They are mushroom-shaped with well vascularized and innervated cores of lamina propria.

**3) Foliate papillae** consist of several parallel ridges on each side of the tongue, anterior to the sulcus terminalis, but are rudimentary in humans, especially older individuals.

**4) Vallate (or circumvallate) papillae** are the largest papillae, with diameters of 1 to 3 mm. Eight to twelve vallate papillae are normally aligned just in front of the terminal sulcus.



## Taste buds

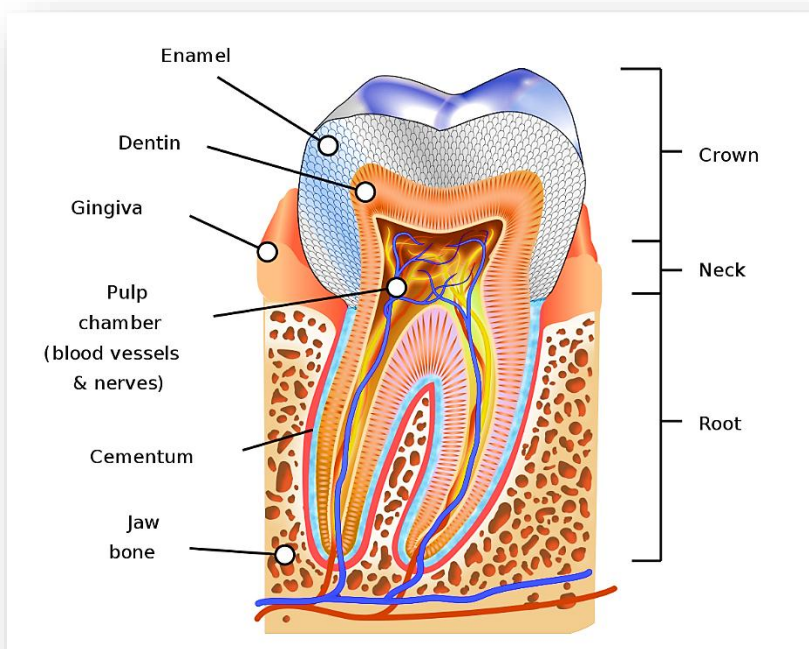
Taste buds are ovoid structures within the stratified epithelium on the tongue's surface, which sample the general chemical composition of ingested material. Approximately 250 taste buds are present on the lateral surface of each vallate papilla, with many others present on fungiform and foliate (but not the keratinized filiform) papillae. They are not restricted to papillae and are also widely scattered elsewhere on the dorsal and lateral surfaces of the tongue, where they are also continuously flushed by numerous minor salivary glands.

Taste buds detect at least five broad categories of tastants: sodium ions (**salty**); hydrogen ions from acids (**sour**); sugars and related compounds (**sweet**); alkaloids and certain toxins (**bitter**); and amino acids such as glutamate and aspartate.

## Teeth

In the adult human there are normally **32** permanent teeth, arranged in two bilaterally symmetric arches in the maxillary and mandibular bones. Each tooth has a **crown** exposed above the gingiva, a constricted **neck** at the gum, and one or more **roots** that fit firmly into bony sockets in the jaws called **dental alveoli**.

The **crown** is covered by very hard, acellular **enamel** and the roots by a bone-like tissue called **cementum**. These two coverings meet at the neck of the tooth. The bulk of a tooth is composed of another calcified material, **dentin**, which surrounds an internal **pulp cavity**. **Dental pulp** is highly vascular and well-innervated and consists largely of loose, mesenchymal connective tissue with much ground substance, thin collagen fibers, fibroblasts, and mesenchymal stem cells. The pulp cavity narrows in each root as the **root canal**, which extends to an opening (apical foramen) at the tip of each root for the blood vessels, lymphatics, and nerves of the pulp cavity. The **periodontal ligaments** are fibrous connective tissue bundles of collagen fibers inserted into both the cementum and the alveolar bone.

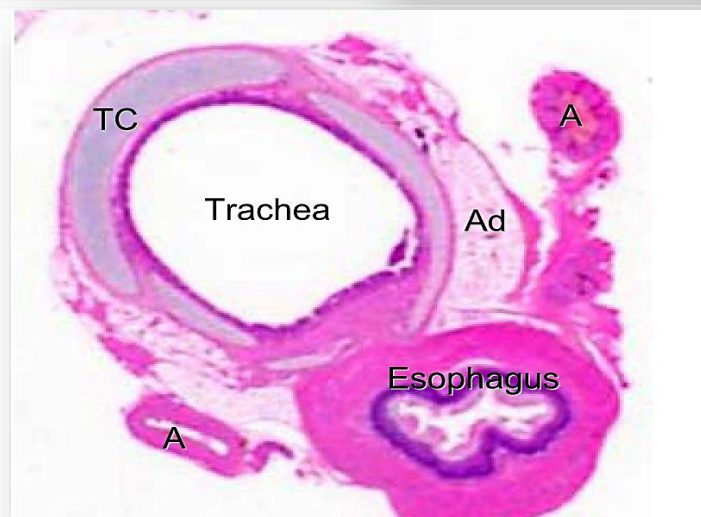
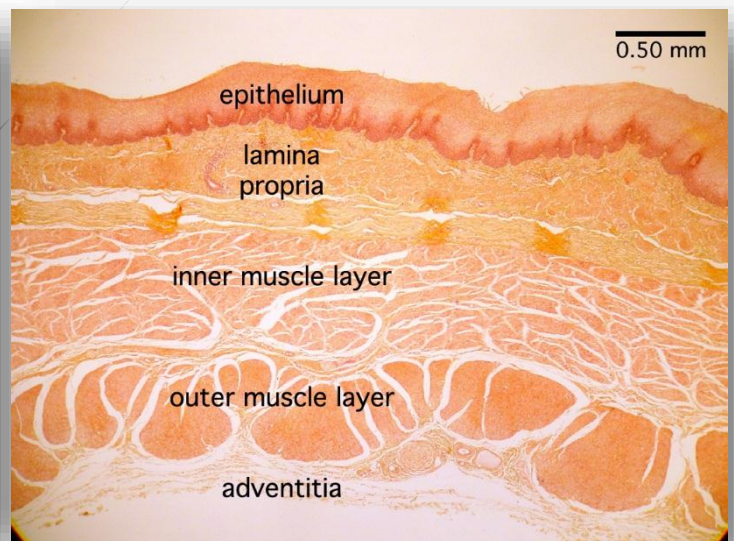
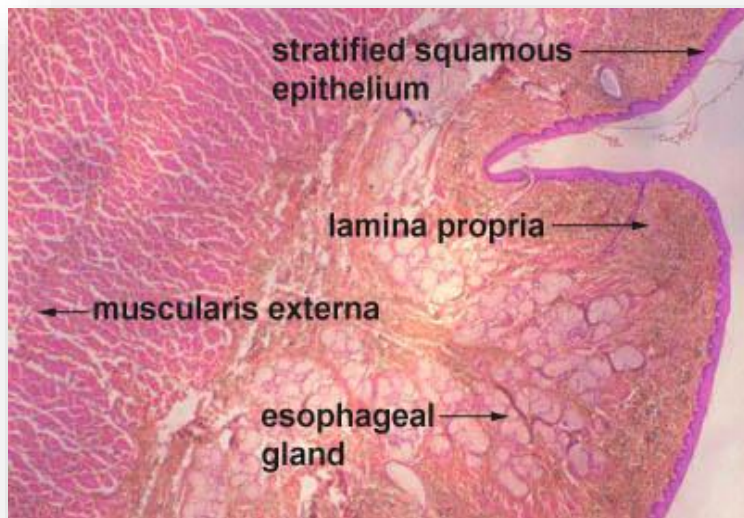




## Esophagus

The **esophagus** is a muscular tube, about 25 cm long in adults, which transports swallowed material from the pharynx to the stomach. The esophageal mucosa has **nonkeratinized stratified squamous epithelium**, and the submucosa contains small mucus-secreting glands, the **esophageal glands**, which lubricate and protect the mucosa. Near the stomach the mucosa also contains groups of glands, the **esophageal cardiac glands**, which secrete additional mucus.

**Swallowing** begins with voluntary muscle action but finishes with involuntary peristalsis. In approximately the upper one-third of the esophagus, the muscularis is exclusively **skeletal muscle** like that of the tongue. The middle portion of the esophagus has a combination of **skeletal and smooth muscle** fibers, and in the lower third the muscularis is exclusively **smooth muscle**. Only the distal 1 to 2 cm of the esophagus, in the peritoneal cavity, is covered by serosa; the rest is enclosed by the loose connective tissue of the adventitia, which blends into the surrounding tissue.



## Stomach

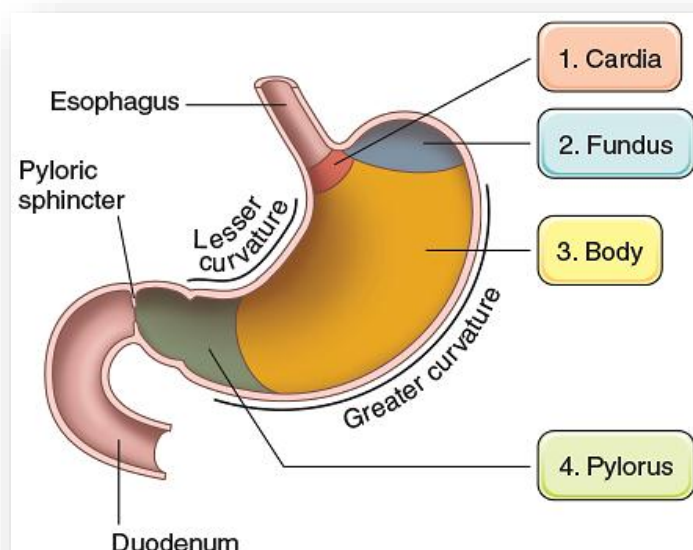
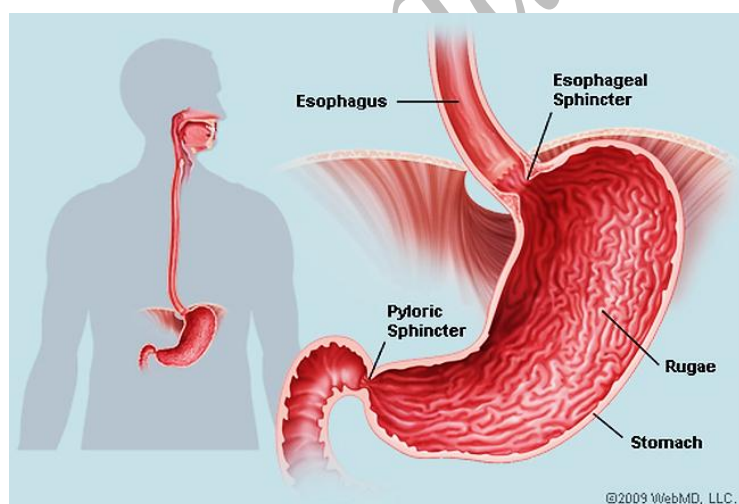
The stomach is a greatly dilated segment of the digestive tract whose **main functions** are:

- To continue the digestion of carbohydrates initiated by the **amylase** of saliva.
- To add an acidic fluid to the ingested food and mixing its contents into a viscous mass called **chyme** by the churning activity of the muscularis.
- To begin digestion of triglycerides by a secreted **lipase**.
- To promote the initial digestion of proteins with the enzyme **pepsin**.

Four major regions make up the stomach: the **cardia**, **fundus**, **body**, and **pylorus**:

- The **cardia** is a narrow transitional zone, 1.5-3 cm wide, between the esophagus and the stomach.
- The **pylorus** is the funnel-shaped region that opens into the small intestine. Both these regions are primarily involved with mucus production and are similar histologically.
- The much larger **fundus** and **body** regions are identical in microscopic structure and are the sites of gastric glands releasing acidic gastric juice.

The mucosa and submucosa of the empty stomach have large, longitudinally directed folds called **rugae**, which flatten when the stomach fills with food. The wall in all regions of the stomach is made up of all four major layers.



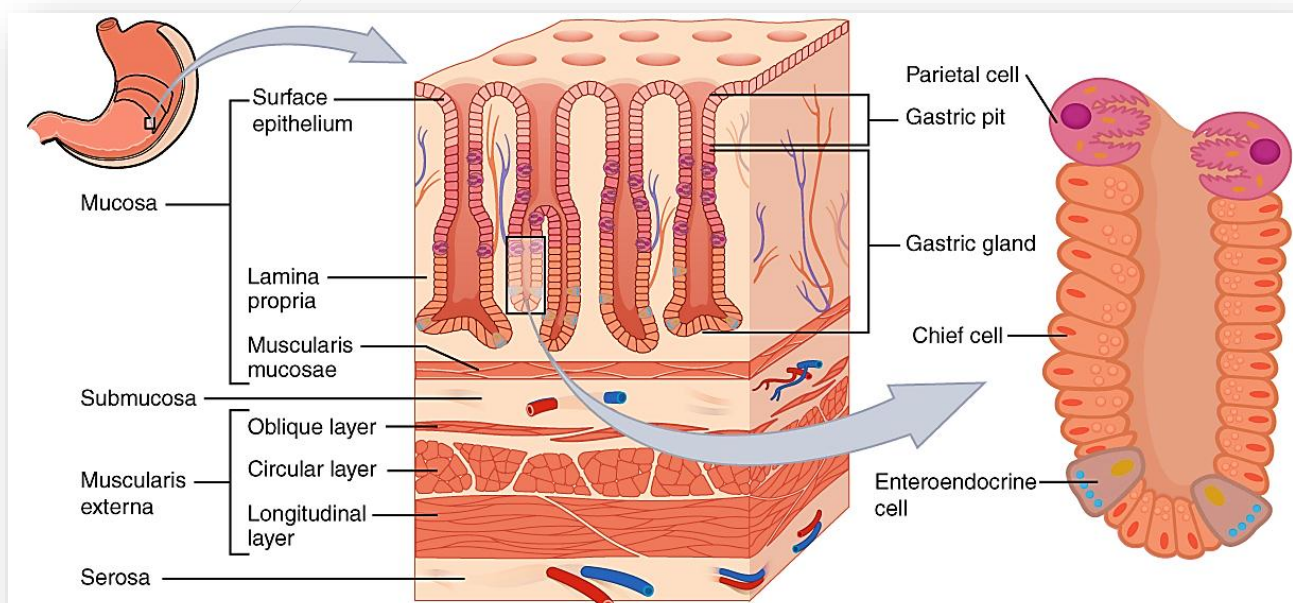


The mucosal surface of the stomach is a **simple columnar epithelium** that invaginates deeply into the lamina propria. The invaginations form millions of **gastric pits**, each with an opening to the stomach lumen. The surface mucous cells that line the lumen and gastric pits secrete a thick, adherent, and highly viscous mucous layer that is rich in bicarbonate ions and protects the mucosa from both abrasive effects of intraluminal food and the corrosive effects of stomach acid.

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:

- 1) **Mucous neck cells** include immature precursors of the surface mucous cells but produce less **alkaline mucus** while migrating up into the gastric pits.
- 2) **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** uptake.
- 3) **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**.
- 4) **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 cardiac and pyloric glands that consist almost entirely of columnar mucous cells, lacking parietal and chief cells.



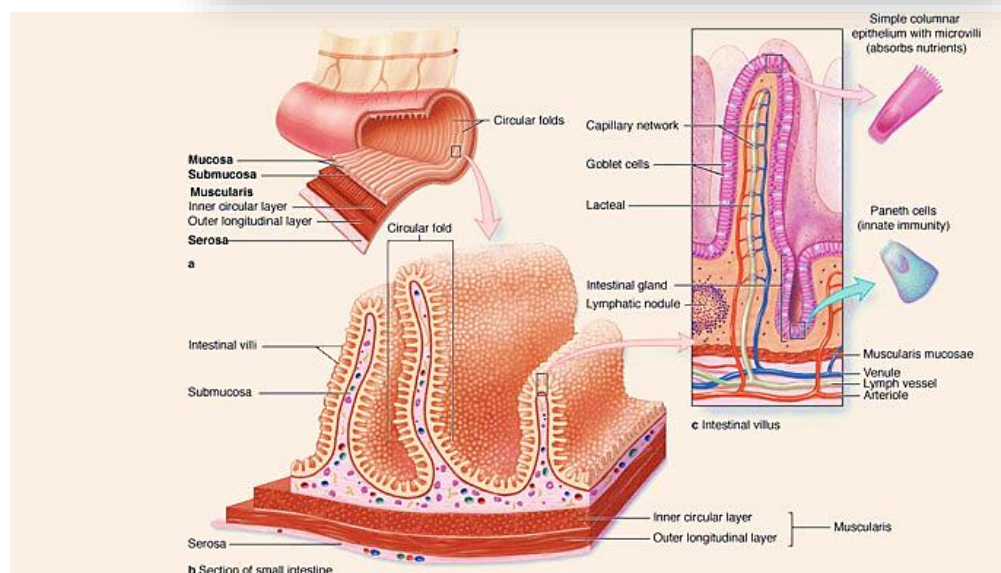
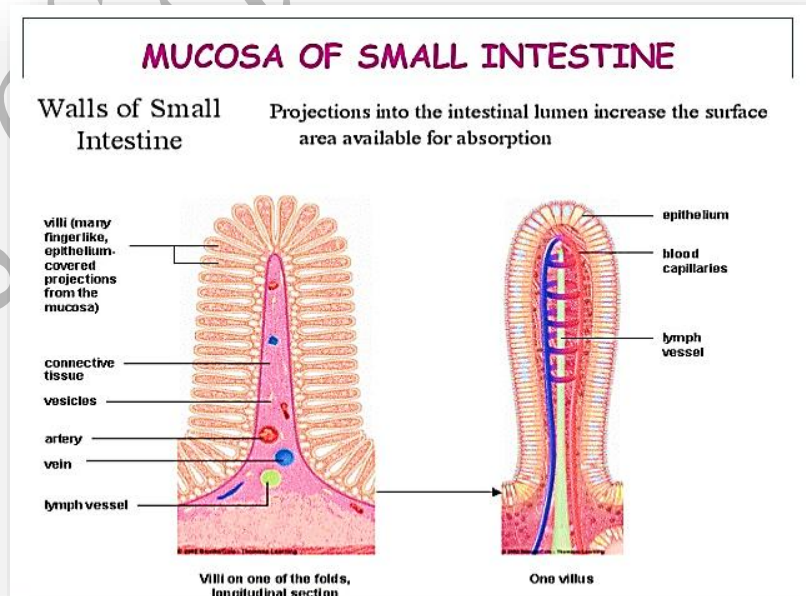
## Small intestine

The small intestine is approximately **7 m** long and has **three** regions: the **duodenum** (proximal), **jejunum** (middle), and **ileum** (distal).

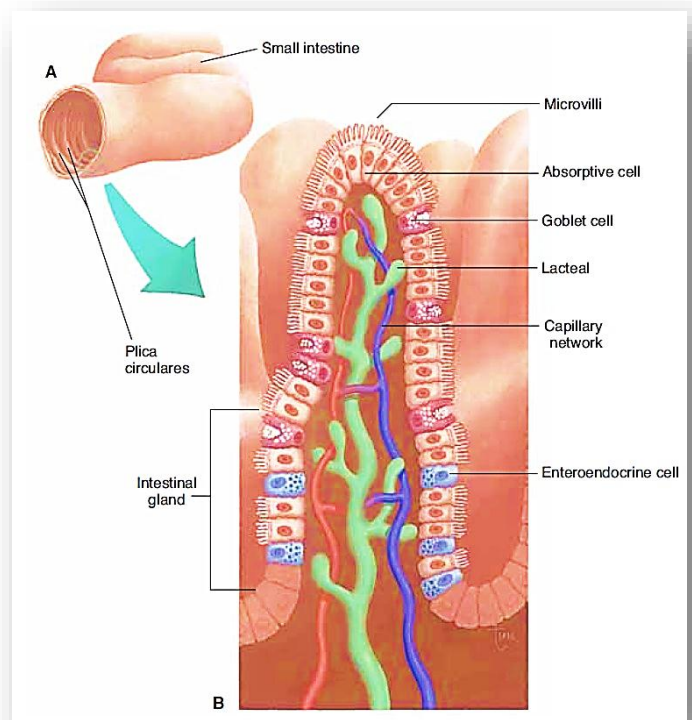
**Function:** The small intestine secretes several **hormones**; it continues and largely completes the digestion of foodstuffs and absorbs the resulting metabolites.

The lining of the small intestine shows a series of permanent circular or semilunar folds (**plicae circulares**), consisting of mucosa and submucosa, which are best developed in the jejunum. Densely covering the entire mucosa of the small intestine are short (0.5 to 1.5-mm) mucosal outgrowths called **villi** that project into the lumen. These finger- or leaflike projections are covered by a **simple columnar epithelium** of absorptive cells called enterocytes, with many interspersed goblet cells. Each villus has a core of **loose connective tissue** that extends from the lamina propria and contains fibroblasts, smooth muscle fibers, lymphocytes and plasma cells, fenestrated capillaries, and a central lymphatic called a **lacteal**.

Between the villi are the openings of short tubular glands called **intestinal glands** or **crypts** (or **crypts of Lieberkühn**) and the epithelium of each villus is continuous with that of the intervening glands. The epithelium of the intestinal glands includes differentiating cells and pluripotent stem cells for all the **cell types** of the **small intestine** include the following:

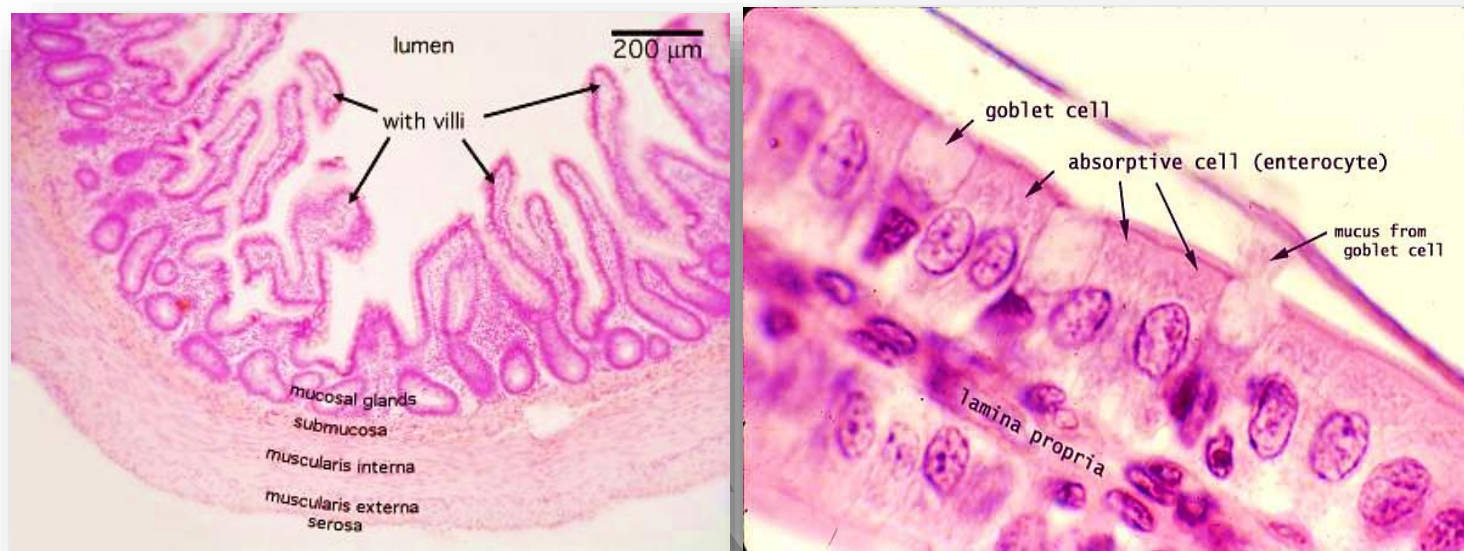


- 1) **Enterocytes**, the absorptive cells, are tall columnar cells, each with an oval nucleus located basally:
  - The apical end of each enterocyte displays a prominent ordered region called the **striated (or brush) border** is seen to be a layer of densely packed **microvilli**.
  - Each enterocyte has an average of 3000 microvilli.
  - Microvilli, villi, and the plicae circulares all greatly increase the mucosal surface area in contact with nutrients in the lumen, which is an important feature in an organ specialized for nutrient absorption.
  
- 2) **Goblet cells** are interspersed among the absorptive enterocytes. They secrete glycoprotein **mucins** that are then hydrated to form mucus, whose main :
  - **Function** is to protect and lubricate the lining of the intestine.
  
- 3) **Paneth cells**, located in the basal portion of the intestinal crypts below the stem cells, are exocrine cells with large, eosinophilic secretory granules in their apical cytoplasm. Paneth cell granules release **lysozyme**, **phospholipase A2**, and hydrophobic peptides called **defensins**, all of which bind and break down membranes of microorganisms and bacterial cell walls.
  - **Function:** paneth cells have an important role in innate immunity and in regulating the microenvironment of the intestinal crypts.
  
- 4) **Enteroendocrine cells** are present in varying numbers throughout the length of the small intestine, secreting various **peptide hormones**. Many of these are of the “open” type, in which the constricted apical end of the cell contacts the intestinal lumen and has chemoreceptors similar to those of taste buds, sampling levels of certain nutrients such as **sugars** to regulate hormone release basally.





- 5) **M (microfold) cells** are specialized epithelial cells in the mucosa of the ileum overlying the lymphoid follicles of **Peyer patches**. M cells selectively endocytose antigens and transport them to the underlying lymphocytes and dendritic cells, which then migrate to lymph nodes for an appropriate immune response.



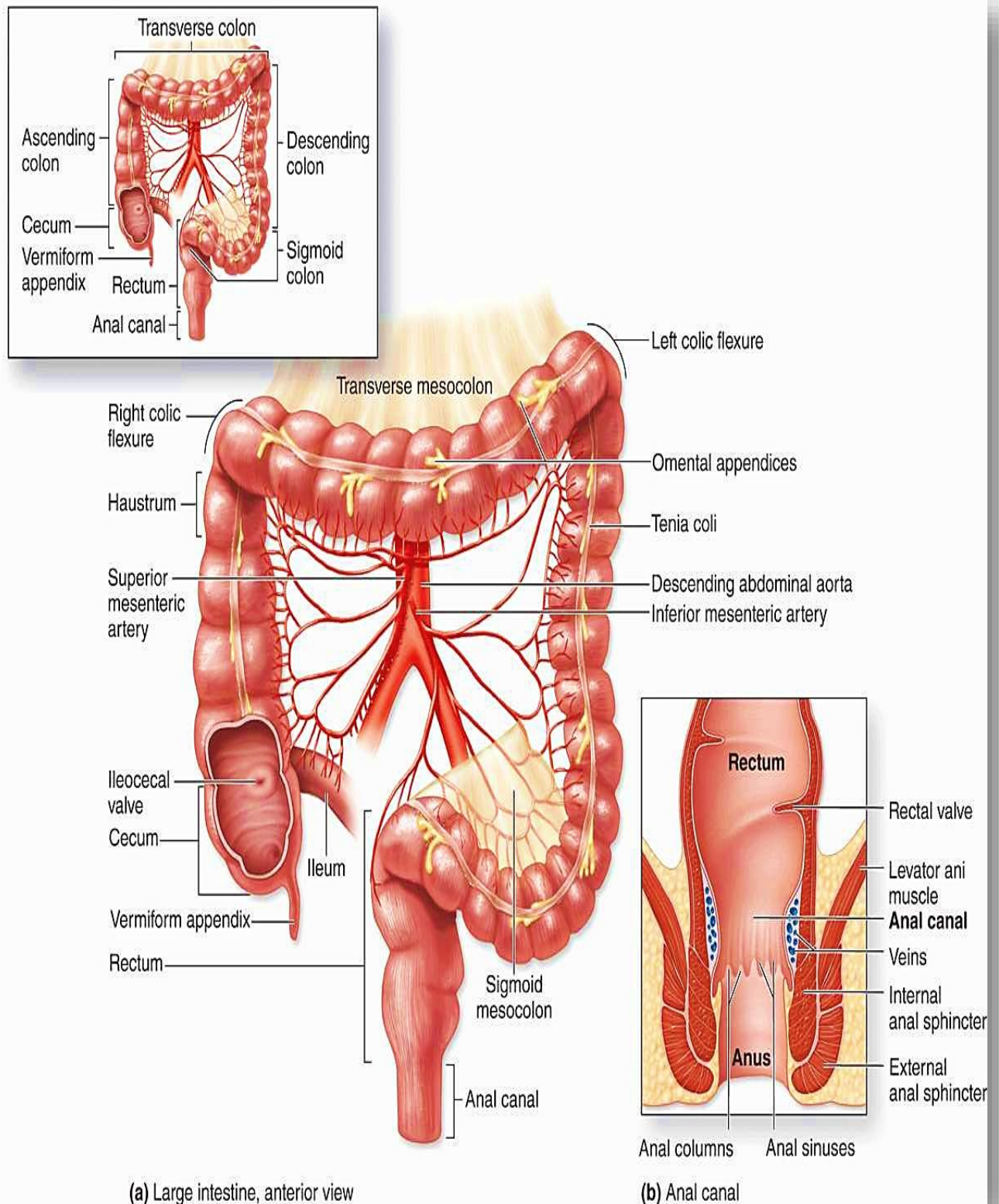
## *Large intestine*

The large intestine consists of the **cecum**, **colon** (ascending, transverse, descending, and sigmoid colon), **rectum**, anal **canal**, and **appendix**. The large intestine contains some digestive enzymes received from the small intestine. It houses bacteria that produce **vitamin B<sub>12</sub>** and **vitamin K**; the former is necessary for **hemopoiesis** and the latter for coagulation. The large intestine produces abundant mucus, which lubricates its lining and facilitates the passage and elimination of feces.

**Function:** The large intestine functions primarily in the **absorption** of **electrolytes**, **fluids** and **gases**. Dead bacteria and indigestible remnants of the ingested material are compacted into feces.

The mucosa lacks villi and except in the rectum has no major folds. Less than one-third as long as the small intestine, the large intestine has a greater diameter (6-7 cm). The wall of the colon is puckered into a series of large sacs called **haustra**. The mucosa of the large bowel is penetrated throughout its length by tubular intestinal glands. These and the intestinal lumen are lined by **goblet** and **absorptive cells**, with a small number of **enteroendocrine cells**. The columnar

absorptive cells or **colonocytes** have irregular microvilli and dilated intercellular spaces indicating active fluid absorption. Goblet cells producing lubricating mucus become more numerous along the length of the colon and in the rectum.





The distal end of the digestive tract is the **anal canal**, 3-4 cm long. At the rectoanal junction the simple columnar mucosal lining of the rectum is replaced by **stratified squamous epithelium**. The mucosa and submucosa of the anal canal form several longitudinal folds, the **anal columns**, in which the lamina propria and submucosa include sinuses of the rectal venous plexus. Near the anus the circular layer of the rectum's muscularis forms the **internal anal sphincter**. Defecation involves the action of voluntary muscle comprising the **external anal sphincter**.

