# HUMAN ANATOMY

## THE DIGESTIVE SYSTEM

AYDIN ÇÖL

## Digestive System Functions

The digestive system performs six basic processes:

**1. Ingestion**.

This process involves taking foods and liquids into the mouth (eating).

**2. Secretion**.

Each day, cells within the walls of the GI tract and accessory digestive organs secrete a total of about 7 liters of water, acid, buffers, and enzymes into the lumen (interior space) of the tract.

**3. Mixing and propulsion**.

Alternating contractions and relaxations of smooth muscle in the walls of the GI tract mix food and secretions and move them toward the anus. This capability of the GI tract to mix and move material along its length is called motility

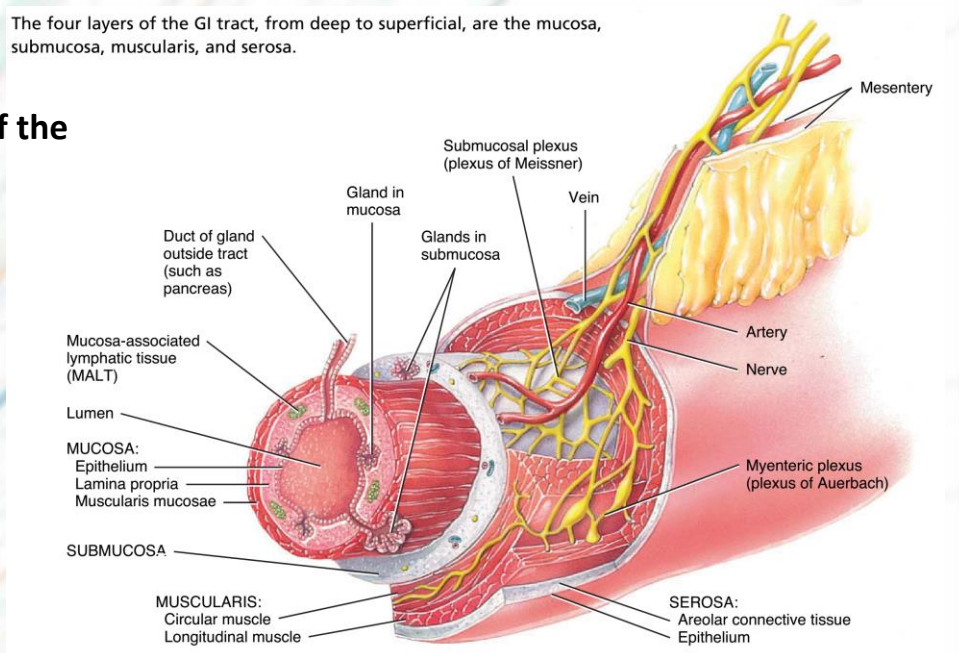
# Digestive System Functions

**4. Digestion**.
Mechanical and chemical processes break down ingested food into small molecules.
In mechanical digestion the teeth cut and grind food before it is swallowed, and then smooth muscles of the stomach and small intestine churn the food to further assist the process.
As a result, food molecules become dissolved and thoroughly mixed with digestive enzymes.
In chemical digestion the large carbohydrate, lipid, protein, and nucleic acid molecules in food are split into smaller molecules by hydrolysis.
Digestive enzymes produced by the salivary glands, tongue, stomach, pancreas, and small intestine catalyze these catabolic reactions.
A few substances in food can be absorbed without chemical digestion.
These include vitamins, ions, cholesterol, and water.

# Digestive System Functions

**5. Absorption**.
The entrance of ingested and secreted fluids, ions, and the products of digestion into the epithelial cells lining the lumen of the GI tract is called absorption.
The absorbed substances pass into blood or lymph and circulate to cells throughout the body.
**6. Defecation**.
Wastes, indigestible substances, bacteria, cells sloughed from the lining of the GI tract, and digested materials that were not absorbed in their journey through the digestive tract leave the body through the anus in a process called defecation.
The eliminated material is termed feces or stool.

## Layers of the GI Tract




## Neural Innervation of the GI Tract

**Enteric Nervous System**

It consists of about **100 million neurons** that extend from the esophagus to the anus.

The neurons of the ENS are arranged into two plexuses:

the **myenteric** plexus and

**submucosal** plexus

The myenteric plexus(myo-muscle), or plexus of Auerbach, is located **between** the **longitudinal** and **circular** smooth **muscle** layers of the muscularis.

The submucosal plexus, or plexus of Meissner, is found within the submucosa.

The **plexuses** of the ENS consist of **motor** neurons, **interneurons**, and **sensory** neurons.

Autonomic Nervous System

Gastrointestinal Reflex Pathways

## Neural Innervation of the GI Tract

**Autonomic Nervous System**

Although the neurons of the ENS can function independently, they are subject to regulation by the neurons of the autonomic nervous system.

The **vagus** (X) nerves supply **parasympathetic** fibers to most parts of the **GI tract**, with the exception of the **last half** of the large intestine, which is supplied with parasympathetic fibers from the **sacral spinal cord**.

The parasympathetic nerves that supply the GI tract form neural connections with the ENS.

**Emotions** such as anger, fear, and anxiety may **slow** digestion because they **stimulate** the **sympathetic** nerves that supply the GI tract.

**Gastrointestinal Reflex Pathways**

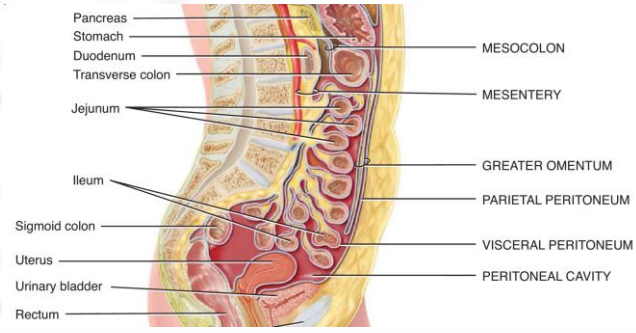
Many neurons of the ENS are components of GI (gastrointestinal) reflex pathways that regulate GI secretion and motility in response to stimuli present in the lumen of the GI tract.

## Peritoneum

The peritoneum (peri-around) is the **largest** serous **membrane** of the body; it consists of a layer of simple squamous epithelium (**mesothelium**) with an underlying supporting layer of **areolar connective** tissue.

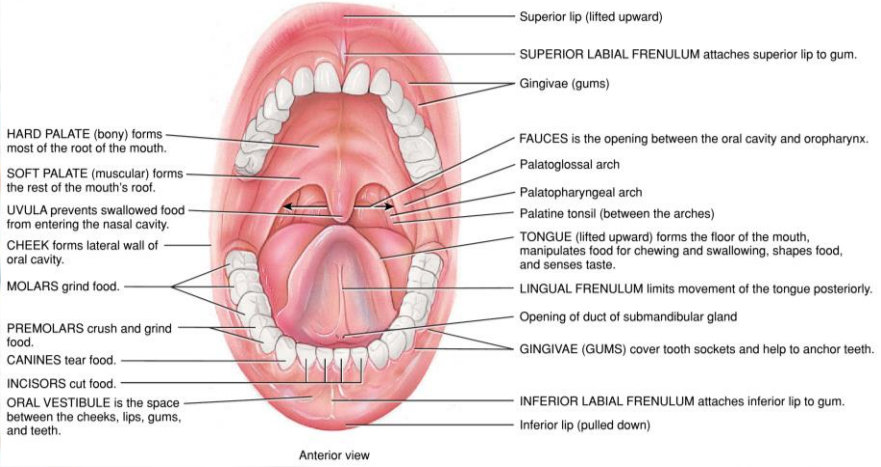
The peritoneum is divided into the **parietal peritoneum**, which lines the wall of the abdominal cavity, and the **visceral peritoneum**, which covers some of the organs in the cavity and is their serosa.

The slim space containing **lubricating serous fluid** that is between the parietal and visceral portions of the peritoneum is called the **peritoneal cavity**.



## Mouth

The mouth, also referred to as the **oral** or buccal **cavity** is formed by the **cheeks**, **hard** and **soft palates**, and **tongue**.



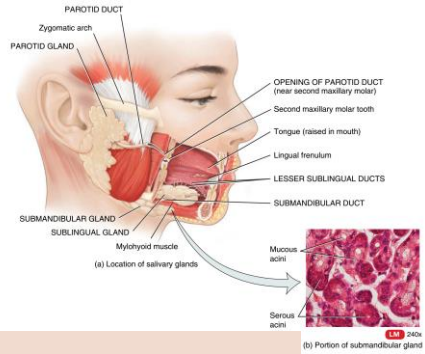

## Salivary Glands

A salivary gland is a gland that releases a secretion called saliva into the oral cavity.
Ordinarily, just enough saliva is secreted to keep the mucous membranes of the mouth and pharynx moist and to **cleanse** the **mouth** and **teeth**.
When food enters the mouth, however, secretion of saliva increases, and it lubricates, dissolves, and begins the chemical breakdown of the food.
Most saliva is secreted by the **major salivary glands**, which lie beyond the oral mucosa, into ducts that lead to the oral cavity.
There are **three pairs** of major salivary **glands**:
the **parotid**, **submandibular**, and **sublingual** glands
Chemically, saliva is 99.5% **water** and 0.5% solutes.
Among the solutes are **ions**, including **sodium**, **potassium**, **chloride**, **bicarbonate**, and **phosphate**. Also present are some dissolved gases and various organic substances, including **urea** and **uric acid**, **mucus**, **immunoglobulin A**, the bacteriolytic enzyme **lysozyme**, and salivary **amylase**, a digestive enzyme that acts on starch.

**Mouth**
- Tongue
- Teeth

**Pharynx**

**Esophagus**




**Summary of Digestive Activities in the Mouth**

| STRUCTURE | ACTIVITY | RESULT |
|---|---|---|
| **Cheeks and lips** | Keep food between teeth. | Foods uniformly chewed during mastication. |
| **Salivary glands** | Secrete saliva. | Lining of mouth and pharynx moistened and lubricated. Saliva softens, moistens, and dissolves food and cleanses mouth and teeth. Salivary amylase splits starch into smaller fragments (maltose, maltotriose, and $\alpha$-dextrins). |
| **Tongue** | | |
| **Extrinsic tongue muscles** | Move tongue from side to side and in and out. | Food maneuvered for mastication, shaped into bolus, and maneuvered for swallowing. |
| **Intrinsic tongue muscles** | Alter shape of tongue. | Swallowing and speech. |
| **Taste buds** | Serve as receptors for gustation (taste) and presence of food in mouth. | Secretion of saliva stimulated by nerve impulses from taste buds to salivatory nuclei in brain stem to salivary glands. |
| **Lingual glands** | Secrete lingual lipase. | Triglycerides broken down into fatty acids and diglycerides. |
| **Teeth** | Cut, tear, and pulverize food. | Solid foods reduced to smaller particles for swallowing. |

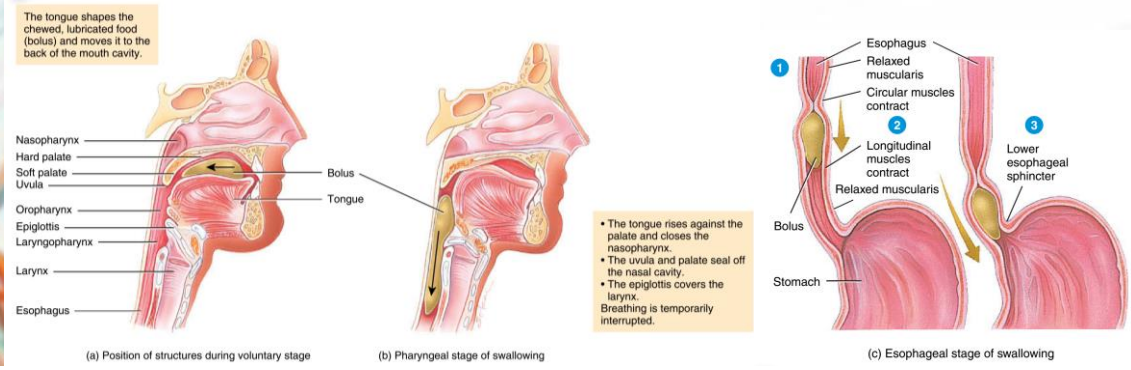
## Deglutition (swallowing)

Deglutition is facilitated by the secretion of saliva and mucus and involves the mouth, pharynx, and esophagus. Deglutition is a mechanism that moves food from the mouth into the stomach. Swallowing occurs in three stages:

(1) the **voluntary stage**, in which the bolus is passed into the oropharynx;

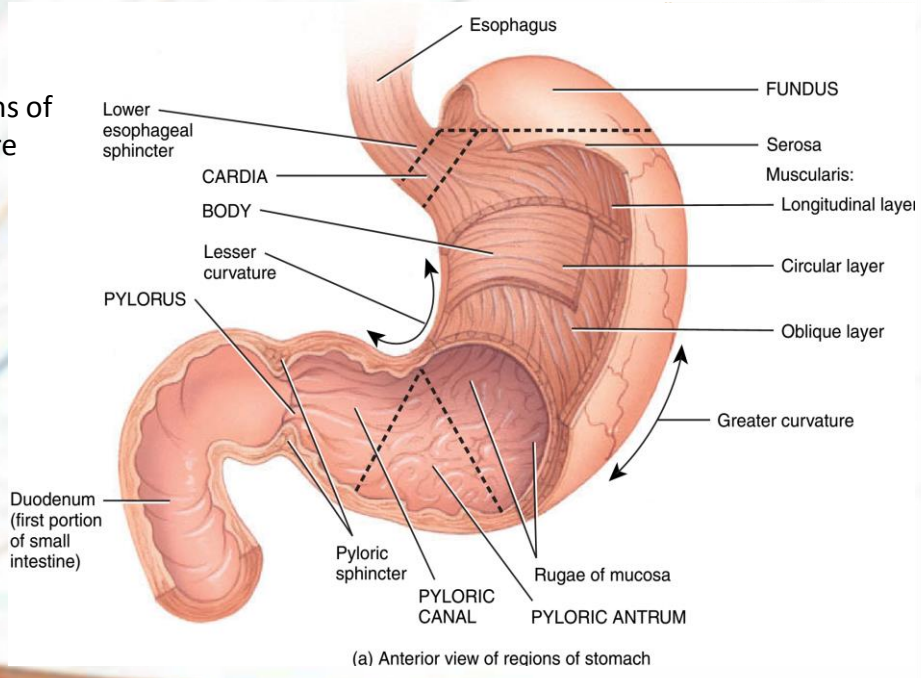
(2) the **pharyngeal stage**, the involuntary passage of the bolus through the pharynx into the esophagus; and

(3) the **esophageal stage**, the involuntary passage of the bolus through the esophagus into the stomach via peristalsis.

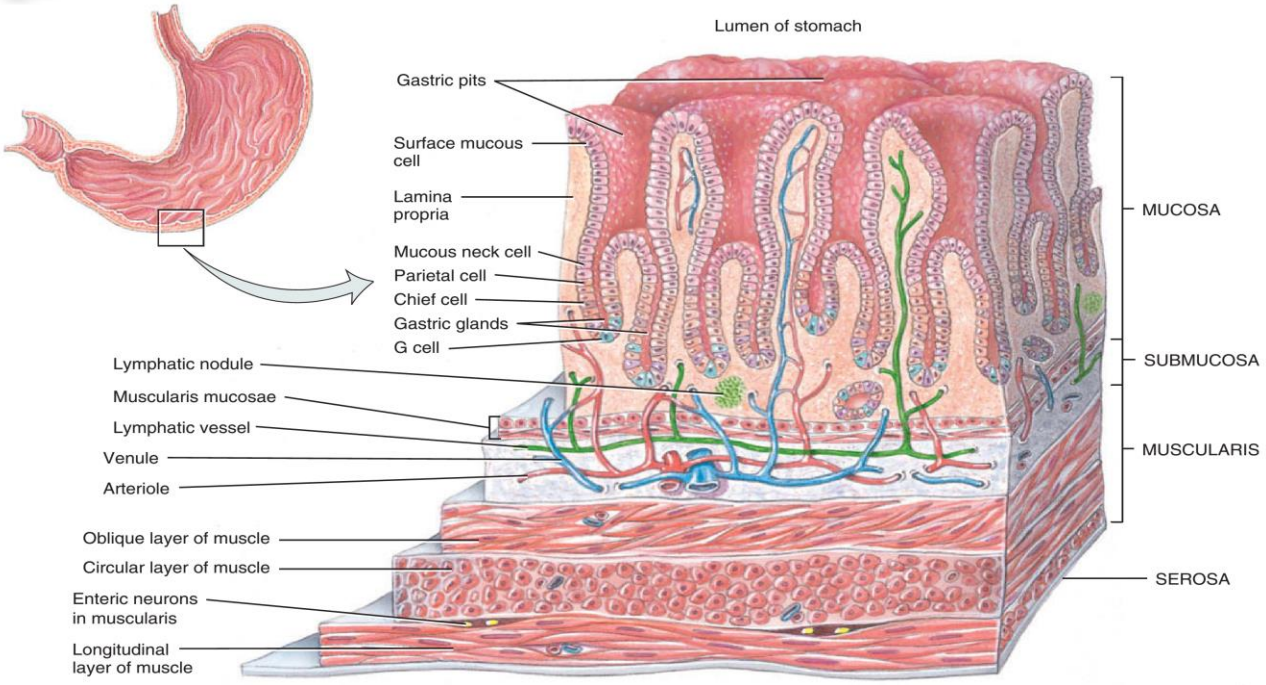


## Stomach

The four regions of the stomach are the **cardia**, **fundus**, **body**, and **pyloric** part.




Gastric juice is the combined secretions of mucous cells, parietal cells, and chief cells.



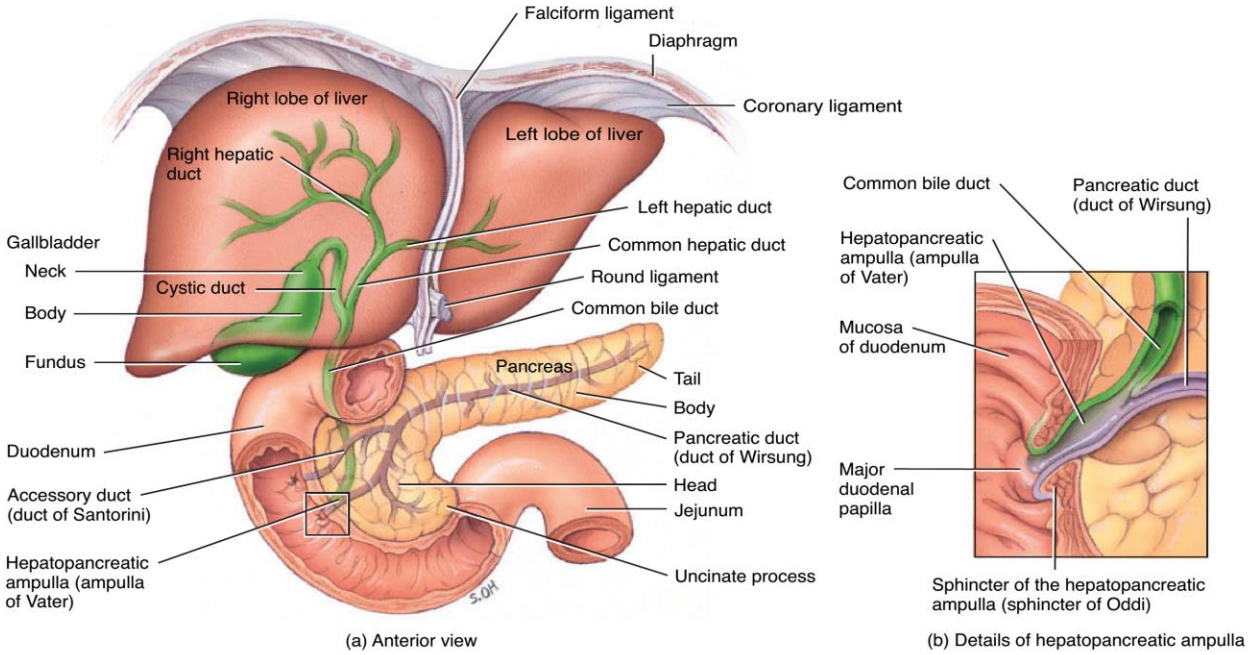
## Pancreas

Each day the pancreas produces 1200–1500 mL of pancreatic juice, a clear, colorless liquid consisting mostly of **water**, some **salts**, **sodium bicarbonate**, and several **enzymes**.

The sodium bicarbonate gives pancreatic juice a slightly alkaline pH (7.1–8.2) that buffers acidic gastric juice in **chyme**, **stops** the action of **pepsin** from the stomach, and **creates** the proper **pH** for the action of digestive enzymes in the **small intestine**.

The enzymes in pancreatic juice include a starch-digesting enzyme called pancreatic **amylase**; several enzymes that digest proteins into peptides called **trypsin**, **chymotrypsin**, **carboxypeptidase**, and **elastase**; the principal triglyceride–digesting enzyme in adults, called pancreatic **lipase**; and nucleic acid–digesting enzymes called **ribonuclease** and **deoxyribonuclease** that digest ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) into nucleotides.

Pancreatic enzymes digest starches (polysaccharides), proteins, triglycerides, and nucleic acids.

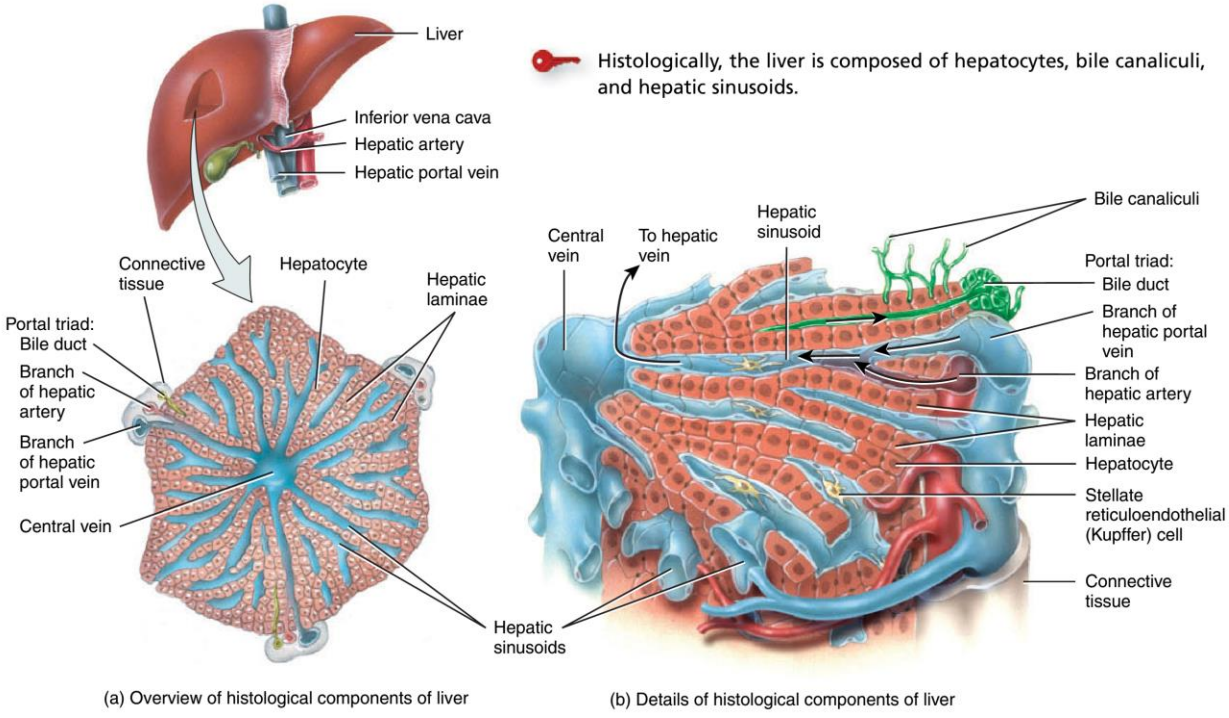


## Liver and Gallbladder

The liver is the heaviest gland of the body, weighing about 1.4 kg in an average adult.
Of all of the organs of the body, it is second only to the skin in size.
The liver is inferior to the diaphragm and occupies most of the right hypochondriac and part of the epigastric regions of the abdominopelvic cavity.
The liver is divided into two principal lobes—a **large right lobe** and a **smaller left lobe**—by the falciform ligament, a fold of the mesentery.
The **gallbladder** (gall-bile) is a pear-shaped sac that is located in a depression of the posterior surface of the liver.
It is 7–10 cm long and typically hangs from the anterior inferior margin of the liver.
The parts of the gallbladder include the broad fundus, which projects inferiorly beyond the inferior border of the liver; the body, the central portion; and the neck, the tapered portion.
The body and neck project superiorly.

## Liver and Gallbladder

Each day, hepatocytes secrete 800–1000 mL of **bile**, a yellow, brownish, or olive-green liquid.
It has a pH of 7.6–8.6 and consists mostly of **water**, **bile salts**, **cholesterol**, a phospholipid called **lecithin**, bile **pigments**, and several **ions**.
The principal bile pigment is **bilirubin**.
The phagocytosis of aged red blood cells liberates **iron**, **globin**, and **bilirubin**.
The iron and globin are recycled; the bilirubin is secreted into the bile and is eventually broken down in the intestine.
One of its breakdown products—**stercobilin**—gives feces their normal brown color.
**Bile salts**, which are sodium salts and potassium salts of bile acids (mostly chenodeoxycholic acid and cholic acid), play a role in emulsification, the breakdown of large lipid globules into a suspension of small lipid globules.
The small lipid globules present a very large surface area that allows pancreatic lipase to more rapidly accomplish digestion of triglycerides. Bile salts also aid in the absorption of lipids following their digestion.




## Liver and Gallbladder

Liver performs many other vital functions:

- **Carbohydrate metabolism.**

The liver is especially important in maintaining a normal blood glucose level.

When blood glucose is low, the liver can break down glycogen to glucose and release the glucose into the bloodstream.

The liver can also convert certain amino acids and lactic acid to glucose, and it can convert other sugars, such as fructose and galactose, into glucose.

When blood glucose is high, as occurs just after eating a meal, the liver converts glucose to glycogen and triglycerides for storage.

- **Lipid metabolism.**

Hepatocytes store some triglycerides; break down fatty acids to generate ATP; synthesize lipoproteins, which transport fatty acids, triglycerides, and cholesterol to and from body cells; synthesize cholesterol; and use cholesterol to make bile salts.

Liver performs many other vital functions:

- **Protein metabolism**.

Hepatocytes deaminate (remove the amino group, NH2, from) amino acids so that the amino acids can be used for ATP production or converted to carbohydrates or fats.
The resulting toxic ammonia (NH3) is then converted into the much less toxic urea, which is excreted in urine.
Hepatocytes also synthesize most plasma proteins, such as alpha and beta globulins, albumin, prothrombin, and fibrinogen.

- **Processing of drugs and hormones.**

The liver can detoxify substances such as alcohol and excrete drugs such as penicillin, erythromycin, and sulfonamides into bile.
It can also chemically alter or excrete thyroid hormones and steroid hormones such as estrogens and aldosterone.

Liver performs many other vital functions:

- **Excretion of bilirubin.**

As previously noted, bilirubin, derived from the heme of aged red blood cells, is absorbed by the liver from the blood and secreted into bile.
Most of the bilirubin in bile is metabolized in the small intestine by bacteria and eliminated in feces.

- **Synthesis of bile salts.**

Bile salts are used in the small intestine for the emulsification and absorption of lipids.

- **Storage.**

In addition to glycogen, the liver is a prime storage site for certain vitamins (A, B12, D, E, and K) and minerals (iron and copper), which are released from the liver when needed elsewhere in the body.

- **Phagocytosis.**

The stellate reticuloendothelial (Kupffer) cells of the liver phagocytize aged red blood cells, white blood cells, and some bacteria.

- **Activation of vitamin D.**

The skin, liver, and kidneys participate in synthesizing the active form of vitamin D.

## Small Intestine

Most digestion and absorption of nutrients occur in a long tube called the small intestine. Its length alone provides a large surface area for digestion and absorption, and that area is further increased by circular folds, villi, and microvilli.

It averages 2.5 cm in diameter; its length is about 3 m.

The small intestine is divided into three regions.

The first part of the small intestine is the **duodenum**, the shortest region, and is retroperitoneal.

It starts at the pyloric sphincter of the stomach and is in the form of a C-shaped tube that extends about 25 cm until it merges with the jejunum.

Duodenum means “12”; it is so named because it is about as long as the width of 12 fingers.

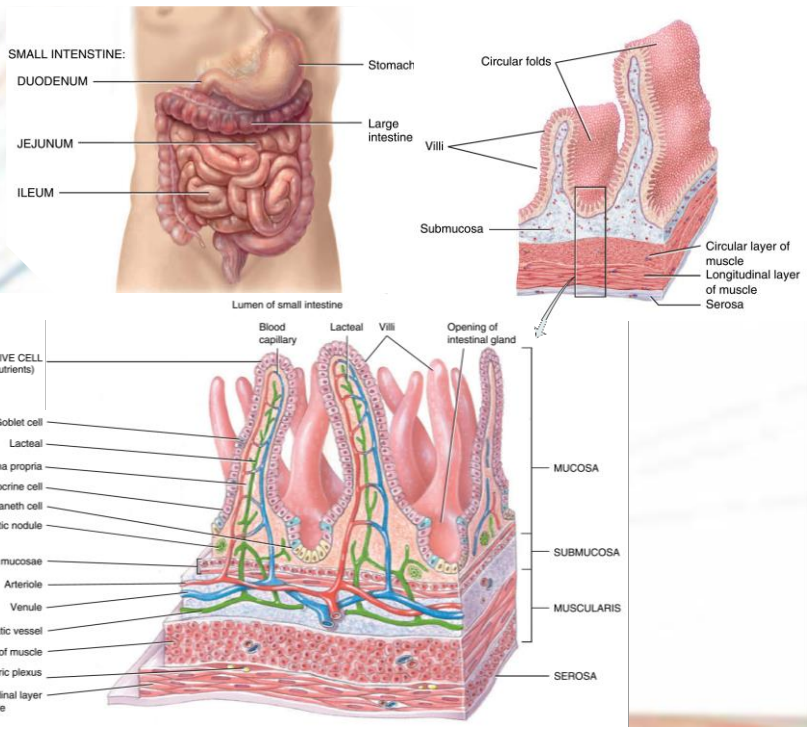
The **jejunum** is the next portion and is about 1 m long and extends to the ileum. Jejunum means “empty,” which is how it is found at death.

The final and longest region of the small intestine, the **ileum**, measures about 2 m and joins the large intestine at a smooth muscle sphincter called the ileocecal sphincter (valve).

Most **digestion** and **absorption** occur in the small intestine.

Circular folds, **villi**, and **microvilli** increase the surface area of the small intestine for digestion and absorption.

There are an estimated 200 million microvilli per square millimeter of small intestine.



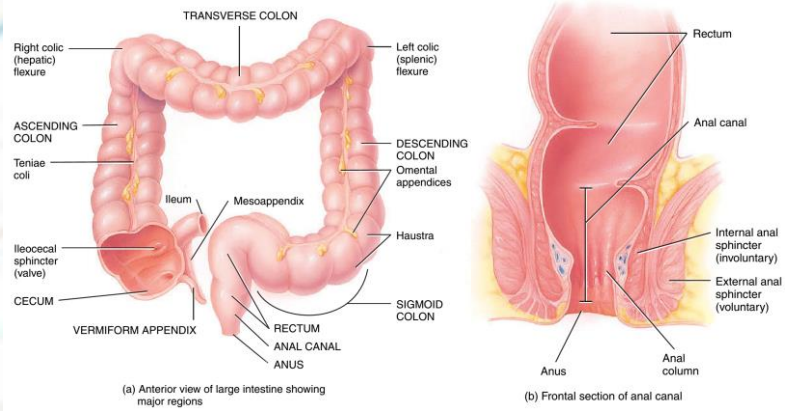
## Large Intestine

The large intestine is the terminal portion of the GI tract.

The overall functions of the large intestine are the completion of absorption, the production of certain vitamins, the formation of feces, and the expulsion of feces from the body.

The large intestine, which is about 1.5 m long and 6.5 cm in diameter.

The regions of the large intestine are the cecum, colon, rectum, and anal canal.

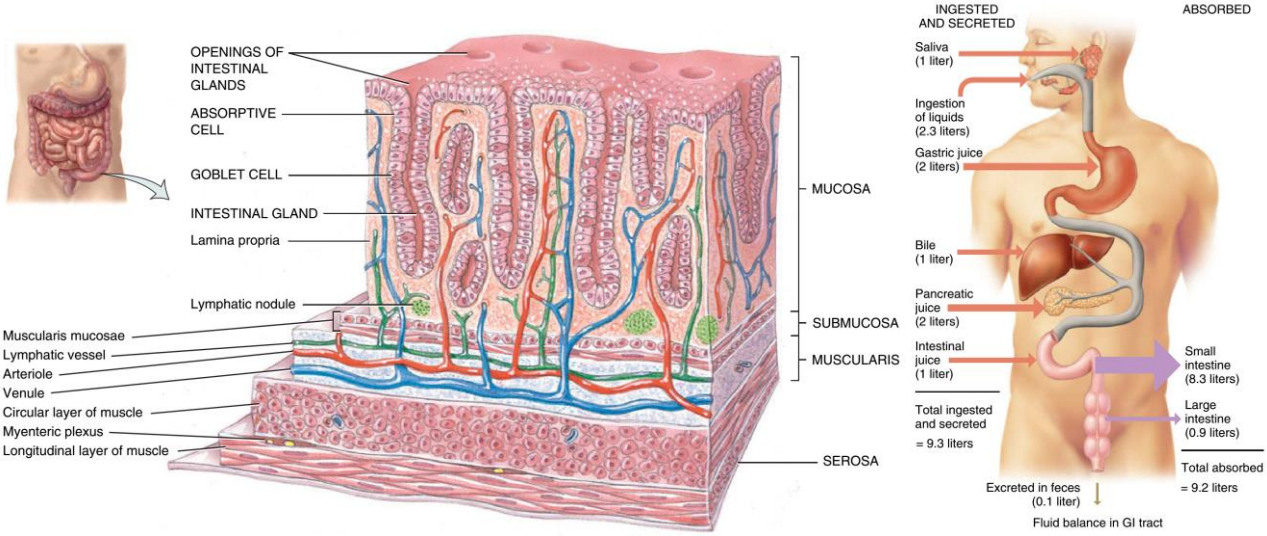



## Large Intestine

The final stage of digestion occurs in the colon through the activity of bacteria that inhabit the lumen.

Mucus is secreted by the glands of the large intestine, but no enzymes are secreted.

Chyme is prepared for elimination by the action of bacteria, which ferment any remaining carbohydrates and remaining proteins and release hydrogen, carbon dioxide, and methane gases.



## Summary of Organs of the Digestive System and Their Functions

| ORGAN | FUNCTION(S) |
|---|---|
| **Tongue** | Maneuvers food for mastication, shapes food into a bolus, maneuvers food for deglutition, detects sensations for taste, and initiates digestion of triglycerides. |
| **Salivary glands** | Saliva produced by these glands softens, moistens, and dissolves foods; cleanses mouth and teeth; initiates the digestion of starch. |
| **Teeth** | Cut, tear, and pulverize food to reduce solids to smaller particles for swallowing. |
| **Pancreas** | Pancreatic juice buffers acidic gastric juice in chyme, stops the action of pepsin from the stomach, creates the proper pH for digestion in the small intestine, and participates in the digestion of carbohydrates, proteins, triglycerides, and nucleic acids. |
| **Liver** | Produces bile, which is required for the emulsification and absorption of lipids in the small intestine. |
| **Gallbladder** | Stores and concentrates bile and releases it into the small intestine. |
| **Mouth** | See the functions of the tongue, salivary glands, and teeth, all of which are in the mouth. Additionally, the lips and cheeks keep food between the teeth during mastication, and buccal glands lining the mouth produce saliva. |
| **Pharynx** | Receives a bolus from the oral cavity and passes it into the esophagus. |
| **Esophagus** | Receives a bolus from the pharynx and moves it into the stomach; this requires relaxation of the upper esophageal sphincter and secretion of mucus. |
| **Stomach** | Mixing waves combine saliva, food, and gastric juice, which activates pepsin, initiates protein digestion, kills microbes in food, helps absorb vitamin $B_{12}$, contracts the lower esophageal sphincter, increases stomach motility, relaxes the pyloric sphincter, and moves chyme into the small intestine. |
| **Small intestine** | Segmentation mixes chyme with digestive juices; peristalsis propels chyme toward the ileocecal sphincter; digestive secretions from the small intestine, pancreas, and liver complete the digestion of carbohydrates, proteins, lipids, and nucleic acids; circular folds, villi, and microvilli help absorb about 90% of digested nutrients. |
| **Large intestine** | Haustral churning, peristalsis, and mass peristalsis drive the colonic contents into the rectum; bacteria produce some B vitamins and vitamin K; absorption of some water, ions, and vitamins occurs; defecation. |


HAVE A
WONDERFUL
DAY
Thank you for being my students!