The digestive System is responsible for the breakdown and absorption of various foods and liquids needed to sustain life. The digestive system is made up by the **alimentary canal** also known as gastrointestinal tract (GIT) and **accessory organs** which include:

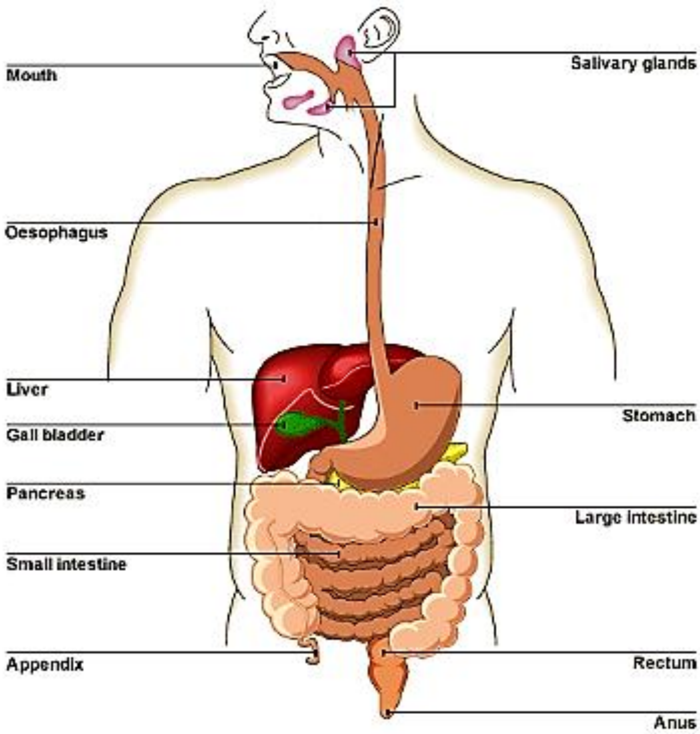
- **Salivary glands** are responsible for producing saliva
- **Tongue** manipulates food for chewing and swallowing and contains taste buds
- **Teeth** are responsible for chewing food up
- **Liver** produces and excretes bile required for emulsifying fats
- **Gallbladder** is responsible for bile storage
- **Pancreas** contains exocrine glands responsible for secretion of digestive enzymes
- **Vermiform appendix** is responsible for immune function and maintains gut flora.

The Alimentary Tract

It is a long tube that runs from the mouth where the food enters to the oral cavity, pharynx, esophagus, stomach, small and large intestines, and anus where indigestible waste leaves. The average length of adult digestive tract is about thirty. The alimentary tract provides the body with a continual supply of water, electrolytes, and nutrients via several activities:

1. Movement of food through the alimentary tract
2. Secretion of digestive juices and digestion of the food
3. Absorption of water, various electrolytes, and digestive products
4. Circulation of blood through GIT to carry away absorbed substances
5. Formation of feces that passes out through the anus.

All these functions are regulated by local nervous, and hormonal control. Each part of GIT is adapted to its specific functions: some to simple passage of food, such as the esophagus; others to temporary storage of food, such as the stomach; and others to digestion and absorption, such as the small intestine.



Anatomy of the Gastrointestinal Wall

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:

1. **Mucosa:** It is also called mucous membrane and consists of three layers:
   a) **Epithelial Lining:** The lumen of GIT is lined with epithelial tissue which begins as stratified squamous at oral cavity and then becomes simple columnar until reach to anal canal which returns stratified squamous. The main functions of the epithelial lining of the digestive tract is to:
      1) Provide a selectively permeable barrier between lumen contents & tissues.
      2) Facilitate the transport and digestion of food.
      3) Promote the absorption of the products of this digestion.
      4) Produce hormones that affects the activity of the digestive system.
      5) Produce mucus for lubrication and protection.

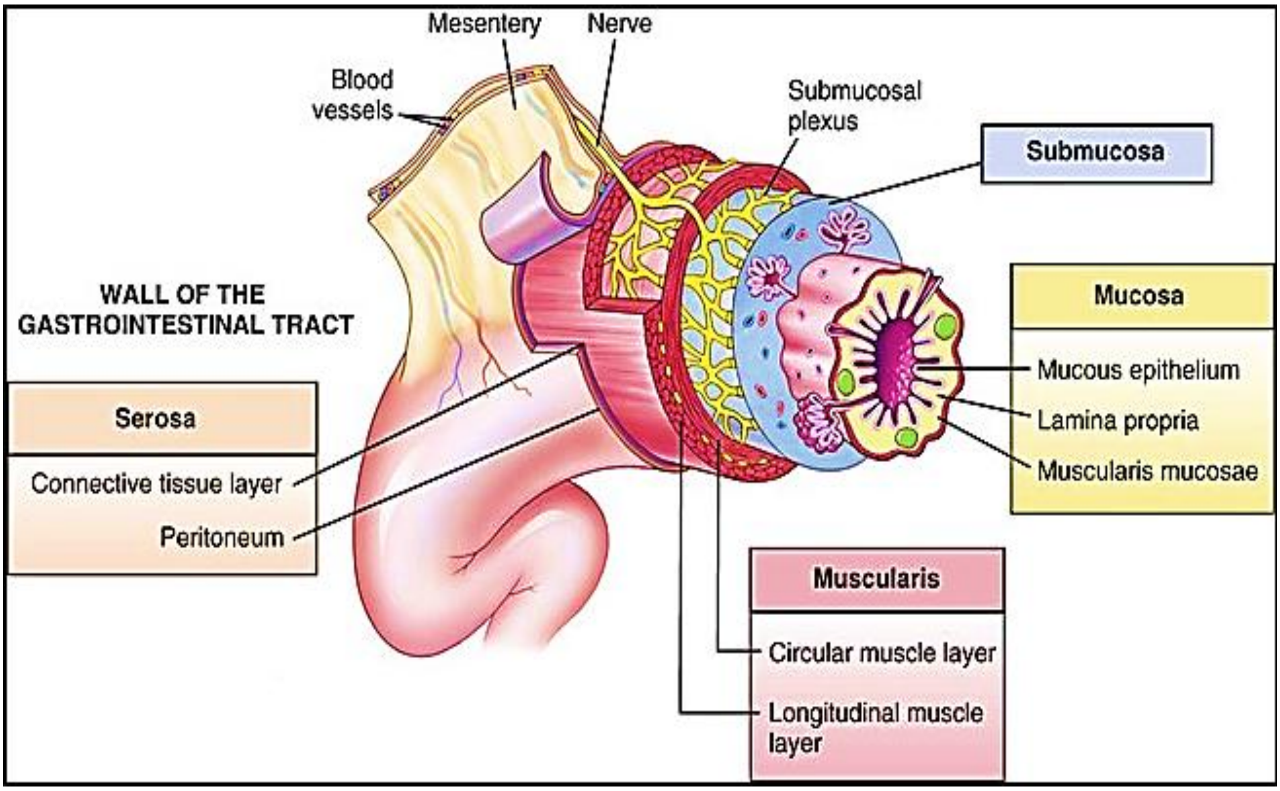
   b) **Lamina Propria:** It is a loose connective tissue rich in blood and lymph vessels, and sometimes containing glands and lymphoid tissue which actively produce antibodies mainly immunoglobulin A (IgA) and are secreted into the intestinal lumen to protect against viral and bacterial invasion.

   c) **Muscularis Mucosa:** It consists of a thin circular layer of smooth muscles that promotes the movement of the mucosa independent of other movements of the digestive tract to increase its contact with the food.

2. **Submucosa:** It is composed of dense connective tissue with many blood and lymph vessels and **Meissner's nerve plexus.** It may also contain glands and lymphoid tissue.

3. **Muscularis:** It is composed of two sublayers of smooth muscles; inner circular and outer longitudinal between them there is a connective tissue rich in blood and lymph vessels and also contains the myenteric nerve plexus **(Auerbach's plexus).** The contractions of the muscularis, generated and coordinated by nerve plexuses to propel and mix the food in the digestive tract.

4. **Serosa:** It is a thin layer of loose connective tissue covered a simple squamous epithelium known as **mesothelium**. In the abdominal cavity, the serosa is continuous with the **mesenteries** (thin membranes covered by mesothelium on both sides to support the intestines) and with the **peritoneum** (serous membrane that lines the wall of abdominal cavity. However, in places where the digestive organ is bound to other organs or structures, the serosa is replaced by a connective tissue containing vessels and nerves without the mesothelium known as **adventitia**.



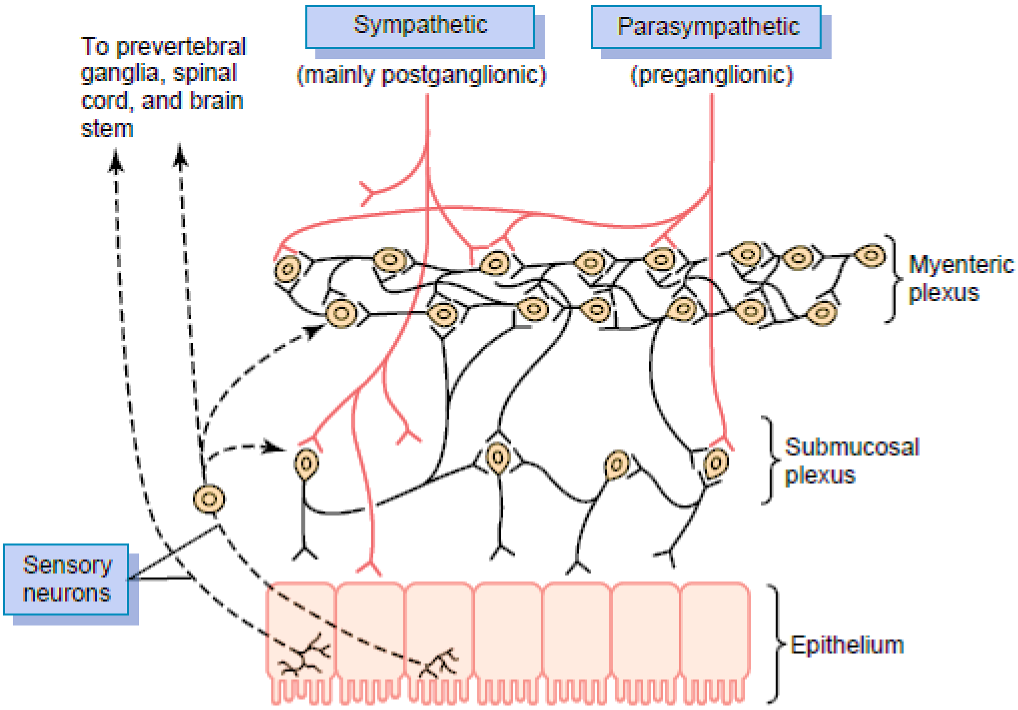
Enteric Nervous System

The gastrointestinal tract has a nervous system lies entirely in the wall of the gut, beginning in the esophagus and extending all the way to the anus known as ***enteric nervous system*** which is especially important in controlling gastrointestinal movements and secretion. The number of neurons in this enteric system is about 100 million, almost exactly equal to the number in the entire spinal cord. The nerve endings of these enteric neurons released a dozen or more different neurotransmitter substances which are either excitatory or inhibitory agents such as *acetylcholine, norepinephrine, serotonin, dopamine, cholecystokinin, substance P, somatostatin,* and *enkephalin.* Two of them are familiar; *acetylcholine* most often excites gastrointestinal activity, while *norepinephrine* always inhibits gastrointestinal activity. The enteric nervous system is composed mainly of two plexuses:

1. **myenteric plexus (Auerbach's plexus):**
   It is an outer plexus lying in muscularis layer between the longitudinal and circular muscle sublayers. It consists mostly of a linear chain of many interconnecting neurons that extends the entire length of the gastrointestinal tract, so it is concerned mainly with controlling muscle activity along the length of the gut. When this plexus is stimulated, its principal effects increased tonic contraction (tone) of the gut wall causing more rapid movement of the gut peristaltic waves. The myenteric plexus should not be considered entirely excitatory because fiber endings of some neurons secrete an inhibitory transmitter useful for inhibiting some of the intestinal sphincter muscles that impede movement of food along successive segments of the gastrointestinal tract, such as the ***pyloric sphincter,*** which controls emptying of the stomach into the duodenum, and the ***ileocecal sphincter***, which controls emptying from the small intestine into the cecum.

2. **Submucosal Plexus (Meissner's Plexus):**
   It is an inner plexus lies in the submucosa and mainly concerned with controlling function within the inner wall of each minute segment of the intestine such as local blood flow, secretion,

absorption, and contraction of the submucosal muscle that causes various degrees of infolding of the gastrointestinal mucosa.



Although the enteric nervous system can function on its own independently, the extrinsic sympathetic and parasympathetic fibers are connected to both the myenteric and submucosal plexuses and can greatly enhance or inhibit gastrointestinal functions.

1. Parasympathetic Innervation

The parasympathetic supply to the gut is divided into *cranial* and *sacral divisions*, and stimulation of these parasympathetic nerves causes general increase in activity of the entire enteric nervous system which in turn enhances activity of most gastrointestinal functions because their nerve endings secrete mainly excitatory neurotransmitter *acetylcholine.*

a) ***Cranial parasympathetic nerve fibers:*** Except for a few parasympathetic fibers to the mouth and pharyngeal regions of the alimentary tract, the cranial parasympathetic nerve fibers are almost entirely in the *vagus nerve*. These fibers provide extensive innervation to the esophagus, stomach, and pancreas and somewhat less to the intestines down through the first half of the large intestine.
b) ***Sacral parasympathetic nerve fibers:*** These fibers originate in the second, third, and fourth sacral segments of the spinal cord (S2, S3, and S4) and pass through the *pelvic nerve* to the distal half of the large intestine and all the way to the anus. The sigmoidal, rectal, and anal regions are considerably better supplied with parasympathetic fibers than are the other intestinal areas and function especially to execute the defecation reflexes.

2. Sympathetic Innervation

The sympathetic fibers to the gastrointestinal tract originate in the spinal cord between the fifth thoracic segment (T5) and the second lumbar segment (L2). Most of the preganglionic fibers that innervate the gut, after leaving the cord, enter the *sympathetic chains* that lie lateral to the spinal column, and many of these fibers then spread through postganglionic sympathetic nerves to all parts of the gut. The sympathetic innervate essentially all of the gastrointestinal tract, rather than being more extensive nearest the oral cavity and anus as is true of the parasympathetic. The sympathetic nerve endings secrete mainly *norepinephrine* but also small amounts of *epinephrine*. In general, stimulation of the sympathetic nervous system inhibits activity of the gastrointestinal tract, causing many effects opposite to those of the parasympathetic system. Therefore, strong stimulation of the sympathetic system can inhibit motor movements of the gut and can block movement of food through the gastrointestinal tract.

In addition to the sympathetic and parasympathetic innervation of the GIT wall, many afferent sensory nerve fibers innervate the gut. Some of them have their cell bodies in the enteric nervous system itself and some in the dorsal root ganglia of the spinal cord. These sensory nerves can be stimulated by (1) irritation of the gut mucosa, (2) excessive distention of the gut, or (3) presence of specific chemical substances in the gut. Signals transmitted through the fibers can then cause *excitation* or, under other conditions, *inhibition* of intestinal movements or intestinal secretion. In addition, other sensory signals from the gut go all the way to multiple areas of the spinal cord and even the brain stem. The anatomical arrangement of the enteric nervous system and its connections with the sympathetic and parasympathetic systems support three types of gastrointestinal reflexes that are essential to gastrointestinal control:

1. ***Reflexes entirely integrated within enteric nervous system.*** These include reflexes that control much gastrointestinal secretion, peristalsis, mixing contractions, local inhibitory effects.

2. ***Reflexes from gut to sympathetic ganglia and then back to GIT.*** These reflexes transmit signals long distances to other areas of the gastrointestinal tract, such as signals from the stomach to cause evacuation of the colon (the *gastro colic reflex*), signals from the colon and small intestine to inhibit stomach motility and stomach secretion (the *enterogastric reflexes*), and reflexes from the colon to inhibit emptying of ileal contents into the colon (the *colonoileal reflex*).

3. ***Reflexes from gut to spinal cord or brain stem and then back to GIT***. These include especially (1) reflexes from the stomach and duodenum to the brain stem and back to the stomach by vagus nerve to control gastric motor and secretory activity; (2) pain reflexes that cause general inhibition of the entire gastrointestinal tract; and (3) defecation reflexes that travel from the colon and rectum to the spinal cord and back again to produce the powerful colonic, rectal, and abdominal contractions required for defecation (the defecation reflexes).

Types of Movements in the GIT

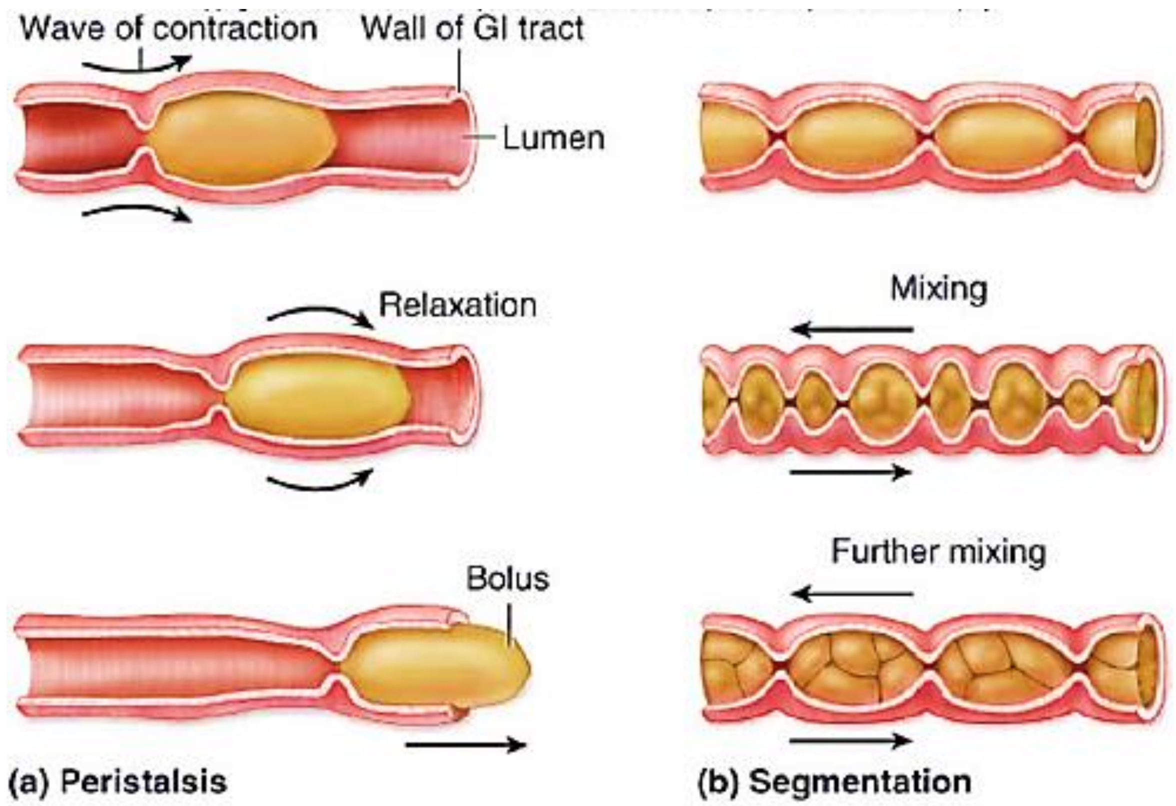
Two types of movements occur in the gastrointestinal tract: ***propulsive movements,*** which cause food to move forward along the tract to accommodate digestion and absorption, and ***mixing movements,*** which keep the intestinal contents thoroughly mixed at all times.

1. Propulsive Movement (Peristalsis):

Peristalsis is an inherent property of many syncytial smooth muscle tubes; thus stimulation at any point in the gut can cause a contractile ring to appear in the circular muscle, and this ring then spreads along the gut tube. Peristalsis also occurs in the bile ducts, glandular ducts, ureters, and many other smooth muscle tubes of the body. The usual stimulus for intestinal peristalsis is distention of the gut when a large amount of food collects at any point in the gut, the stretching of the gut wall stimulates the enteric nervous system to contract the gut wall 2-3 centimeters behind this point, and a contractile ring appears that initiates a peristaltic movement. Other stimuli that can initiate peristalsis include chemical or physical irritation of the epithelial lining in the gut. Also, strong parasympathetic nervous signals to the gut will elicit strong peristalsis. Peristalsis, theoretically, can occur in either direction from a stimulated point, but it normally dies out rapidly in the orad direction while continuing for a considerable distance toward the anus. The exact cause of this directional transmission of peristalsis is probably results mainly from the *law of the gut*, in which the contractile ring causing the peristalsis normally begins on the orad side of the distended segment and moves toward the distended segment, pushing the intestinal contents in the anal direction for 5-10 centimeters before dying out. At the same time, the gut sometimes relaxes several centimeters downstream toward the anus, which is called *receptive relaxation*, allowing the food to be propelled more easily anally than orad. This complex pattern does not occur in the absence of the myenteric plexus. Therefore, congenital absence of the myenteric plexus in any portion of the gastrointestinal tract leading to weak peristalsis or not at all occur. Also, it is greatly depressed or completely blocked in the entire gut when a person is treated with atropine to paralyze the cholinergic nerve endings of the myenteric plexus.

2. **Mixing Movement (Segmentation)**

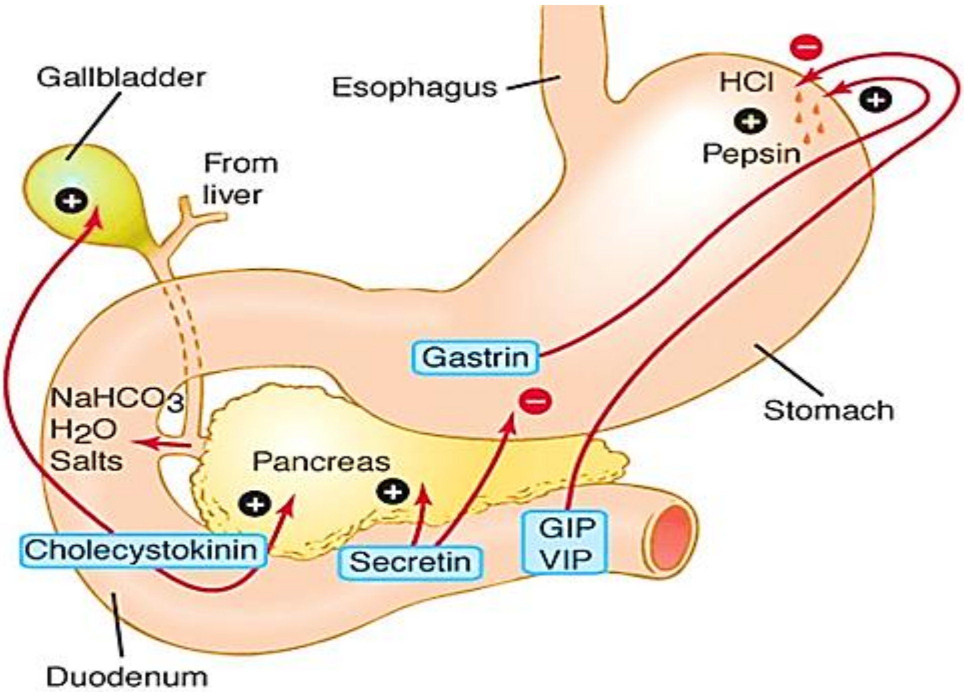
Mixing movements differ in different parts of the alimentary tract. In some areas, the peristaltic contractions themselves cause most of the mixing which is especially true when forward progression of the intestinal contents is blocked by a sphincter, so that a peristaltic wave can then only churn the intestinal contents, rather than propelling them forward. At other times, *local* intermittent constrictive contractions called *segmentations* occur every few centimeters in the gut wall and usually last only 5 to 30 seconds; then new constrictions occur at other points in the gut, thus “chopping” and “shearing” the contents first here and then there.



Hormonal Control of GIT Motility

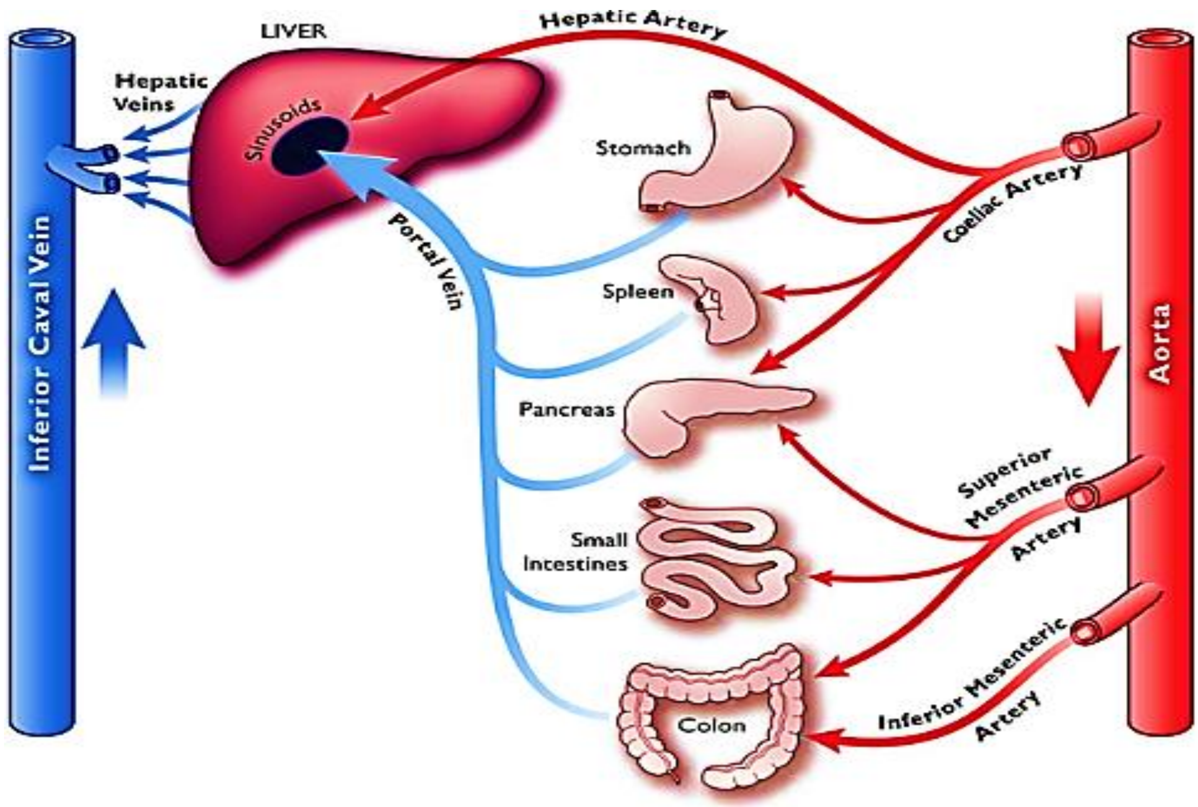
Although the motility effects are usually less important than the secretory effects of the hormones, some of the more important of them are the following:

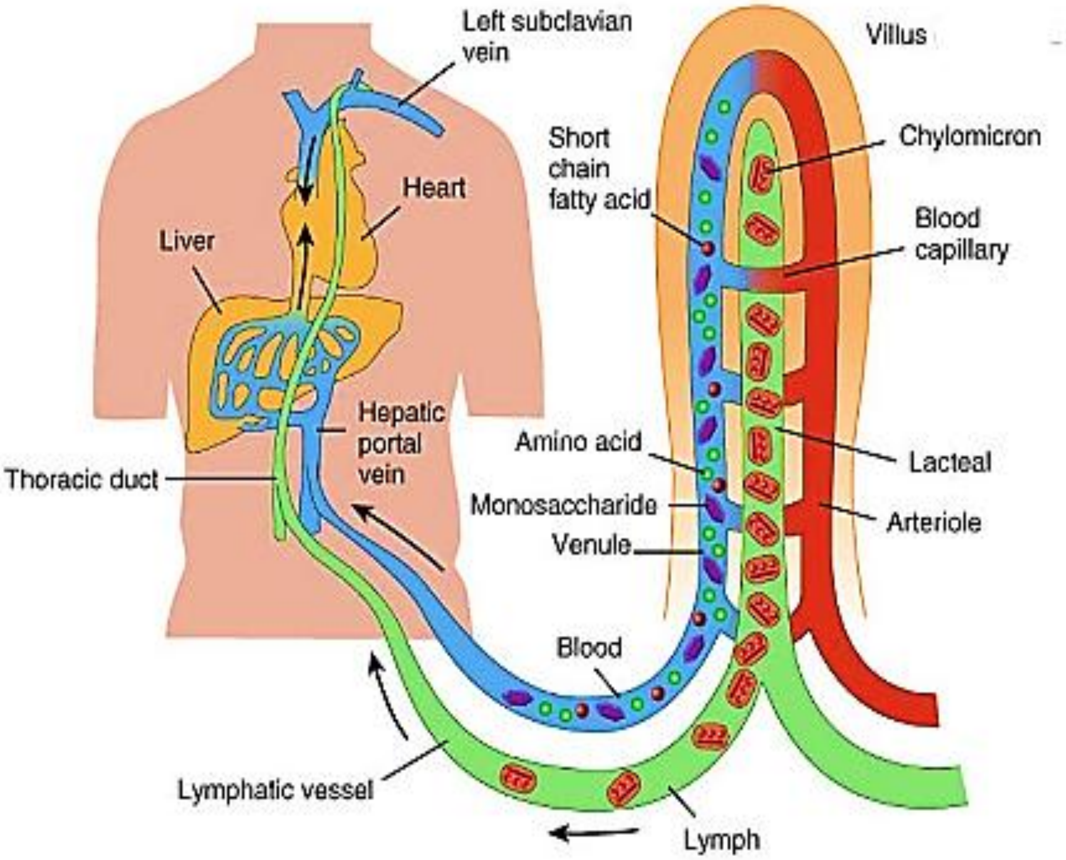
1. ***Gastrin*** is secreted by the "G" cells of the *antrum* of the stomach in response to stimuli associated with ingestion of a meal, such as distention of the stomach, the products of proteins, and *gastrin releasing peptide,* which is released by the nerves of the gastric mucosa during vagal stimulation. The primary actions of gastrin are (1) stimulation of gastric acid secretion and (2) stimulation of growth of the gastric mucosa.
2. ***Cholecystokinin*** is secreted by "I" cells in the mucosa of the duodenum and jejunum mainly in response to digestive products of fat, fatty acids, and monoglycerides in the intestinal contents. This hormone strongly contracts the gallbladder, expelling bile into the small intestine where the bile in turn plays important roles in emulsifying fatty substances, allowing them to be digested and absorbed. Cholecystokinin also inhibits stomach contraction moderately. Therefore, at the same time that this hormone causes emptying of the gallbladder, it also slows the emptying of food from the stomach to give adequate time for digestion of the fats in the upper intestinal tract.
3. ***Secretin*** was the first gastrointestinal hormone discovered and is secreted by the "S" cells in the mucosa of the duodenum in response to acidic gastric juice emptying into the duodenum from the pylorus of the stomach. Secretin has a mild effect on motility of the gastrointestinal tract and acts to promote pancreatic secretion of bicarbonate which in turn helps to neutralize the acid in the small intestine.
4. ***Gastric inhibitory peptide*** is secreted by the mucosa of the upper small intestine, mainly in response to fatty acids and amino acids but to a lesser extent in response to carbohydrate. It has a mild effect in decreasing motor activity of the stomach and therefore slows emptying of gastric contents into the duodenum when the upper small intestine is already overloaded with food products.
5. ***Motilin*** is secreted by the upper duodenum during fasting, and the only known function of this hormone is to stimulate waves of gastrointestinal motility that move through the stomach and small intestine every 90 minutes in a fasted person. Motilin secretion is inhibited after ingestion by mechanisms that are not fully understood.



Gastrointestinal Blood Flow

The blood vessels of the gastrointestinal system are part of a more extensive system called the ***splanchnic circulation***, which includes the blood flow through the gut itself plus blood flows through the spleen, pancreas, and liver. In this circulation, all the blood that courses through the gut, spleen, and pancreas flows immediately into the liver by way of the ***portal vein*****.** In the liver, the blood passes through millions of minute ***liver sinusoids*** and finally leaves the liver by way of ***hepatic veins*** that empty into the vena cava of the general circulation. This flow of blood through the liver, before it empties into the vena cava, allows the ***reticuloendothelial cells*** that line the liver sinusoids to remove bacteria and other particulate matter that might enter the blood from the gastrointestinal tract, thus preventing direct transport of potentially harmful agents into the remainder of the body. All water-soluble nutrients (non-fat) such as carbohydrates and proteins that have been absorbed from the gut are transported in the portal venous blood to the liver sinusoids. Here, both the reticuloendothelial cells and the principal parenchymal cells of the liver, the ***hepatic cells***, absorb and store temporarily from one half to three quarters of the nutrients. Also, much chemical intermediary processing of these nutrients occurs in the liver cells. Almost all of the *fats* absorbed from the intestinal tract are not carried in the portal blood but instead are absorbed into the intestinal lymphatics and then conducted to the systemic circulating blood by way of the ***thoracic duct,*** bypassing the liver.





The nervous control of gastrointestinal blood flow can be regulated by sympathetic and parasympathetic stimulation. The parasympathetic nerves going to the stomach and lower colon increases local blood flow that is probably results secondarily from the increased glandular activity and not as a direct effect of the nervous stimulation. Sympathetic stimulation, by contrast, has a direct effect on all the gastrointestinal tract to cause intense vasoconstriction of the arterioles with greatly decreased blood flow. After a few minutes of this vasoconstriction, the flow returns almost normal by means of a mechanism called ***auto regulatory escape*** that is a local metabolic vasodilator mechanisms elicited by ischemia and become prepotent over the sympathetic vasoconstriction resulting in redilation of the arterioles and return of necessary nutrient blood flow to the gastrointestinal glands and muscle. The depression of gastrointestinal blood flow is very important when other parts of the body need extra blood flow. For instances a major value of sympathetic vasoconstriction in the gut is that it allows shut-off of gastrointestinal and other splanchnic blood flow for short periods of time during heavy exercise, when increased flow is needed by the skeletal muscle and heart. Also, in circulatory shock, when all the body's vital tissues are in danger of cellular death for lack of blood flow (especially the brain and the heart), sympathetic stimulation can decrease splanchnic blood flow to very little for many hours. In hemorrhagic shock or other states of low blood volume, sympathetic stimulation also causes strong vasoconstriction of the large-volume intestinal and mesenteric veins, thereby displacing large amounts of blood into other parts of the circulation and can provide as much as 200 to 400 milliliters of extra blood to sustain the general circulation.