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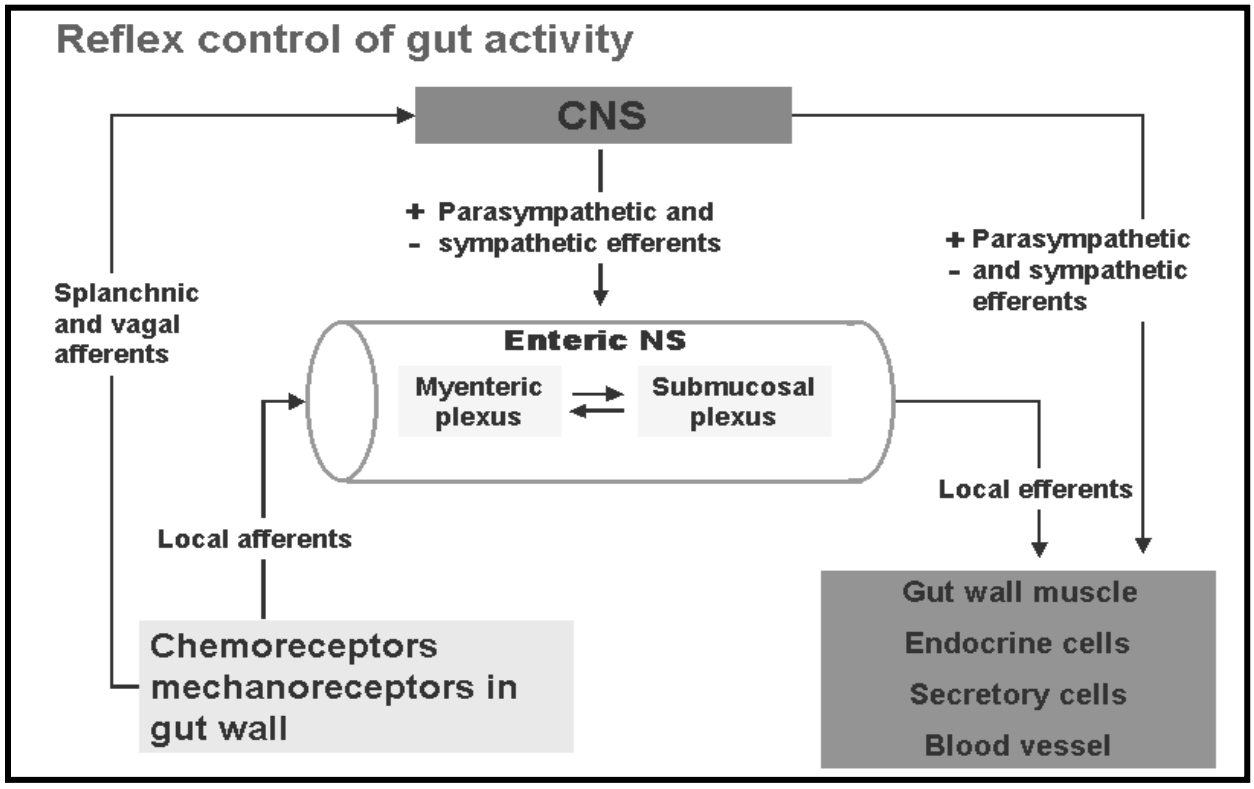
Gastrointestinal tract - Digestive System

The primary function of the alimentary tract is to break down food and to provide the body with a continual supply of water, electrolytes and nutrients. In order to achieve this function, the GIT must performs the following processes: ingestion, movement, digestion, absorption, secretion and egestion. The adult GIT is a tube running through the body from mouth to anus.

The enteric nervous system: The GIT has an intrinsic nervous system of its own called the **enteric nervous system** which controls most GI functions, especially GIT movements and secretion. The enteric nervous system is composed of two layers of neurons and connecting fibers, the outer layer is called the **myenteric (Auerbach's) plexus**, the inner layer is called the **submucous (Meissner's) plexus**.

The degree of activity of this enteric nervous system can strongly be altered by extrinsic (autonomic) nervous system, i.e. parasympathetic and sympathetic nervous systems. Both systems send signals to GIT from the brain and spinal cord to modulate the activity of the enteric nervous system.



The parasympathetic nerve fibers: Stimulation of the parasympathetic nerves fibers releases acetylcholine and causes a general increase in activity of the entire enteric nervous system which in turn enhances the activity of most GIT functions, but causing sphincters to relax (except the lower esophageal sphincter, which they stimulate), however, some of enteric neurons are inhibitory and, therefore inhibit certain functions. The parasympathetic supply to the gut is divided into:

The sympathetic nerve fibers: The sympathetic nerve endings secrete norepinephrine. In general, stimulation of the sympathetic nervous system inhibits activity in the GIT, while causing sphincters to contract

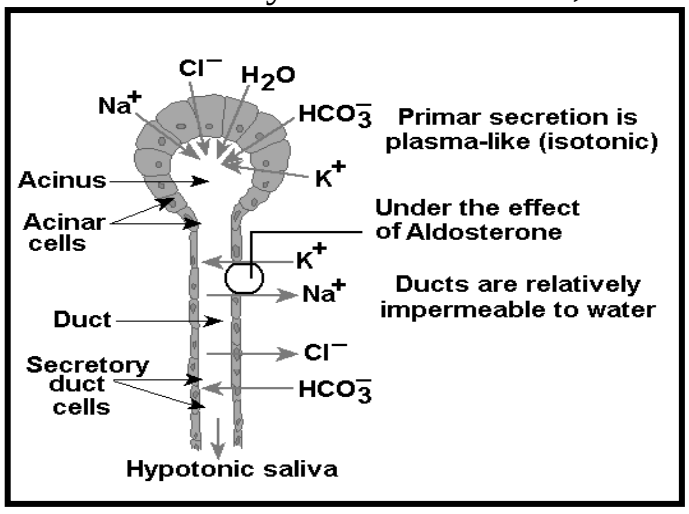
Types of GIT smooth muscle contractions:

-Phasic (rhythmical) contractions that occur in the esophagus, stomach, and intestine. *They include peristaltic and segmentation contractions.*
-Tonic contractions that occur in the lower esophageal sphincter, pyloric sphincter, ileocecal sphincter, and internal anal sphincter. Tonic contraction is continuous, occasionally increases or decreases in intensity.

Mastication (chewing): The teeth is designed for chewing. The incisors providing a strong cutting action and the molars for grinding action. The **chewing reflex** is controlled by nuclei in the medulla and cerebral cortex. Most of the muscles of chewing are innervated by the motor branch of the 5th cranial nerve (trigeminal N). Voluntary contraction of the muscles of chewing in response to the presence of a bolus of food in the mouth . The contact of food with with buccal receptors causes reflex inhibition of the muscles of mastication, which allows the lower jaw to drop. The drop in turn initiates a stretch reflex of the jaw muscles that leads to rebound contraction. This automatically raises the jaw to cause closure of the teeth, but again, it also compresses the bolus against the linings of the mouth and push the food to come in contact with the buccal receptors, which inhibit the jaw muscles once again and allowing the jaw to drop and rebound another time, and this is repeated again and again.
The importance of chewing are:
[1] Chewing breaks down the indigestible cellulose membranes
[2] Chewing increases the surface area of food to a very fine particulate consistency prevents excoriation of the GIT and increases the ease

with which food is swallowed and emptied from the stomach
[3] Chewing mixes the food with salivary gland secretions by salivary amylase and lingual lipase
[4] Chewing brings food into contact with taste receptors and releases odors that stimulate the olfactory receptors.
Salivary glands: The daily normal secretion of saliva is between 500—1500 ml. Saliva is secreted from the glands of salivation, the parotids (25%), submandibular glands (70%), and sublingual glands (5%). In addition, there are many small buccal glands.
In comparison to plasma, saliva is:
1. Hypotonic.
2. Contains higher concentration of K ions and bicarbonate ions and lower concentrations of Na and Cl ions.
3. Saliva has a pH between 6.0 - 7.4.

The structure of each gland is similar to a bunch of grapes. The acinus is lined with acinar cells and secretes an initial saliva which is a plasma-like solution (isotonic) containing amylase and/or mucin. As the primary secretion flows through the ducts, Na^+ actively reabsorbs from the initial saliva in an exchange to K^+ by Na^+-K^+ countertransport mechanism which is controlled by hormone aldosterone. The excess Na reabsorption over that of K secretion creates negativity in the salivary ducts, and this causes Cl ions to be reabsorbed passively. HCO_3^- ions are secreted actively by the ductal epithelium into the lumen of the duct.
Therefore, the composition of saliva varies with the salivary flow rate:
[1] lowest flow rates, saliva has the lowest osmolarity and lowest Na^+, and Cl^- concentrations, but has the highest K^+ and HCO_3^- ion concentration.
[2] highest flow rates, saliva is closet to that of plasma.



Saliva consists of two major types of protein secretions:
1.Serous secretion (watery saliva) containing ptyalin (α-

amylase) which is an enzyme for digesting starches and electrolytes.
2.Mucous secretion containing mucin (glycoprotein) for lubricating purposes.

The parotid glands secrete entirely the serous type, and the submandibular and sublingual glands secrete both the serous type and mucus. The buccal glands secrete only mucus.

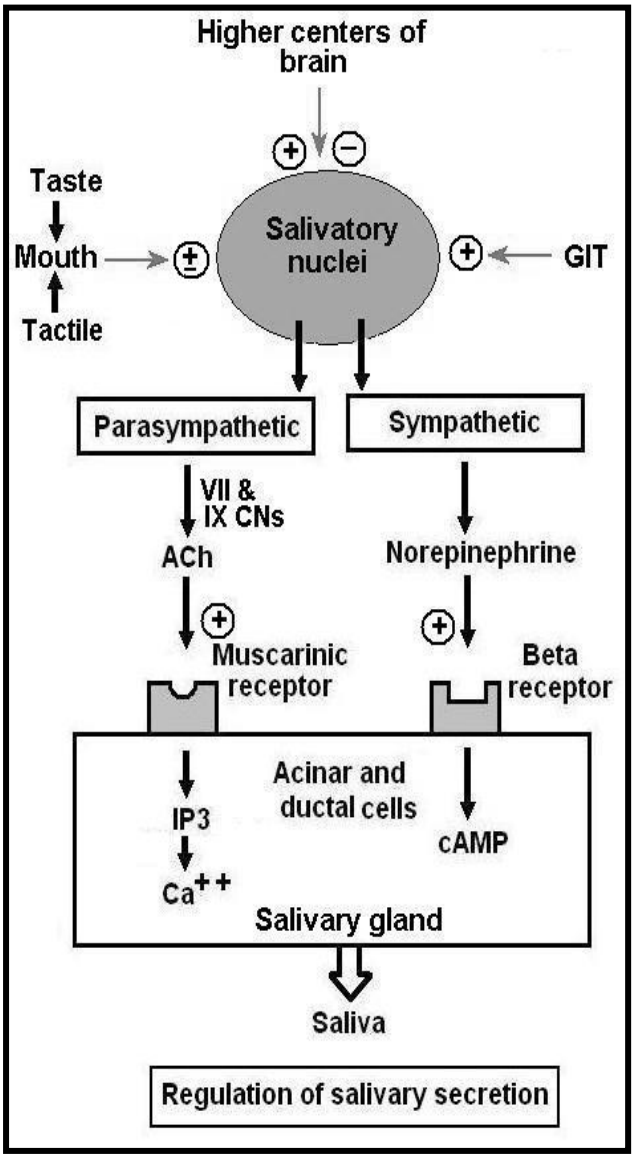
Salivary glands are controlled by salivatory nuclei which are located at the medulla and pons. Salivatory nuclei control saliva production mainly through parasympathetic [7^{th} cranial nerve (Facial N) and 9^{th} crainal nerve (Glossopharyngeal N)] and to less extent by sympathetic nervous signals originates from the superior cervical ganglia and then travels along blood vessels to the salivary glands. *Saliva production is unique in that it is increased by both parasympathetic and sympathetic activity*. Both parasympathetic and sympathetic stimulation increase the rate of saliva secretion. Parasympathetic stimulation produces a greater and more sustained increase of a watery saliva rich in enzymes while increased sympathetic stimulation produces a smaller volume of thick saliva rich in mucus.

Salivatory nuclei are excited or inhibited by:

[A] Signals from the mouth: Taste (especially the sour taste-excitatory, bitter taste-inhibitory) and tactile stimuli (especially smooth objects-excitatory) from the tongue and other areas of the mouth.

[B] Signals from higher centers of CNS: Salivation can also be stimulated or inhibited by impulses arriving in the salivatory nuclei from higher centers of CNS. For instance, when a person smells or see favorite foods, salivation is greater than when disliked food is smelled or seen.

[C] Signals from GIT: Salivation also occurs in response to reflex originating in the stomach and upper intestine particularly when very irritating foods are swallowed or when a person is nauseated. The swallowed saliva may help to remove the irritating factor in the GIT by diluting or neutralizing the irritant substances.



Parasympathetic nerve stimulation causes the salivary gland cells to secrete a large volume of watery fluid that is high in electrolytes (K and bicarbonate) but low in proteins. Sympathetic nerve stimulation causes the salivary glands to secrete a small volume of fluid that is low in electrolytes (K and bicarbonate) by containing a high concentration of mucus.

Saliva production is decreased (via inhibition of the parasympathetic nervous system) by sleep, dehydration, fear, and anticholinergic drugs (such as atropine). Under basal conditions, saliva is almost entirely of the mucus type and is secreted all the time except during sleep when the secretion become very little.

This secretion plays very important role in:

[A] Protection of the mouth by cooling hot foods, by maintaining healthy oral tissues. saliva helps prevent the harmful effects of bacteria by:

Continuous washing away the pathogenic bacteria (cause dental caries).

Saliva contains many factors that can kill bacteria such as thiocyanate ions, proteolytic enzymes, and antibodies (IgA).

[B] Digestion of starch by α-amylase, and fat by lingual lipase.

[C] Lubrication of food and making swallowing easier, moisten the mouth, facilitating speech, neutralizes any gastric acid that refluxes from stomach into the lower esophagus (heartburn).

Pathophysiological conditions associated with saliva secretion:

-**Xerostomia** (dry mouth) is associated with chronic ulceration's of the buccal mucosa and with dental caries. Siliva dissolves and washes out food particles from between teeth.

-**Congenital xerostomia** - absence of saliva.

-**Sjogren's syndrome** - atrophy of the glands and decreased saliva production.In cystic fibrosis, salivary sodium, calcium and protein are elevated. Digitalis drugs cause increased calcium and potassium concentrations in saliva.

-**Addison's disease** - sodium concentrations are increased.

-**Cushing's syndrome** - sodium concentrations are decreased as they are in primary aldosteronism and during pregnancy.

Tumors - Excessive salivation is observed with tumors of the mouth or esophagus and with Parkinson's disease.

Swallowing (deglutition): Swallowing can be divided into the following stages:

- Oral stage.
- Pharyngeal stage.
- Esophageal stage.
- Relaxation of lower esophageal sphincter.

[A]. Oral (voluntary) stage of swallowing: the process of swallowing becomes entirely automatic and cannot be stopped.

[B]. Pharyngeal (involuntary) stage of swallowing: When the bolus of food is pushed backward in the mouth, it stimulates swallowing receptor areas around the opening of the pharynx, and impulses from these pass to medulla oblongata through the sensory portions of the trigeminal (5th) and glossopharyngeal (9th) nerves to initiate a series of automatic pharyngeal muscular contractions which are controlled in orderly sequence by neuronal areas collectively called swallowing (or deglutition) center

[C]. Esophageal stage of swallowing:

[D]. Relaxation of lower esophageal sphincter:

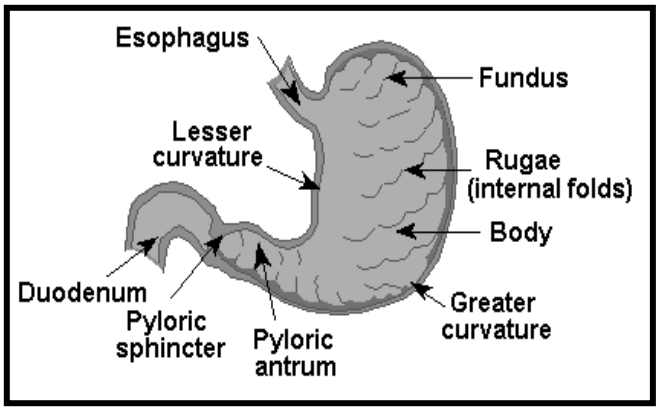
Disorders of swallowing:

[1] Esophageal reflux: Reflux of stomach acid to the esophagus causes esophageal pain (heartburn) and may lead to esophagitis Esophageal reflux.

[2] Belching (eructation): Following a heavy meal or the ingestion of large amounts of gas (e.g., from carbonated beverages), the gas bubble that is usually in the fundus of the stomach is displaced to the cardia. When lower esophageal sphincter relaxes during the swallowing process, gas enters the esophagus and is regurgitated.
[3] Achalasia: It is a neuromuscular disorder of the lower two-thirds of the esophagus that leads to absence of peristalsis and failure of the lower esophageal sphincter to relax. Food accumulates above this sphincter, taking hours to enter the stomach and dilating the esophagus.

The stomach: The stomach can be divided into a. the fundus, b. the body, and c. the antrum. Physiologically the fundus functions mainly as part of the body.

Gastric motility: There are two types of gastric motility which are increased by vagal stimulation and decreased by sympathetic stimulation: [A] *Peristalsis*: Peristaltic contractions that propels the food towards the pylorus. Peristaltic contractions occur every 20 sec. [B] *Retropulsion*: It is the back and forth movement of the chyme .



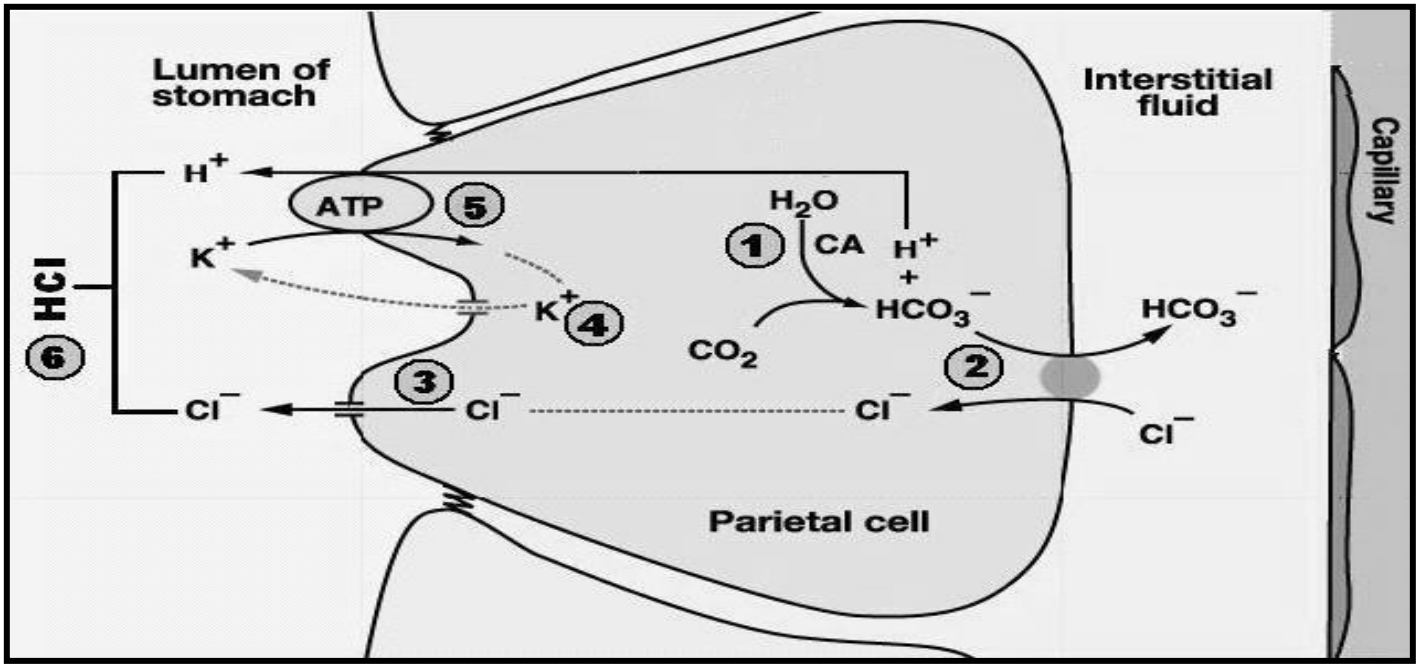
The functions of the stomach are:
1. storage of food
2. Mixing of this food with gastric secretions chyme. When the stomach is filled, weak peristaltic constrictor waves, also called mixing waves, move toward the antrum along the stomach wall approximately once every 20 seconds.
3. slow emptying of the food from the stomach into the small intestine the pyloric pump.

Gastric secretion: The stomach mucosa contains two main types of gastric glands:
[A] Oxyntic glands They contain three types of secretory cells:
1. Mucus secreting cells which sectetes mucus.
2. Oxyntic (parietal) cells which secrete intrinsic factor and HCl.

3. Peptic (chief) cells which secrete pepsinogen, the precursor for the proteolytic enzyme pepsin.

[B] Pyloric glands They contain G cells, G cells are responsible for the release of the hormone gastrin.

Gastric HCl secretion: HCl is secreted into the parietal cell canaliculi by the following steps:



Vomiting (emesis): It is a forceful expulsion of contents of the stomach and upper intestinal tract through the mouth. Often preceded by nausea, tachycardia, dizziness, pallor, sweating, and dilation of pupils. All characteristic of a general discharge of the sympathetic nervous system in response to stress. Often preceded by retching (UES remains closed). A series of retches of increasing strength may lead to vomiting.

Vomiting is a reflex coordinated by the region in the brain stem medulla known as the vomiting center. Stimuli that elicit vomiting include: distension of stomach or duodenum, tickling back of throat, painful

injury to genitourinary system, and dizziness. Chemicals called emetics can elicit vomiting. These act by stimulating receptors in the stomach or duodenum [e.g. ipecac] or the chemoreceptor trigger zone near the floor of 4th ventricle, on the blood side of blood-brain barrier [e.g. apomorphine]. Neural input to these centers

from receptors in many different regions of the body can initiate the vomiting reflex.

Vomiting center can be stimulated by excessive distension of the stomach or small intestine, tickling the back of the throat, and vestibular stimulation (motion sickness).

The importance of vomiting is to remove the ingested toxic substances before they can be absorbed. Moreover, the nausea that usually accompanies vomiting may have the importance in conditioning the individual to avoid the future ingestion of food containing the same toxic substances.

Vomiting is usually preceded by increased salivation, sweating, increased heart rate, pallor, and feeling of nausea,