General Principles of Alimentary Tract Secretion

Anatomical T pes y of Glands Single-cell mucous glands / goblet Cells : On the surface of the epithelium in most parts of the GI tract are, mucus secretion secretion mainly in response response to local irritation irritation of the epithelium. Crypts of Lieberkühn: many surface areas of the GI tract are lined by pits that represent invaginations of the epithelium into the submucosa, In the small intestine, these pits, are deep and contain specialized secretory cells. Tubular Tubular gland: In the stomach stomach and upper duodenum duodenum are large numbers numbers of deep tubular glands. Eg. acid- and pepsinogen-secreting gland of the stomach (oxyntic gland). C l omp ex gl d an s: salivary gl d an s, pancreas, and liver—th t a provide secretions for digestion or emulsification of food. The salivary glands and the pancreas are compound acinous glands, lying outside the walls of the GI tract , contain millions of acini lined with secreting glandular cells; these acini feed into a system of ducts that finally empty into the alimentary tract itself. Basic Mechanisms of Stimulation of the Alimentary Tract Glands ¬Direct contact stimulation of the surface glandular cells by the food. ¬Local epithelial stimulation also activates the enteric nervous system of the gut wall. (1) tactile stimulation, (2) chemical irritation, (3) distention of the gut wall. The resulting nervous reflexes stimulate both the mucous cells on the gut epithelial surface and the deep glands in the gut wall to increase their secretion. ¬Autonomic Stimulation of Secretion ( ) 1 Parasy p m athetic Stimulation: Increase secretion in glands in the upper portion of the tract (innervated by the glossopharyngeal and vagus parasympathetic nerves) such as the salivary, esophageal, gastric glands, pancreas, and Brunner's glands in the duodenum. glands in the distal portion of the large intestine, innervated by pelvic parasympathetic nerves. (2) Sympathetic Stimulation: dual effect, stimulation alone usually slightly increases secretion. If parasympathetic or hormonal stimulation is already causing copious secretion by the glands, superimposed sympathetic stimulation usually reduces the secretion, because of vasoconstrictive reduction of the blood supply. ¬Regulation of Glandular Secretion by Hormones. polypeptides Basic Mechanism of Secretion by Glandular Cells Secretion of Organic Substances.

1. Nutrient material needed for formation of the secretion must first diffuse or be actively transported by the blood in the capillaries into the base of the glandular cell.

2. Many mitochondria located inside the glandular cell near its base use oxidative energy to form ATP.

3. Energy from the ATP, along with appropriate substrates provided by the nutrients, is then used to synthesize the organic secretory substances; almost entirely in the ER and

Golgi complex. Ribosomes adherent to the reticulum are specifically responsible for formation of the proteins that are secreted

4. The secretory materials are transported through the tubules of the ER, passing in about 20 min all the way to the vesicles vesicles of the Golgi complex.

5. In the Golgi complex, complex, the materials materials are modified, added to, concentrated, and discharged into the cytoplasm in the form of secretory vesicles, which are stored in the apical ends of the secretory cells.

6. These vesicles remain stored until nervous or hormonal control signals cause the cells to extrude the vesicular contents through the cells' surface, in the following way: a. The control control signal first increases increases the cell membrane membrane permeability permeability to calcium calcium ions, and calcium enters the cell. b. The calcium in turn causes many of the vesicles to fuse with the apical cell membrane. c. The apical cell membrane breaks open, thus emptying the vesicles to the exterior; this process is called exocytosis

Water and Electrolyte Secretion. A second necessity for glandular secretion is secretion of sufficient water and electrolytes to go along with the organic substances. 1. Nerve stimulation of the basal portion of the cell membrane causes active transport of Cl- ions to the cell interior. 2. Resulting Resulting increase increase in electronegativity electronegativity inside the cell causes +ive ions such as Na+ ions to move inside the cell. 3. Excess of both -ive and +ive ions inside the cell creates an osmotic force that causes osmosis of water increasing the hydrostatic hydrostatic pressure pressure inside the cell. 4. The pressure pressure opens minute openings openings of the secretory secretory border of the cell, causing causing flushing flushing of water, electrolytes, and organic materials out of the secretory end of the glandular cell. Lubricating and Protective Properties of Mucus, and Importance of Mucus in the GI Tract Mucus is a thick secretion composed mainly of water, electrolytes, and a mixture of several glycoproteins . Mucus is slightly different in different parts of the GI tract , everywhere it has several important characteristics that make it both an excellent lubricant and a protectant for the wall of the gut. a. Adherent qualities that make it adhere tightly to the food or other particles and to spread as a thin film over the surfaces. b. Sufficient Sufficient body that it coats the wall of the gut and prevents prevents actual contactof contactof most food particles with the mucosa. c. Low resistance for slippage, so that the particles can slide along the epithelium with great ease. d. Causes f l eca parti l c es to adhere to one another to form the feces th t a are expell de during a bowel movement. e. Strongly resistant to digestion by the GI enzymes. f. The gy p l co roteins of mucus have amphoteric pp , ro erties, which means that they are capable of buffering small

amounts of either acids or alkalies; also, mucus often contains moderate quantities of bicarbonate ions which specifically neutralize acids. Secretion of Saliva Salivary Glands; Characteristics of Saliva. The principal glands of salivation are the parotid, submandibular, and sublingual glands; in addition, there are many very small buccal glands Daily Buccal gland there are many very small buccal glands. Daily secretion of saliva normally ranges between 800 and 1500 ml. Saliva contains contains two major types of protein protein secretion: secretion: (1) serous secretion that contains ptyalin (an a-amylase), an enzyme for digesting starches. (2) mucus secretion that contains mucin for lubricating and for surface protective purposes. Parotid glands secrete serous. Buccal glands secrete mucus. Submandibular and sublingual glands secrete both serous and mucus. Saliva has a pH between 6.0 and 7.0, favorable range for the digestive action of ptyalin. Secretion of Ions in Saliva Saliva contains large quantities of K+ & HCO3- ions. Conc of both Na+ and Cl- ions are several times less in saliva than in plasma. acini Salivary secretion is a two-stage operation: salivary ducts 1. The acini secrete a primary secretion that contains ptyalin and/or mucin in a solution of ions in conc similar to ECF. 2. As the primary secretion flows through the As the primary secretion flows through the ducts, two major active transport processes: (i) Na+ ions are actively reabsorbed from all the salivary ducts and K+ ions are actively secreted in exchange for the Na+, creating electrical negativity of about −70 mV in the salivary ducts; this in turn causes Cl- ions to be reabsorbed passively Na+ & Cl- 15mE/L K+ 30mE/L HCO3- 50-70mE/L causes Cl- ions to be reabsorbed passively. (ii) HCO3- ions are secreted by the ductal epithelium into the lumen of the duct, partly by passive exchange of HCO3- for Cl- ions, partly from an active secretory process. Function of Saliva for Oral Hygiene Under basal awake conditions, about 0.5 ml of saliva, almost entirely of the mucous type, is secreted each minute; but during sleep, little secretion occurs. Saliva helps prevent the deteriorative processes in the mouth by several Saliva helps prevent the deteriorative processes in the mouth by several ways.

1. Flow of saliva itself helps wash away pathogenic bacteria, as well as food particles that provide their metabolic support.

2. Contains several factors that destroy bacteria, thiocyanate ions, proteolytic enzymes enzymes—most important most important, lysozyme lysozyme —that (a) attack the bacteria (b) aid the that (a) attack the bacteria, (b) aid the thiocyanate ions in entering the bacteria where these ions in turn become bactericidal, and (c) digest food particles, thus helping further to remove the bacterial metabolic support.

3. Often contains significant amounts of antibodies that can destroy oral bacteria, including some that cause dental caries. In the absence of salivation, oral tissues often become ulcerated and otherwise infected, and caries of the teeth can become rampant.

Nervous Regulation of Salivary Secretion ¬Controlled mainly by parasympathetic nervous signals all the way from the superior and inferior salivatory nuclei in the brain stem. ¬Excited by both taste and tactile stimuli from the tongue and other areas of the mouth and pharynx. ¬Can be stimulated or inhibited by nervous signals signals arriving arriving in the salivatory salivatory nuclei from higher centers of the CNS (appetite center). ¬In response to reflexes originating in the stomach and upper small intestines ( ) irritant), nausea due to GI abnormality., to dilute or neutralizie the irritant. ¬Sympathetic stimulation to a lesser extent through cervical nerves from superior cervical ganglia . ¬Vasodilation by either PNS or by kallikrein secreted by the activated salivary cells, which splits alpha2-globulin in the blood to form bradykinin, a strong vasodilator.

Esophageal secretions ¬Entirely mucous and mainly provide lubrication for swallowing. ¬Esophagus is lined with many simple mucous glands. ¬At the gastric end and to a lesser extent in the initial portion of the esophagus, there are also many compound mucous glands. ¬Compound glands in the upper esophagus prevents mucosal excoriation by newly entering food. ¬Compound glands located near the esophagogastric junction protect the esophageal wall from digestion by acidic gastric juices that often reflux from the stomach back into the lower esophagus. ¬Despite this protection, a peptic ulcer at times can still occur at the gastric end of the esophagus. Gastric Secretion Characteristics of the Gastric Secretions ¬In addition to mucus-secreting cells th t a line the entire surface of the stomach, the stomach mucosa has two important types of tubular glands: oxyntic glands (also called gastric glands) and pyloric glands. ¬The oxyntic (acid-forming) glands secrete HCl, pepsinogen, intrinsic factor, and mucus, located in the body & fundus (80%) of stomach. ¬The pyloric glands secrete mainly mucus for protection of the pyloric mucosa from the stomach acid. They also secrete the hormone gastrin, located in the antral portion of the stomach (20 % of the stomach). Secretions from the Oxyntic (Gastric) Glands Composed of 3 types of cells: (1) mucous neck cells, secrete mainly mucus; (2) peptic (or chief) cells, secrete large quantities of pepsinogen; and (3) parietal (or oxyntic) cells, secrete HCl & intrinsic factor. Secretion of HCl by the parietal cells involves special mechanisms: ¬When stimulated stimulated, the parietal parietal cells secrete secrete an acid solution that contains about 160 mmol/L of HCl nearly, pH 0.8. ¬Hydrogen ion conc is 3 million times that of the arterial blood. To concentrate the hydrogen ions more than 1500 calories of energy per liter of gastric juice is required. ¬Parietal cell contains large branching intracellular canaliculi. The HCl formed at the villus- like projections inside these canaliculi and is then conducted through the canaliculi to the secretory end of the cell. Chemical mechanism of HCl formation

1. Water inside the parietal cell dissociates into H+ and OH− . The H+ is acΘvely secreted into the canaliculus in exchange for K+ by H+ K+ ATPase

2. K+ ions transported into the cell by the Na+-K+ ATPase pump on the basolateral the canaliculus in exchange for K+, by H+- K+ ATPase. 1 1/4 y p p side of the membrane tend to leak into the lumen but are recycled back into the cell by the H+-K+ ATPase.

3. The basolateral Na+-K+ ATPase creates low intracellular Na+, which contributes to Na+ reabsorption from the lumen of the canaliculus.

4. Thus, most of the K+ and Na+ in the canaliculus is reabsorbed into the cell cytoplasm, and H+ ions take their place in the canaliculus.

5. The pumping of H+ out of the cell by the H+-K+ ATPase permits OH− to accumulate and form HCO3 − from CO2 (metabolic product/enter from blood),carbonic anhydrase)

6. The HCO3 − is then transported to the ECF in exchange for Cl- ions, whi hc enter the cell and are secreted through Cl- channels into the canaliculus, forming HCl, which is secreted into the lumen. Water passes into the lumen by osmosis because of extra ions in the canaliculus. Prevention of back leak of acid ¬A major part of the stomach's ability to prevent back leak of acid can be attributed to the gastric barrier due to the formation of alkaline mucus (surface mucosal mucosal cells) and to tight junctions junctions between between epithelia epithelia cells. ¬If this barrier is damaged by toxic substances, such as occurs with excessive use of aspirin or alcohol, the secreted acid does leak down an electrochemical gradient into the mucosa, causing stomach mucosal damage. Basic Factors That Stimulate Gastric Secretion (Acetylcholine, Gastrin, and Histamine) . ¬Acetylcholine released by parasympathetic stimulation excites secretion of pepsinogen by peptic cells, HCl by parietal cells, and mucus by mucous cells. ¬B th o gast ir n and hi t i s am ne st l rong y sti l t mu a e secretion of acid by paritl e a cells but have little effect on the other cells. Secretion of Intrinsic Factor by Parietal Cells. Intrinsic factor is essential for absorption of vitamin B12 in the ileum, is secreted by the parietal parietal cells along with the secretion secretion of HCl. When parietal parietal cells of the stomach stomach are destroyed, which frequently occurs in chronic gastritis, the person develops not only achlorhydria (lack of stomach acid secretion) but often also pernicious anemia. Secretion and Activation of Pepsinogen. Several slightly different types of pepsinogen are secreted by the peptic and mucous cells of the gastric glands, perform the same functions. Pepsinogen is activated by HCl to pepsin which functions as an active proteolytic enzyme in a highly acid medium (optimum (optimum pH 1 8. to 3 5) . , but above a pH of about 5 it has almost no proteolytic activity and

becomes completely inactivated in a short time. Regulation of pepsinogen secretion (1) stimulation of the peptic cells by acetylcholine released from the vagus nerves or from the gastric enteric nervous plexus ( ) 2 stimulation of p pe tic cell secretion in response to acid in the stomach. The acid probably does not stimulate the peptic cells directly but instead elicits additional enteric nervous reflexes that support the original nervous signals to the peptic cells Pyloric Glands—Secretion of Mucus and Gastrin ¬The pyloric glands are structurally similar to the oxyntic glands but contain few p pe tic cells and almost no parietal cells. Instead, they contain mostly mucous cells that are identical with the mucous neck cells of the oxyntic glands. ¬S t ecre e small amount of pepsinogen, and an especially large amount of thin mucus ¬Also secrete the hormone gastrin, which p y la s a key role in controlling gastric secretion. Surface Mucous Cells ¬The entire surface surface of the stomach stomach mucosa between between glands has a continuous continuous layer of a special type of mucous cells called simply "surface mucous cells." ¬They secrete large quantities of viscid alkaline mucus protecting from highly acidic, proteolytic stomach secretion. Contact with food or any irritation of the mucosa directly stimulates them. Stimulation of Gastric Acid Secretion Secretion of acid by Parietal Cells of the Oxyntic glands is under continuous ¬Parietal cells operate in close association with another type f ll ll d h ffi lik ll (C ll) h control by both endocrine and nervous signals. of cell called enterochromaffin like cells (ECL cells), the primary function of which is to secrete histamine which regulates HCl formation and secretion. ¬ECL cells are stimulated to secrete histamine by the hormonal substance gastrin, which is formed by Pyloric glands in response to proteins in the foods being digested. ¬The ECL cells may also be stimulated by hormonal substances secreted by the enteric nervous system of the stomach wall. ¬EC cells are neuroendocrine cells. As enteric afferent and efferent nerves do not protrude into the intestinal lumen, EC cells act as a form of sensory transduction to ENS. Secrete serotonin & Atrial natriuretic peptide (ANP) to regulate sensory and motor gastrointestinal reflexes & antral somatostatin secretion resp. by binding to receptors on ENS neurons. Phases of Gastric Secretion Cephalic Phase (30%). Occurs even before food enters the stomach, while it is being eaten. It results results from the sight, smell, thought thought, or taste of food, and the appetite appetite. Neurogenic Neurogenic signals signals originate in the cerebral cortex and in the appetite centers of the amygdala and hypothalamus, transmitted through the dorsal motor nuclei of the vagi and thence through the vagus nerves to the stomach. (emotional stimuli can cause peptic ulcers by increasing gastric secretion, like the cephalic phase) Gastric Phase (60%). Once food enters cephalic phase) the stomach, it excites (1) long vagovagal reflexes from the stomach to the brain and back to the stomach, (2) local enteric reflexes reflexes, and (3) the gastrin gastrin mechanism mechanism, Intestinal Phase. (10%) Presence of food in the upper portion of the small intestine, particularly in the duodenum, will continue to cause stomach secretion of small amounts of gastric juice, probably partly

because of small amounts of gastrin released by the duodenal mucosa. Inhibition of Gastric Secretion by Intestinal Factors Although intestinal chyme slig y htl stimulates gastric secretion during the early intestinal phase of stomach secretion but inhibits gastric secretion at other times due to : 1. Neuronal Inhibition: The presence of food in the small intestine initiates a reverse ent ti erogastric reflex, t itt d transmitted th h roug the myent i er c nervous system and exti i r ns c sympathetic and vagus nerves, that inhibits stomach secretion. (stimulated by distention, acid, protein breakdown products, or by irritation of the mucosa) 2. Hormonal Inhibition: The presence of acid, fat, protein breakdown products, hyperosmotic or hypo-osmotic fluids, or any irritating factor in the upper small intestine causes release of several intestinal hormones. Secretin, stimulates pancreatic secretion & opposes opposes stomach stomach secretion secretion, GIP, VIP and somatostatin somatostatin slight to moderate moderate inhibition inhibition. (These factors also reduce motility, to slow passage of chyme) Chemical Composition of Gastrointestinal Hormones: Gastrin, cholecystokinin (CCK), and secretin are all large polypeptides (2, 4.2 & 3.4 kDa). The terminal 5 aa in the gastrin and CCK molecular chains are the same. The functional activity of gastrin resides in the terminal terminal 4aa, CCK in the terminal terminal 8aa. All the aa in the secretin secretin molecule molecule are essential essential. A synthetic gastrin (penagastrin) of the terminal 4 aa of natural gastrin plus the amino acid alanine, has all the same physiologic properties as the natural gastrin. Pancreatic Secretion Most of its internal structure similar to that of the salivary glands ¬The pancreatic digestive enzymes are secreted by pancreatic acini, and large volumes of sodium bicarbonate solution are secreted secreted by the small ductules ductules and larger ducts leading leading from the acini ¬The combi d ne product of enzymes and sodium bi b car onate then flows th h roug a long pancreatic duct that normally joins the hepatic duct immediatelybefore it empties into the duodenum through the papilla of Vater, surrounded by the sphincter of Oddi. ¬Pancreatic juice is secreted most abundantly in response to the presence of chyme in the upper portions of the small intestine, and the characteristics of the pancreatic juice are determined to some extent by the types of food in the chyme. Pancreatic Digestive Enzymes Protein Protein Digestion Digestion: Most important important of the pancreatic pancreatic enzymes enzymes for digesting digesting proteins are trypsin, chymotrypsin (digested proteins into peptides), and carboxypolypeptidase (peptides into individual amino acids). By far the most abundant abundant of these is trypsin trypsin. Carbohydrate Carbohydrate Digestion: Digestion: Pancreatic Pancreatic amylase, amylase, which hydrolyzes hydrolyzes starches, starches, glycogen, and most other carbohydrates (except cellulose) to form mostly disaccharides and a few trisaccharides. Fat Digestion: (1) pancreatic lipase, which is capable of hydrolyzing neutral fat into fatty acids and monoglycerides; (2) cholesterol esterase, which causes hydrolysis of cholesterol esters; and (3) phospholipase, which splits fatty acids from phospholipids ¬Proteolytic digestive enzymes are in the inactive

forms trypsinogen, chymotrypsinogen, Regulation of Enzymatic activity y g y yp g y yp g and procarboxypolypeptidase, become activated only after they are secreted into the intestinal tract. ¬Trypsinogen Trypsinogen is activated activated by an enzyme called enterokinase enterokinase, which is secreted secreted by the intestinal mucosa when chyme comes in contact with the mucosa. ¬ Also, trypsinogen can be autocatalytically activated by trypsin that has already been f h b f h lf formed from previously secreted trypsinogen. Chymotrypsinogen is activated by trypsin to form chymotrypsin, and procarboxypolypeptidase is activated in a similar manner. Secretion of Trypsin Inhibitor Prevents Digestion of the Pancreas Itself. Galndular cells that secrete proteolytic enzymes into the acini of the pancreas also secrete trypsin inhibitor (Pancreatic secretory trypsin inhibitor (PSTI)/ serine protease inhibitor Kazal type I(SPINK1). Trypsin inhibition subsequently inhibits other enzymes as well. Acute pancreatitis: When pancreas becomes severely damaged or when a duct becomes blocked, accumulation of large quantities of pancreatic secretion, the effect of trypsin inhibitor is often overwhelmed leading to digestion of pancreas with in few hours resulting in circulatory shock or pancreatic insufficiency. Secretion of Bicarbonate Ions Pancreatic juice, bicarbonate ions and water, are secreted mainly by the epithelial cells of the ductules and ducts that lead from the acini. 1. HCO_3^- ions formed by CA enzyme are actively transported transported in association association with Na^+ ions through the luminal border of the cell into the lumen of the duct. 2. H^+ ions formed by dissociation of carbonic acid inside the cell are exchanged for Na^+ ions through the blood border of the cell by a secondary active transport transport process process. This supplies the Na^+ that are transported through the luminal border into the pancreatic duct lumen to provide electrical neutrality for the secreted bicarbonate ions. 3. The overall movement of Na^+ and HCO_3^- ions from the blood into the duct lumen creates an osmotic pressure gradient that causes osmosis of water also into the pancreatic duct, thus forming an almost completely isosmotic HCO_3^- solution.

Digestion

igestion and absorption occur in the digestive tract. After the nutrients are absorbed, they are available to all cells in the body and are utilized by the body cells in metabolism.

The digestive system prepares nutrients for utilization by body cells through six activities, or functions.

Ingestion

The first activity of the digestive system is to take in food through the mouth. This process, called ingestion, has to take place before anything else can happen.

Mechanical Digestion

The large pieces of food that are ingested have to be broken into smaller particles that can be acted upon by various enzymes. This is mechanical digestion, which begins in the mouth with chewing or mastication and continues with churning and mixing actions in the stomach.

Chemical Digestion

The complex molecules of carbohydrates, proteins, and fats are transformed by chemical digestion into smaller molecules that can be absorbed and utilized by the cells. Chemical digestion, through a process called hydrolysis, uses water and digestive enzymes to break down the complex molecules. Digestive enzymes speed up the hydrolysis process, which is otherwise very slow.

Movements

After ingestion and mastication, the food particles move from the mouth into the pharynx, then into the esophagus. This movement is deglutition, or swallowing. Mixing movements occur in the stomach as a result of smooth muscle contraction. These repetitive contractions usually occur in small segments of the digestive tract and mix the food particles with enzymes and other fluids. The movements that propel the food particles through the digestive tract are called peristalsis. These are rhythmic waves of contractions that move the food particles through the various regions in which mechanical and chemical digestion takes place.

Absorption

The simple molecules that result from chemical digestion pass through cell membranes of the lining in the small intestine into the blood or lymph capillaries. This process is called absorption.

Elimination

The food molecules that cannot be digested or absorbed need to be eliminated from the body. The removal of indigestible wastes through the anus, in the form of feces, is defecation or elimination.

Digestion is the process of breaking large, insoluble food molecules into smaller molecules for absorption into the bloodstream. This process involves the use of many digestive fluids and enzymes such as saliva, mucus, bile and hydrochloric acid, among others.

There are four primary stages of food digestion in the human body that include:

- After the intake of food through the mouth, it makes its way through the stomach into the small intestine, where it is digested.
- The nutrients from the digested food get absorbed into the bloodstream through small pores in the small intestine.
- The remaining undigested food is sent to the large intestine, where any unprocessed water or nutrients are reabsorbed into the body.
- The remaining waste food product is passed out of the body in the form of stools.

General Structure of the Digestive System

The long continuous tube that is the digestive tract is about 9 meters in length. It opens to the outside at both ends, through the mouth at one end and through the anus at the other. Although there are variations in each region, the basic structure of the wall is the same throughout the entire length of the tube.

The wall of the digestive tract has four layers or tunics:

- Mucosa
- Submucosa
- Muscular layer
- Serous layer or serosa

The mucosa, or mucous membrane layer, is the innermost tunic of the wall. It lines the lumen of the digestive tract. The mucosa consists of epithelium, an underlying loose connective tissue layer called lamina propria, and a thin layer of smooth muscle called the muscularis mucosa. In certain regions, the mucosa develops folds that increase the surface area. Certain cells in the mucosa secrete mucus, digestive enzymes, and hormones. Ducts from other glands pass through the mucosa to the lumen. In the mouth and anus, where thickness for protection against abrasion is needed, the epithelium is stratified squamous tissue. The stomach and intestines have a thin simple columnar epithelial layer for secretion and absorption.

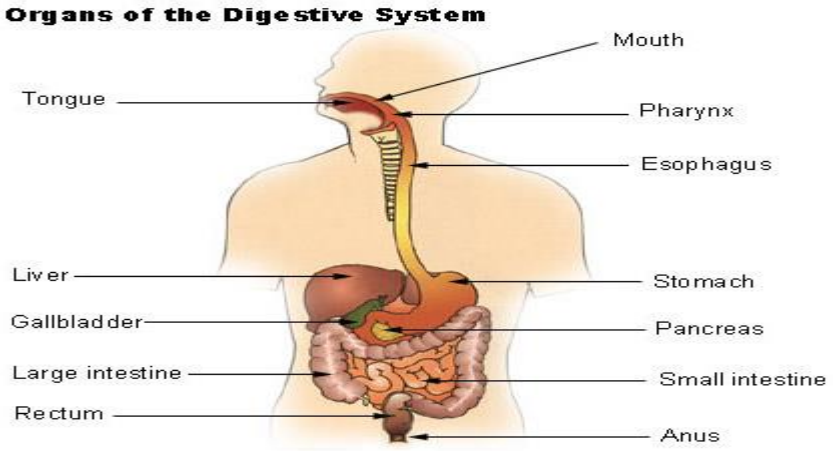
The submucosa is a thick layer of loose connective tissue that surrounds the mucosa. This layer also contains blood vessels, lymphatic vessels, and nerves. Glands may be embedded in this layer.

The smooth muscle responsible for movements of the digestive tract is arranged in two layers, an inner circular layer and an outer longitudinal layer. The myenteric plexus is between the two muscle layers.

Above the diaphragm, the outermost layer of the digestive tract is a connective tissue called adventitia. Below the diaphragm, it is called serosa.

Regions of the Digestive System

At its simplest, the digestive system is a tube running from mouth to anus. Its chief goal is to break down huge macromolecules (proteins, fats and starch), which cannot be absorbed intact, into smaller molecules (amino acids, fatty acids and glucose) that can be absorbed across the wall of the tube, and into the circulatory system for dissemination throughout the body.



Regions of the digestive system can be divided into two main parts: the alimentary tract and accessory organs. The alimentary tract of the digestive system is composed of the mouth, pharynx, esophagus, stomach, small and large intestines, rectum and anus. Associated with the alimentary tract are the following accessory organs: salivary glands, liver, gallbladder, and pancreas.

To learn more about the regions of the digestive system, use the hyperlinks listed below to branch into a specific topic.

1. Alimentary Tract of the Digestive System
    - Mouth
    - Pharynx & Esophagus
    - Stomach
    - Small and Large Intestine
2. Accessory Organs of the Digestive System
    - Salivary Glands
    - Liver
    - Gallbladder

- Pancreas

Pharynx & Esophagus

Pharynx

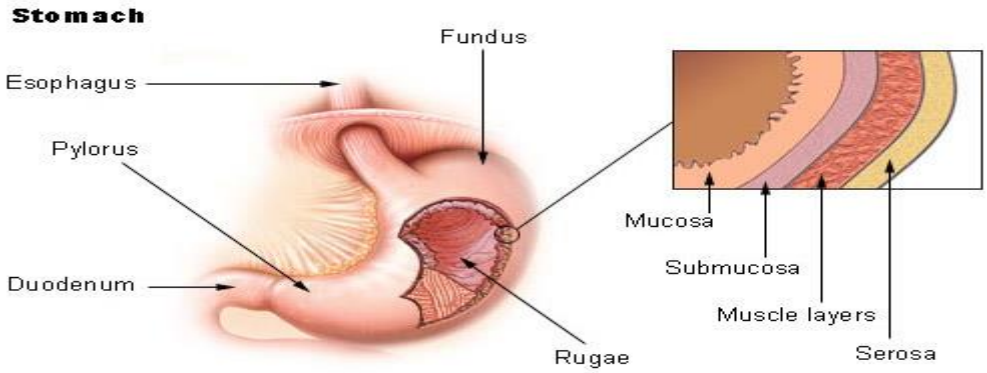
Food is forced into the pharynx by the tongue. When food reaches the opening, sensory receptors around the fauces respond and initiate an involuntary swallowing reflex. This reflex action has several parts. The uvula is elevated to prevent food from entering the nasopharynx. The epiglottis drops downward to prevent food from entering the larynx and trachea in order to direct the food into the esophagus. Peristaltic movements propel the food from the pharynx into the esophagus.

Esophagus

The esophagus is a collapsible muscular tube that serves as a passageway between the pharynx and stomach. As it descends, it is posterior to the trachea and anterior to the vertebral column. It passes through an opening in the diaphragm, called the esophageal hiatus, and then empties into the stomach. The mucosa has glands that secrete mucus to keep the lining moist and well lubricated to ease the passage of food. Upper and lower esophageal sphincters control the movement of food into and out of the esophagus. The lower esophageal sphincter is sometimes called the cardiac sphincter and resides at the esophagogastric junction.

Stomach

The stomach, which receives food from the esophagus, is located in the upper left quadrant of the abdomen. The stomach is divided into the fundic, cardiac, body, and pyloric regions. The lesser and greater curvatures are on the right and left sides, respectively, of the stomach.



Gastric Secretions

The mucosal lining of the stomach is simple columnar epithelium with numerous tubular gastric glands. The gastric glands open to the surface of the mucosa through tiny holes called gastric pits. Four different types of cells make up the gastric glands:

- Mucous cells
- Parietal cells
- Chief cells
- Endocrine cells

The secretions of the exocrine gastric glands - composed of the mucous, parietal, and chief cells - make up the gastric juice. The products of the endocrine cells are secreted directly into the bloodstream and are not a part of the gastric juice. The endocrine cells secrete the hormone gastrin, which functions in the regulation of gastric activity.

Regulation of Gastric Secretions

The regulation of gastric secretion is accomplished through neural and hormonal mechanisms. Gastric juice is produced all the time but the amount varies subject to the regulatory factors. Regulation of gastric secretions may be divided into cephalic, gastric, and intestinal phases. Thoughts and smells of food start the cephalic phase of gastric secretion; the presence of food in the stomach initiates the gastric phase; and the presence of acid chyme in the small intestine begins the intestinal phase.

Stomach Emptying

Relaxation of the pyloric sphincter allows chyme to pass from the stomach into the small intestine. The rate of which this occurs depends on the nature of the chyme and the receptivity of the small intestine.

Small & Large Intestine

Small Intestine

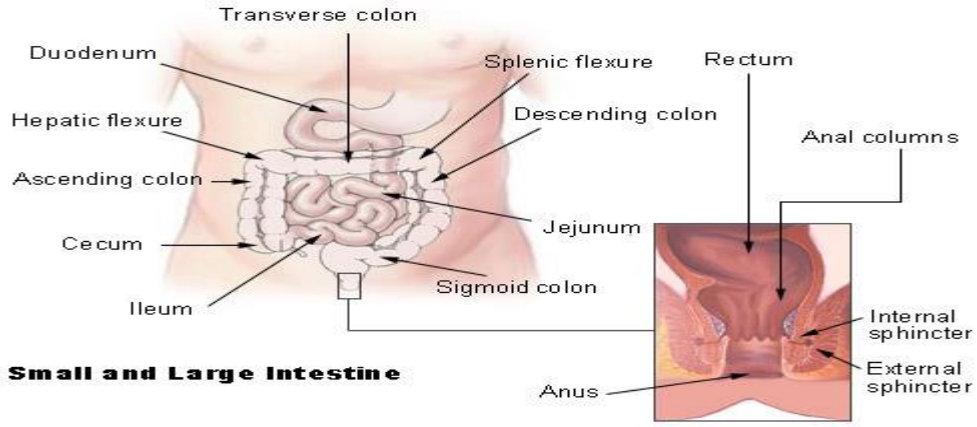
The small intestine extends from the pyloric sphincter to the ileocecal valve, where it empties into the large intestine. The small intestine finishes the process of digestion, absorbs the nutrients, and passes the residue on to the large intestine. The liver, gallbladder, and pancreas are accessory organs of the digestive system that are closely associated with the small intestine.

The small intestine is divided into the duodenum, jejunum, and ileum. The small intestine follows the general structure of the digestive tract in that the wall has

a mucosa with simple columnar epithelium, submucosa, smooth muscle with inner circular and outer longitudinal layers, and serosa. The absorptive surface area of the small intestine is increased by plicae circulares, villi, and microvilli.

Exocrine cells in the mucosa of the small intestine secrete mucus, peptidase, sucrase, maltase, lactase, lipase, and enterokinase. Endocrine cells secrete cholecystokinin and secretin.

The most important factor for regulating secretions in the small intestine is the presence of chyme. This is largely a local reflex action in response to chemical and mechanical irritation from the chyme and in response to distention of the intestinal wall. This is a direct reflex action, thus the greater the amount of chyme, the greater the secretion.



Small and Large Intestine

Large Intestine

The large intestine is larger in diameter than the small intestine. It begins at the ileocecal junction, where the ileum enters the large intestine, and ends at the anus. The large intestine consists of the colon, rectum, and anal canal.

The wall of the large intestine has the same types of tissue that are found in other parts of the digestive tract but there are some distinguishing characteristics. The mucosa has a large number of goblet cells but does not have any villi. The longitudinal muscle layer, although present, is incomplete. The longitudinal muscle is limited to three distinct bands, called teniae coli, that run the entire length of the colon. Contraction of the teniae coli exerts pressure on the wall and creates a series of pouches, called haustra, along the colon. Epiploic appendages, pieces of fat-filled connective tissue, are attached to the outer surface of the colon.

Unlike the small intestine, the large intestine produces no digestive enzymes. Chemical digestion is completed in the small intestine before the chyme reaches the large intestine. Functions of the large intestine include the absorption of water and electrolytes and the elimination of feces.

Rectum and Anus

The rectum continues from the sigmoid colon to the anal canal and has a thick muscular layer. It follows the curvature of the sacrum and is firmly attached to it by connective tissue. The rectum ends about 5 cm below the tip of the coccyx, at the beginning of the anal canal.

The last 2 to 3 cm of the digestive tract is the anal canal, which continues from the rectum and opens to the outside at the anus. The mucosa of the rectum is folded to form longitudinal anal columns. The smooth muscle layer is thick and forms the internal anal sphincter at the superior end of the anal canal. This sphincter is under involuntary control. There is an external anal sphincter at the inferior end of the anal canal. This sphincter is composed of skeletal muscle and is under voluntary control.

Digestion and Absorption of Proteins

Proteins play a vital role in the growth and replenishment of body cells and tissues. The digestion of proteins takes place in the stomach with the help of protease and pepsin enzymes, which breaks down the proteins into **amino acids**. The process is facilitated by the hydrochloric acid present in the stomach. Amino acids are tiny elements which get absorbed into the blood system through the wall of the small intestine. Also refer: Proteins

Digestion and Absorption of Lipids

Lipids are organic compounds comprising fatty acids, which are insoluble in water. Fats are the most common examples of lipids. The insoluble property of lipids makes the digestion and absorption of fats a complicated process.

Since they are hydrophobic, fats stick together as a large glob of insoluble mass after reaching the stomach. It is broken down with the help of bile juice, which contains bile salts. These broken molecules are then acted upon by pancreatic lipase, the major fat-absorbing enzymes in the body.

Pancreatic lipase breaks down fats into tiny molecules of free fatty acids and monoglycerides, which are small enough for the small intestine to push through into the bloodstream.

What is Absorption?

Absorption is the process of the absorbing or assimilating substances into the cells or across the tissues and organs through the process of diffusion or osmosis.

Digestion and Absorption of Carbohydrates

Carbohydrates are one of the essential nutrients in the human diet. There are two types of carbohydrates that can be digested by the **human digestive system**– sugar and starch.

Sugar is broken down in the gastrointestinal tract by the small intestine and three enzymes present in the mouth, namely, Lactase, Sucrase, and Maltase.

In the same way, starch is broken down with the help of the Amylase enzymes which are present in the mouth and the stomach. After digestion, carbohydrates are absorbed in the small intestine with the help of minute finger-shaped projections known as Villi. The chemical digestion of carbohydrates begins in the mouth. The below flowchart explains in detail about the series of steps involved in breaking down the carbohydrates into their monomers.