CHAPTER 11

DIGESTION

Major Concepts:

Number of allotted teaching periods: 13

11.1 Digestive System of Man (9 Periods)

11.1.1 Alimentary Canal: Structure and Functional Details

11.1.2 Role of Accessory Glands

11.2 Disorders: Digestive System and Food Habits (4 Periods)

Every cell of the body needs nourishment, but most cells cannot travel to a food source, so the food must be delivered. Food is necessary to sustain life. The food is utilized at the cellular level. Most of the food we eat, however, is not suitable for cellular utilization until it is mechanically and chemically reduced to forms that can be absorbed through the intestinal wall and transported to the cells by the blood. Ingested food is not technically inside the body until it is absorbed, in fact a large portion of this food remains undigested and passes through the body as waste material. This chapter presents a general view of the digestive system describes its anatomy and physiology and disorders related to digestive system and food habits.

11.1 DIGESTIVE SYSTEM OF MAN

Anatomically and functionally the digestive system can be divided into a tubular **gastrointestinal tract** (GIT) or **digestive tract** or alimentary canal and **accessory digestive organs**. **Viscera** are frequently used to refer the abdominal organs of digestion but actually **viscera** can be any organ such as spleen, stomach, lungs etc. **Gut** is an anatomical term that generally refers to the developing stomach and intestine. The first section of the digestive tract is the mouth, or oral cavity. The oral cavity opens posteriorly into the **pharynx**, which in turn, continues inferiorly into the **oesophagus** (meaning: passageway) (American spelling: esophagus). Oesophagus opens into the stomach.

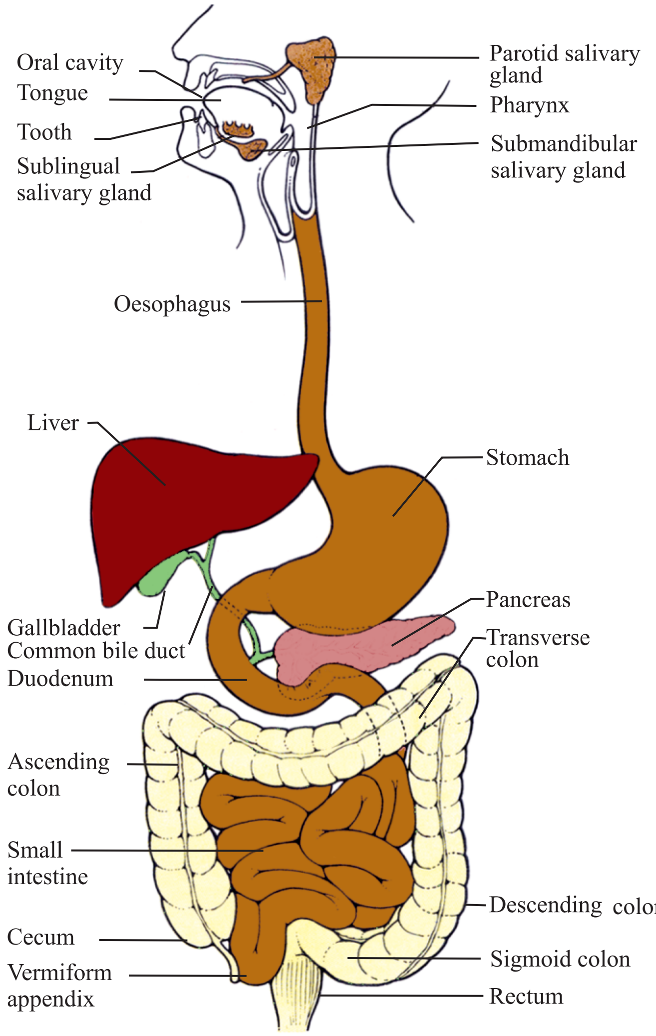


Fig: 11.1 Digestive System of Man

The stomach opens inferiorly into the **small intestine**. The first segment of the small intestine is the **duodenum** (meaning: twelve fingers breadth in length). The next segment of small intestine is the **jejunum** (meaning, empty). The last segment of the small intestine is the **ileum** (meaning, twisted). The last section of the digestive tract is the **large intestine**. The first segment is the **cecum** (meaning, blind), with the attached **vermiform** (meaning, wormlike) **appendix**. The cecum is followed by the **ascending**, **transverse**, **descending** and **sigmoid colon** and the **rectum** (meaning, straight). The rectum joins the **anal canal**, which ends at the **anus**, the inferior termination of the digestive tract.

11.1.1 ALIMENTARY CANAL - Structure and Functional Details

The organs of **GI tract** include oral cavity, pharynx, oesophagus, stomach, small intestine and large intestine. The accessory organs include the teeth, tongue, salivary glands, liver, gallbladder and pancreas. The GI tract, which extends from the mouth to the anus, is a continuous tube. It is a locally differentiated structure. It is specialized at various points along its length, with each region designed to carry out a different role in the overall process of digestion and absorption. GI is approximately 9m (30 ft) long. It traverses the thoracic cavity and enters the abdominal cavity at the level of diaphragm.

The digestive tube consists of four major layers, or **tunics**: an internal mucosa and an external serosa with a submucosa and muscularis in between. These four tunics are present in all areas of the digestive tract from the oesophagus to the anus.

Oral Cavity

The oral cavity, or mouth, is that part of the digestive tract bounded by the lips anteriorly, the fauces (meaning, throat, opening into the pharynx) posteriorly, the cheeks laterally, the palate superiorly and a muscular floor inferiorly. The oral cavity is lined with moist stratified squamous epithelium, which provides protection against abrasion.

Palate and Palatine Tonsils

The **palate** (fig. 11.2) consists of a two parts, an anterior bony part, the **hard palate** and a posterior, non-bony part, the **soft palate**, which consists of skeletal muscle and connective tissue. The **uvula** (meaning, a grape) is the projection from the posterior edge of the soft palate. The palate is important in the swallowing process, preventing food from passing into the nasal cavity. **Palatine tonsils** are located in the lateral wall of the fauces.

Salivary Glands

A considerable number of salivary glands are scattered throughout the oral cavity. There are three pairs of the large multicellular glands: the **parotid**, the **submandibular** and the **sublingual glands** (fig. 11.1).

> **Science Titbits**
>
> Inflammation of the parotid is called parotiditis. The most common type of parotidits, caused by a viral infection, is mumps.

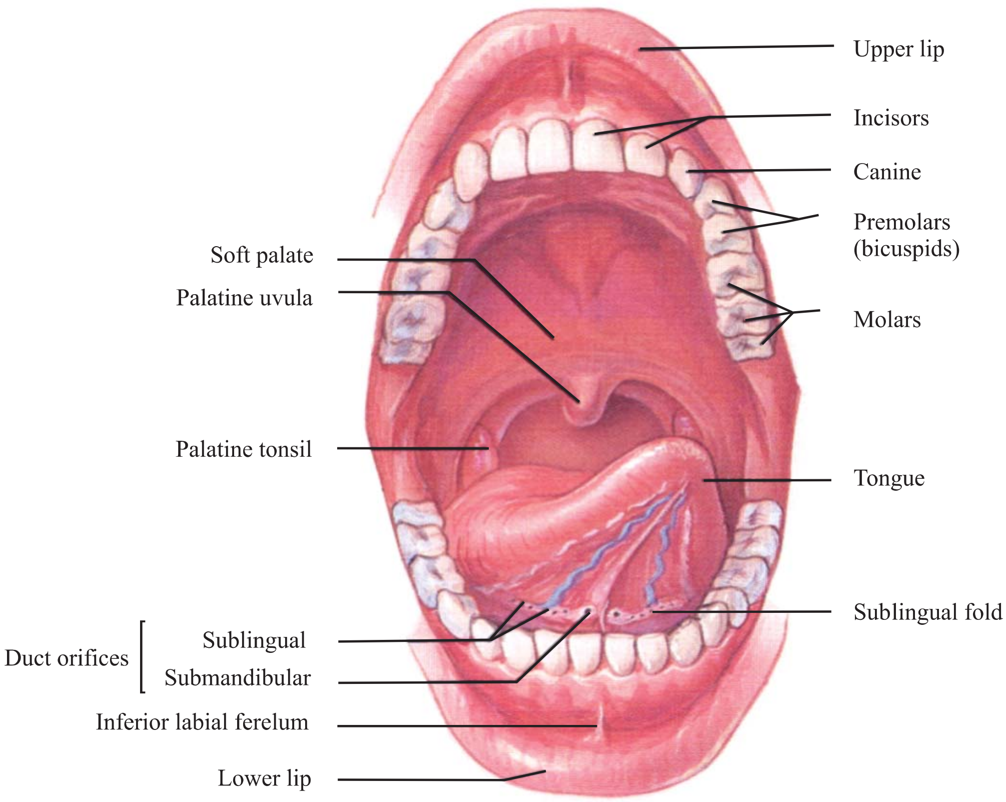


Fig 11.2 Superficial Structures of the Oral Cavity

Pharynx

The pharynx consists of three parts: the nasopharynx, the oropharynx and the laryngopharynx. Normally only the **oropharynx** and **laryngopharynx** transmit food. The oropharynx communicates with the nasopharynx superiorly, the larynx and laryngopharynx inferiorly, and the mouth anteriorly.

Oesophagus

The oesophagus is that part of the digestive tube that extends between the pharynx and the stomach. It is about 25 cm long and lies in anterior to the vertebrae and posterior to the trachea. It passes through the oesophageal hiatus (opening) of the diaphragm and ends at the stomach. An **upper oesophageal sphincter** and a **lower oesophageal sphincter** are present at the upper and lower ends of the oesophagus respectively, regulate the movement of materials into and out of the oesophagus.

Science Titbits

A hiatal hernia is a widening of the oesophageal hiatus, occurring most commonly in adults, which allows part of the stomach to extend through the opening into the thorax.

Stomach

The stomach is an enlarged segment of the digestive tract in the left superior part of the abdomen immediately below the diaphragm. Typically J-shaped when empty, the stomach is continuous with the oesophagus superiorly and empties into the small intestine inferiorly. The opening from the oesophagus into the stomach is the gastro-oesophageal, or **cardiac opening** (located near the heart), and the region of the stomach around the cardiac opening is the **cardiac region** (fig. 11.3). The lower oesophageal sphincter, also called the **cardiac sphincter**, surrounds the cardiac opening. Although this is an important structure in the normal function of the stomach, it is a physiologic constrictor only and cannot be seen anatomically. The largest part of the stomach is the **body** which narrows to form the **pyloric** (meaning, gatekeeper) region, that joins the small intestine. The opening between the stomach and the small intestine is the **pyloric opening**, which is surrounded by a relatively thick ring of smooth muscle called the **pyloric sphincter**. The stomach is lined with simple columnar epithelium. The mucosal surface forms

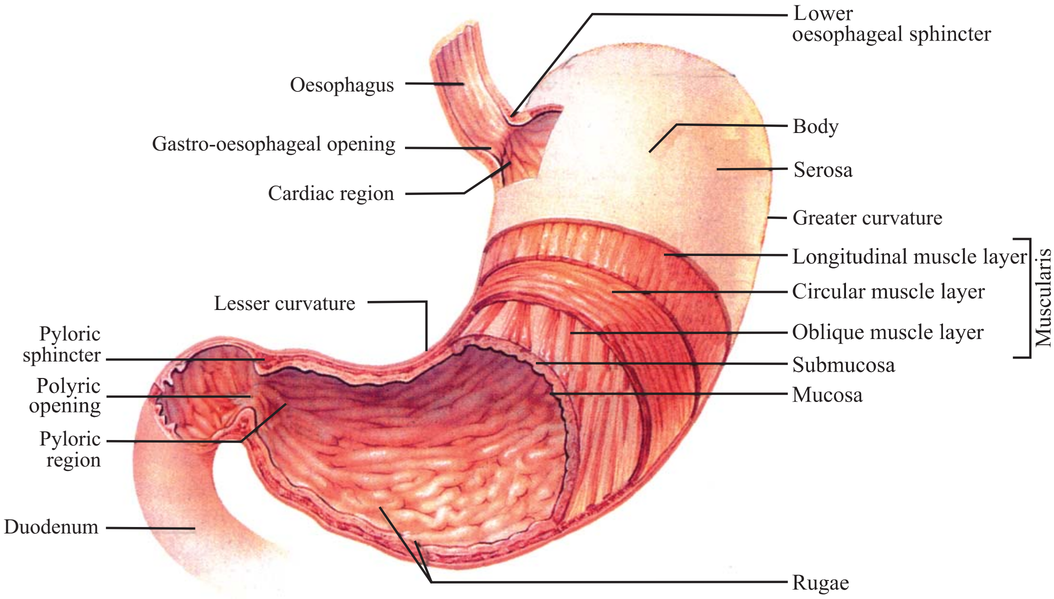


Fig: 11.3 Cutaway section of the Stomach reveals Muscular layers and internal Anatomy

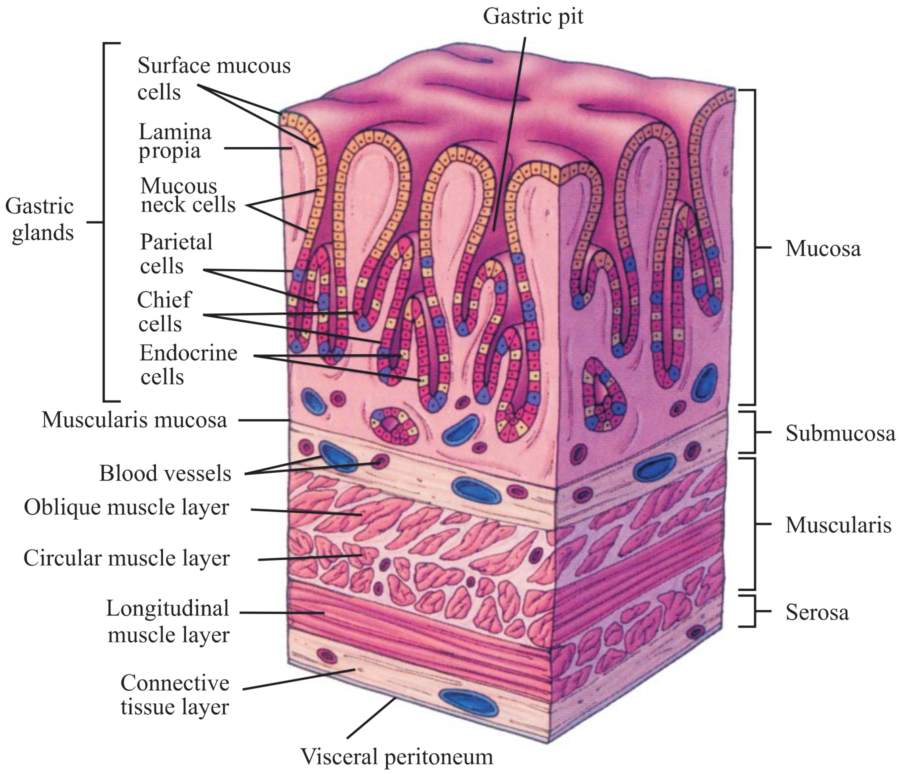


Fig. 11.4 A Section of the Stomach wall that Illustrates its Histology, Including Several Gastric Pits and Glands

numerous tubelike **gastric pits**, which are the openings for the gastric glands. There are five types of epithelial cells in the stomach:

(1) **Goblet cells** secrete protective mucus (2) **Parietal (oxyntic) cells** produce hydrochloric acid (3) **Principal cells** or **chief (zymogenic) cells** secrete pepsinogen (4) Endocrine cells secrete the hormone gastrin into the blood. In addition to these products, the gastrin mucosa (the parietal cells) secretes intrinsic factors.

Small Intestine

The small intestine consists of three parts: the duodenum, the jejunum, and the ileum (fig. 11.5). The entire small intestine is about 6m long (range: 4.6-9 m). The duodenum is about 25 cm long. The jejunum, constituting about two-fifths of the total length of the small intestine, is about 2.5 m long; and the ileum, constituting three-fifths of the small intestine, is about 3.5 m long. Two major accessory glands, the liver and the pancreas, are associated with the duodenum.

Duodenum

The duodenum begins with a short superior part, which is where it exits the pylorus of the stomach and ends in a sharp bend, which is where it joins the jejunum. Tiny fingerlike projections of the mucosa form numerous **villi** (meaning, shaggy hair, fig. 11.6), which are 0.5-1.5 mm in length. Each villus is covered by simple columnar epithelium and contains a blood capillary network and a lymph capillary called a **lacteal**.

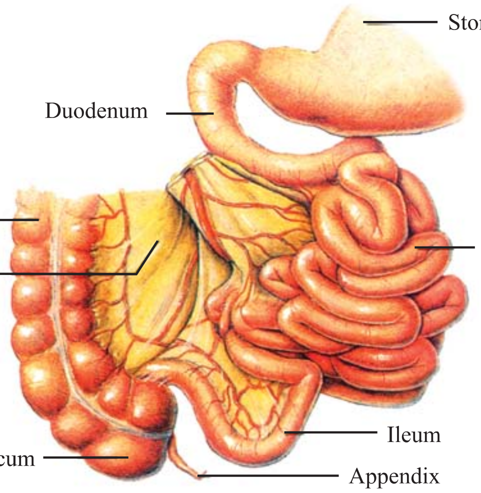


Fig 11.5 The Small Intestine

Jejunum and Ileum

The jejunum and ileum are similar in structure to the duodenum, except that there is a gradual decrease in the diameter of the small intestine, the thickness of the intestinal wall, the number of circular folds and the number of villi as one progresses through the small intestine. The duodenum and jejunum are the major sites of nutrient absorption, The junction between the ileum and the large intestine is the **ileocecal junction**. It has a ring of smooth muscle the **ileocecal sphincter**, and a one-way **ileocecal valve**.

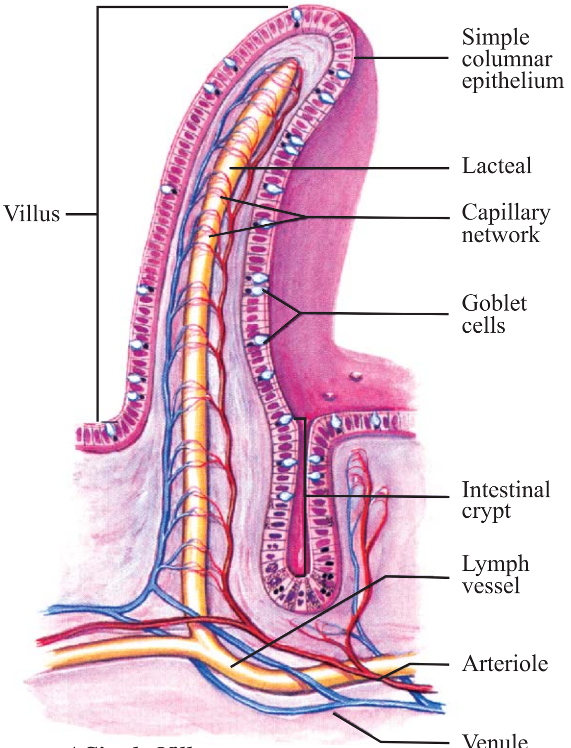
The structural features increase the surface area of small intestine and make it the largest part of the alimentary canal. The internal walls are folded to increase surface area for absorption. Villi and microvilli further increase surface area for absorption.

Large Intestine

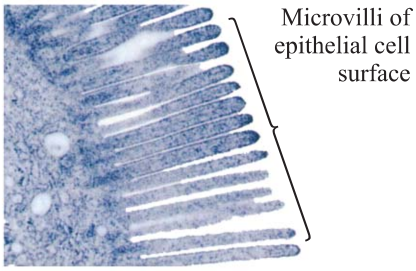
The **cecum**, which is the proximal end of the large intestine, is where the large and small intestines meet. The cecum extends inferiorly about 6 cm behind the ileocecal junction in the form of a blind sac. Attached to the cecum

Skills: Analyzing, Interpreting and Communication

- List structural features that increase surface area of small intestine



A Single Villus



Transmission electron micrograph of microvilli on the surface a villus.

Fig: 11.6 Histology of the Duodenum

is a small blind tube about 9 cm long called the **vermiform appendix**. The walls of the appendix contain many lymph nodules. The **colon** is about 1.5 to 1.8 m long and consists of four parts: the **ascending colon**, **transverse colon**, **descending colon**, and **sigmoid colon**. The **rectum** (means: straight) is a straight, muscular tube that begins at the termination of the sigmoid colon and ends at the anal canal. The last 2-3 cm of the digestive tract is the **anal canal**. It begins at the inferior end of the **rectum** and ends at the **anus** (external GI tract opening). The smooth muscle layer and skeletal muscle form **sphincter** of the anal canal.

Appendicitis

Appendicitis is an inflammation of the vermiform appendix and usually occurs because of obstruction of the appendix. Secretions from the appendix cannot pass the obstruction and accumulate, causing enlargement and pain. Symptoms include sudden abdominal pain. If the appendix bursts, the infection can spread throughout the peritoneal cavity, causing peritonitis, with life-threatening results. An appendectomy is removal of the appendix.

Functions of the Digestive System

As food moves through the digestive tract, secretions are added to liquify and digest it and to provide lubrication. Each segment of the digestive tract is specialized to assist in moving its contents from the oral end to the anal end. Parts of the digestive system are also specialized to transport molecules from lumen of the digestive tract into the extracellular spaces. The processes of secretion, movement, and absorption are regulated by elaborate nervous and hormonal mechanisms.

Functions of the Oral Cavity

Saliva is secreted at the rate of about 1-1.5 liter per day. The serous (watery) part of saliva contains a digestive enzyme called **salivary amylase** (meaning, starch-splitting enzyme), which breaks the covalent bonds between glucose molecules in starch and other polysaccharides to produce the disaccharides, maltose and isomaltose. Only about 3%-5% of the total carbohydrates are digested in the mouth. Cooking and thorough chewing of food destroys the cellulose of starch covering and increases the efficiency of the digestive process. Food taken into the mouth is chewed, or masticated, by the teeth. Mastication breaks large food particles into smaller ones, which have a

Composition of Saliva

Salivary amylase digests starch. Mucin is a proteoglycan that gives a lubricating quality to the secretions of the salivary glands. Water moistens food and mucous membrane. Saliva also contains various mineral salts including chloride ions which speed up the activity of enzymes. Saliva prevents bacterial infection in the mouth as it contains lysozyme and immunoglobulin. Saliva has a pH between 6.00 ND 7.0, a favourable range for the digestive action of amylase.

Q. How is chewing important to human digestion?

much larger total surface area for the action of digestive enzymes.

Deglutition or Swallowing

The tongue forms the chewed and moistened food into a ball like mass called **bolus** and pushes it into the **pharynx**. Muscles raise the soft palate against the back wall of the pharynx, which closes the passage between nasal cavity and pharynx, preventing food from entering the nasal cavity. The pressure of the food in the pharynx stimulates nerves in its walls that begins the swallowing reflex, an involuntary action. As part of this reflex action the voice box or **larynx** raises up to meet the **epiglottis** (meaning upon the glottis), with this action epiglottis cartilage drops over the **glottis**, the opening to the larynx and trachea. In this way food is passed over the trachea without entering it. If you place your hand over your larynx (Adam's apple), you can feel it moves up when you swallow. After food enters the oesophagus, the soft palate lowers and the epiglottis is raised.

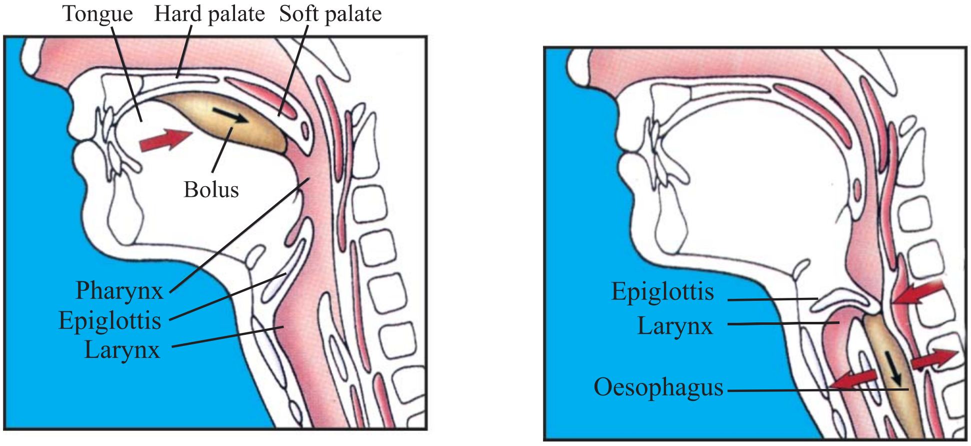


Fig: 11.7 Process of Swallowing

Peristalsis

In peristalsis a wave of relaxation of circular muscles infront of food is followed by a wave of strong contraction of circular muscles behind food, propels the mass of the food through the digestive tract. As the food moves it expands the tube wall, the expansions stimulates peristalsis. If there is any irritation of the oesophagus or stomach the process of peristalsis may be reversed and vomiting occurs. This reversal of peristalsis is called **antiperistalsis**.

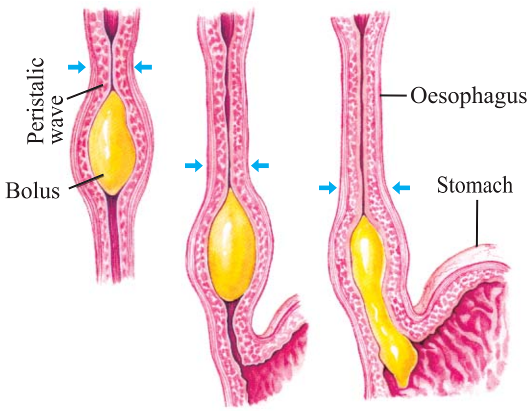


Fig. 11.8 Peristalsis

Stomach Function

Ingested food and stomach secretions, mixed together, form a semi fluid material called **chyme** (meaning, juice). The stomach functions primarily as storage and mixing chamber for the chyme. Stomach secretions include mucus, hydrochloric acid, gastrin, intrinsic factor and pepsinogen.

The mucous cells secrete viscous and alkaline **mucus**. The thick layer of mucous lubricates and protects the epithelial cells of the stomach wall from the damaging effect of the acidic chyme and pepsin. **Parietal cells** in the gastric glands of the pyloric region secrete intrinsic factor and a concentrated solution of hydrochloric acid. **Intrinsic** factor is a glycoprotein that binds with vitamin B_{12} and makes the vitamin more readily absorbed in the ileum.

Hydrochloric acid produces the low pH of the stomach, which is normally between 1 and 3. Although the hydrochloric acid secreted into the stomach has a minor digestive effect on digested food, one of its main functions is to kill bacteria that are ingested with essentially everything humans put into their mouths. The low pH of the stomach also stops carbohydrate digestion by inactivating salivary amylase. The low pH also denatures many proteins so that proteolytic enzymes can reach internal peptide bonds, and it provides the proper pH environment for the function of pepsin. **Chief cells** within the gastric glands secrete inactive **pepsinogen**. Pepsinogen is packaged in **zymogen** (meaning, related to enzymes) granules, which are released by exocytosis when pepsinogen secretion is stimulated. Once **pepsinogen** enters the lumen of the stomach, it is converted to **pepsin** by hydrochloric acid and previously formed pepsin molecules. Pepsin exhibits optimum enzymatic activity at a pH of 3 or less. Pepsin catalyzes the cleavage of some covalent bonds in proteins, breaking them into smaller peptide chains.

Q. Why is it necessary for pepsin to be secreted in an inactive state?

Regulation of Stomach Secretion

Approximately 2-3 litres of gastric secretions (gastric juice) is produced each day. Both nervous and hormonal mechanisms regulate gastric secretions. The neural mechanisms involve reflexes integrated within the medulla oblongata and local reflexes integrated within the GI tract. Hormones that regulate stomach secretions include gastrin, secretin, gastric inhibitory polypeptide, and cholecystokinin.

The sensations of the taste and smell of food, stimulation of tactile receptors during the process of chewing and swallowing, and pleasant thoughts of food stimulate centres within the medulla that influences **gastric secretion**. Neuronal stimulation of the stomach mucosa results in the secretion of **acetylcholine**, which stimulates the secretory activity of both the parietal and chief cells and stimulates the secretion of **gastrin** from endocrine cells. Gastrin is released into the circulation and travels to the parietal cells, where it stimulates additional hydrochloric acid and pepsinogen secretion.

The greatest volume of gastric secretions is initiated by the presence of food in the stomach. The primary stimuli are distention of the stomach and the presence of amino acids and peptides in the stomach. Distention of the stomach wall, especially in the body or fundus, results in the stimulation of mechanoreceptors. As food enters the stomach, its volume increases. Ingested food is thoroughly mixed with the secretions of the stomach glands to form **chyme**. This mixing is accomplished by gentle mixing waves, which are peristaltic-like contractions that occur about every 20 seconds and proceed from the body toward the pyloric sphincter to mix the ingested material with the secretions of the stomach.

Peristaltic waves occur less frequently, are significantly more powerful than mixing waves, and force the chyme near the periphery of the stomach toward the pyloric sphincter. The pyloric sphincter usually remains partially closed because of mild tonic contraction. Each peristaltic contraction is sufficiently strong to force a small amount of chyme through the pyloric opening and into the duodenum.

Q. Is human digestive system intracellular or extracellular?

Functions of the Small Intestine

The small intestine is the site at which the greatest amount of digestion and absorption occurs. The intestinal phase of gastric regulation is controlled by the entrance of acidic stomach contents into the duodenum. Acidic solutions in the duodenum cause the release of the hormone **secretin** into the circulatory system. Secretin inhibits gastric secretion by inhibiting both parietal and chief cells. Fatty acids and certain other lipids in the duodenum and the proximal jejunum initiate the release of two hormones: **gastric inhibitory peptide** and **cholecystokinin**. Gastric inhibitory peptide strongly inhibits gastric secretion, and cholecystokinin inhibits gastric secretions to a lesser degree. Hypertonic solutions in the duodenum and jejunum also inhibit gastric secretions.

The mucosa of the intestine produces secretions that primarily contain mucus, electrolytes, and water. Intestinal secretions lubricate and protect the intestinal wall from the acidic chyme and the action of digestive enzymes. They also keep the chyme in the small intestine in a liquid form to facilitate the digestive process. Most of the digestive enzymes that enter the small intestine come from the pancreas. The intestinal mucosa also produces enzymes that remain associated with the intestinal epithelial surface.

Mucus is secreted in large amount by duodenal glands, intestinal glands, and goblet cells. The mucus provides the wall of intestine with protection against the irritating effects of acidic chyme and against the digestive enzymes that enter the duodenum from the pancreas. Secretin and cholecystokinin are released from the intestinal mucosa and stimulate hepatic and pancreatic secretions. Secretion by duodenal glands is stimulated by the vagus nerve, secretion, and chemical or tactile irritation of the duodenal mucosa.

Movement in the Small Intestine

Mixing and propulsion of chyme are the primary mechanical events that occur in the small intestine. Segmental contractions mix the intestinal contents, and peristaltic contractions propel the intestinal contents along the digestive tract. The ileocecal sphincter at the junction between the ileum and the large intestine remains mildly contracted most of the time, but peristaltic contractions reaching it from the small intestine cause it to relax and allow movement of chyme from the small intestine into the cecum.

Absorption and Transport

Absorption of certain molecules can occur all along the digestive tract, a few chemicals, can be absorbed through the thin mucosa of the oral cavity below the tongue. Some small molecules (e.g. alcohol and aspirin) can pass through the stomach epithelium into the circulation. Most absorption, however, occurs in the duodenum and jejunum, although some absorption occurs in the ileum.

Science Titbits

Certain drugs, which are lipid-soluble and can, diffuse through the cell membranes of the oral cavity, can be quickly absorbed into the circulation. An example is nitroglycerin, which is a vasodilator used to treat cases of angina pectoris. The drug is placed under the tongue, where, in less than 1 minute, it dissolves and passes through the very thin oral mucosa into the lingual vein.

Carbohydrates: Ingested carbohydrates consist primarily of polysaccharides, and monosaccharides such as glucose and fructose. During the digestion process polysaccharides are broken down into monosaccharides. Carbohydrate digestion begins in the oral cavity with the partial digestion of starches by salivary amylase and is completed in the intestine by **pancreatic**

amylase. The monosaccharides are transferred by facilitated diffusion to the capillaries of the intestinal villi and are carried by the hepatic portal system to the liver, where the nonglucose sugars are converted to glucose. Glucose enters the cells through facilitated diffusion.

Lipids: The first step in lipid digestion is **emulsification**. Emulsification is accomplished by bile salts secreted by the liver. **Lipase** secreted by the pancreas digests lipid molecules. The primary products of this digestive process are free fatty acids and glycerol. Cholesterol and phospholipids also constitute part of the lipid digestion products. Once lipids are digested in the intestine, bile salts aggregate around the small droplets to form **micelles** (meaning a small morsel). When a micelle comes into contact with the epithelial cell of the small intestine, the contents of the micelle pass by means of simple diffusion through the lipid cell membrane of the epithelial cells.

Lipid Transport: In the intestinal epithelial cell, **triacylglycerol** is formed. Proteins combine with triacylglycerold to form **chylomicrons**. The chylomicrons leave the epithelial cell and enter the lacteals of the lymphatic system within the villi. They are carried through the lymphatic system to the blood stream. Before entering the adipose cells, **triacylglycerol** is broken back down into fatty acids and glycerol, which enter the fat cells and are once more converted back to triacylglycerol. Triacylglycerol is stored in **adipose tissue**. In the liver the chylomicron lipids are stored, converted into other molecules, or used as energy. Because lipids are either insoluble or only slightly soluble in water, they are transported through the blood in combination with proteins, which are water-soluble. Chylomicrons are one type of lipoproteins.

Science Titbits

Lipoproteins are referred to as high or low-density lipoproteins. A lipoprotein with high lipid content has a very low density (LDL), whereas a lipoprotein with high protein content has a relatively high density (HDL). Chylomicrons, which are made up of 99% lipid and only 1% protein, have an extremely very low density.

Proteins: Pepsin secreted by the stomach catalyzes the cleavage of covalent bonds in proteins, producing smaller **polypeptide chains**. Once the proteins and polypeptide chains leave the stomach, proteolytic enzymes produced in the pancreas continue the digestive process, producing small peptide chains. These are broken down into dipepetide, tripeptides and amino acids by **peptidases** bound to the **microvilli** of the small intestine. Dipeptides and tripeptides enter intestinal epithelial cells.

Once inside the cells, dipeptidase and tripeptidase split the dipeptides and tripeptides into their component **amino acids**. Individual amino acids then leave the epithelial cells and enter the **hepatic portal system**, which transports them to the **liver**. The amino acids may be modified in the liver or released into the bloodstream and distributed throughout the body. Most amino acids are used as building blocks to form new proteins, but some amino acids may be used for energy.

Water: About 9 litres of water enters the digestive tract each day, of which about 92% is absorbed in the small intestine, and another 6%-7% is absorbed in the large intestine. Water can move in either direction across the wall of the small intestine by osmosis.

Ions: Sodium, potassium, calcium, magnesium, and phosphate ions are also actively transported.

Function of the Large Intestine

In the colon, chyme is converted to faeces. Absorption of water and salts, the secretion of mucus, and extensive action of microorganisms are involved in the formation of faeces, which the colon stores until the faeces are eliminated by the process of **defaecation**.

Movement in the Large Intestine

Peristaltic waves are largely responsible for moving chyme along the ascending colon. Distention of the rectal wall by faeces acts as a stimulus that initiates the **defaecation reflex**. Local reflex action causes weak contractions of the rectum and relaxation of the internal anal sphincter.

The external anal sphincter, which is composed of skeletal muscle and is under conscious cerebral control, prevents the movement of faeces out of the rectum and through the anal opening. If this sphincter is relaxed voluntarily, faeces are expelled. The defaecation reflex persists only for a few minutes and quickly dies. In **infants**, the **defaecation reflexes** cause automatic emptying of the lower bowel at inconvenient times during the day because of lack of conscious control exercised through voluntary contraction of the external anal sphincter.

Science Titbits

Some bacteria in the intestine synthesize vitamin K, which is passively absorbed in the colon, and breakdown a small amount of cellulose to glucose. Gases called flatus (meaning, blowing) are produced by bacterial actions in the colon.

11.1.2 ROLE OF ACCESSORY GLANDS

The Accessory glands of the digestive sysem are liver, gall bladder and pancreas

Liver

The liver is the largest internal organ of the body. The liver consists of two major lobes, left and right, and two minor lobes. A **porta** (gate) is on the inferior surface of the liver where the various vessels, ducts, and nerves enter and exit the liver. The **hepatic ducts** transport **bile** out of the liver. The right and left hepatic ducts unite to form a single **common hepatic duct**. The common hepatic duct is joined by the **cystic duct** from the gallbladder to form the **common bile duct**, which empties into the duodenum at the major duodenal papilla in union with the pancreatic duct.

Functions of Liver

The liver performs important digestive and excretory functions, stores and processes nutrients, synthesizes new molecules and detoxifies harmful chemicals.

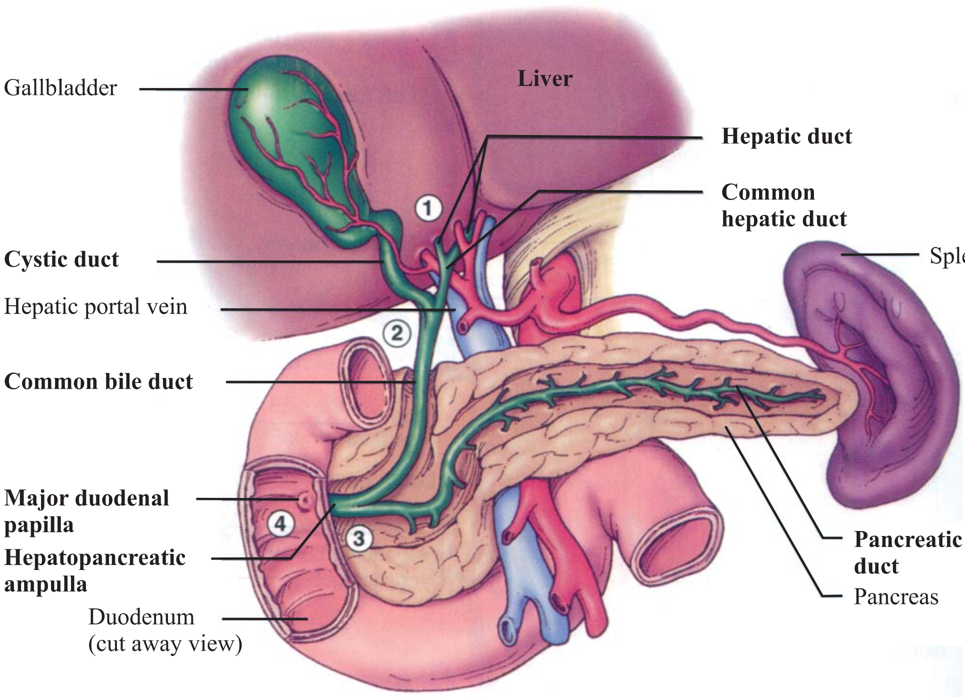


Fig: 11.9 Duct System of the Major Abdominal Digestive Glands

Bile Production

The liver produces and secretes **bile**, which contains no digestive enzymes. Bile helps to neutralize the acidic chymes and to bring the pH up to a level at which pancreatic enzymes can function. Bile salts emulsify fats. Bile also contains excretory products such as bile pigments. Bilirubin is a bile pigment that results from the breakdown of **hemoglobin**. Most bile salts are reabsorbed in the ileum and carried in the blood back to the liver, where they stimulate further bile secretion.

Storage Role of Liver

Hepatocytes can remove sugar from the blood and store it in the form of glycogen. They can also store fat, vitamins (A, B_{12}, D, E, and K), copper and iron. This storage function is usually short-term and the amount of stored material in the hepatocytes varies, thus the cell size fluctuates during a given day.

Metabolic Role of Liver

Metabolism of glucose occurs in liver. Excess of glucose from blood is converted into glycogen (glycogenesis) and stored in the liver cells. Whenever needed, glucose is obtained by the hydrolysis of glycogen (glycogenolysis). Glucose is also synthesized from amino acids or fatty acids and glycerol (gluconeogenesis). Denaturation of fatty acids and phosphorylation of fats takes place in liver cells. Excess of amino acids undergo deamination producing pyruvic acid and ammonia. Ammonia produced by deamination of amino acids in hepatic cells is converted to urea (ornithine-arginine cycle).

Synthesis of Vitamin A from carotin and synthesis of albumin from amino acids takes place in liver. Formation of blood proteins (like prothrombin, fibrinogen) are synthesized in liver cells. These are necessary for blood clotting. **Phagocytosis** also occurs in liver i.e. Kupffer cells destroy dead RBCs. The bile pigments **bilirubin** and **biliverdin** are formed from the breakdown of haemoglobin. Liver produces heparin, an enzyme that prevents clotting of blood inside the blood vessels. Red blood cells are formed during foetal (fetal) life. **Detoxification** occurs in liver. Liver cells detoxify or inactive the toxic substances like cresol, carbolic acid, etc. (produce by intestinal bacteria) or convert them to non-toxic substances. Similarly prussic acid produced during metabolism is converted into non-toxic substance. Liver is centre of heat production.

Science, Technology and Society Connections

Relate hepatitis and Jaundice with the function of liver.

Gallbladder

The gallbladder is a saclike structure on the inferior surface of the liver that is about 8 cm long and 4 cm wide. The gallbladder is connected to the common bile duct by the cystic duct.

Functions of the Gallbladder

Bile is continually secreted by the liver and stored in the gallbladder. While the bile is in the gallbladder, water and electrolytes are absorbed, and bile salts and pigments become as much as 5 to 10 times more concentrated than they were when secreted by the liver.

Pancreas

The pancreas is a complex organ composed of both endocrine and exocrine tissues that perform several functions. The pancreas consists of a head, located within the curvature of the duodenum, a body and a tail, which extends to the spleen. The endocrine part of the pancreas consists of **pancreatic islets** (islets of Langerhans).

Functions of the Pancreas

The exocrine secretion of the pancreas is called **pancreatic juice** and has two major components: an aqueous component and an enzymatic component. The aqueous component is produced principally by columnar epithelial cells that line the smaller ducts of the pancreas. It contains sodium and potassium ions in about the same concentration found in exracellular fluid. Bicarbonate neutralize the acidic chyme that enters the small intestine from the stomach.

Pancreatic Enzymes

The enzymatic component of the pancreatic juice is produced by the acini cells of the pancreas and is important for the digestion of all major classes of food. Without the enzymes produced by the pancreas, lipids, proteins, and carbohydrates are not adequately digested. The **proteolytic pancreatic enzymes**, which digest proteins, are secreted in inactive forms, whereas many of the other enzymes are secreted in active form. The major proteolytic enzymes are **trypsin**, **chymotrypsin**, and **carboxypeptidase**.

They are secreted in their inactive forms as trypsinogen, chymotrypsinogen, and procarboxypeptidase and are activated by the removal of certain peptides from the larger precursor proteins. If these were produced in their active forms, they would digest the tissues producing them. **Trypsinogen** is activated by the proteolytic enzyme enterokinase (meaning, intestinal enzyme), which is an enzyme attached to the brush border (microvilli) of the small intestine.

Trypsin then activates more trypsinogen, as well as **chymotrypsinogen** and **procarboxypeptidase**. Pancreatic juice also contains pancreatic **amylase**, which continues the polysaccharide digestion that was initiated in the oral cavity. In addition, pancreatic juice contains a group of lipid digesting enzymes called **pancreatic lipases**, which break down lipids into free fatty acids, glycerides, cholesterol, and other components. Enzymes that reduce DNA and ribonucleic acid to their component nucleotides, **deoxyribonucleases** and **ribonucleases**, respectively are also present in pancreatic juice.

Control of Pancreatic Secretion

The exocrine secretions of the pancreas are controlled by both hormonal and neural mechanisms. **Secretin** stimulates the secretion of a watery solution that contains a large amount of bicarbonates ions from the pancreas. The primary stimulus for secretin release is the presence of acidic chyme in duodenum.

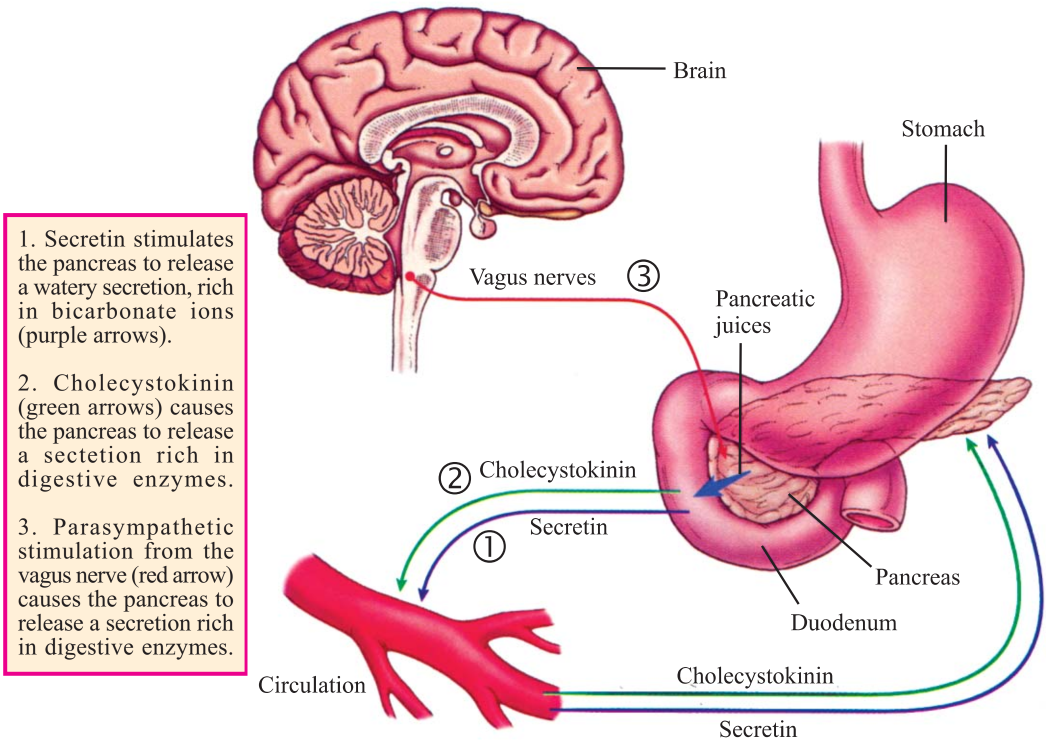


Fig: 11.10 Control of Pancreatic Secetion

Q. What would happen if sodium bicarbonate from the pancreas do not reach the small intestine?

11.2 DISORDERS: Digestive System and Food Habits

Ulcer

Etiology: Peptic ulcer is classically viewed as a condition in which the stomach acids digest the mucosal lining of the GI tract itself. The sites of peptic ulcer are: oesophagus, stomach, duodenum and jejunum. 90-95% of duodenal ulcer occurs in the first part of duodenum, 50% are on the anterior wall. It is common four times than gastric ulcer. More than 90% of gastric ulcer occurs in the lesser curvature. *Helicobacter pylori* is the most important factor in peptic ulcer disease, accounting for 90% of duodenal ulcer and 70% of the gastric ulcer. Aspirin (acetyl salicylic acid) and other non-steroidal anti-inflammatory agents are an important etiologic factor. Peptic ulcer tends to run in families i.e. it is a hereditary disease. Those with blood group O and those unable to secrete their blood group antigen into the saliva and gastric juice are more predisposed to peptic ulceration. Smoking is an important risk factor.

Prevention: Aggravating factors such as smoking, asprin, excess intake of coffee and tea, alcohol, missing a meal are to be avoided.

Treatment: The relieving factors of ulcer are antacid and milk, vomiting relieves pain in gastric ulcer, and intake of food relieves pain in duodenal ulcer. Medicines for acid suppression are the first choice of therapy.

Nobel Prize Winner in 2005: Barry Marshall (right side) and his co-workder Robin Varan

In the early 1980's an Australian medical resident named Barry Marshall firmly believed that bacteria play a role in ulcers, but physicians have always blamed the open sores on stress or prescription drug side effects. Marshall set out to prove the bacterial link. One morning in 1984, he walked into his lab, stirred a beaker full of beef soup and *Helicobacter pylori* and gulped the concoction. After five days he began to vomit. Marshall and others demonstrated that *Helicobacter pylori* is responsible for 70% of ulcer. Marshall and his co-worker Robin Varan were awarded Nobel Prize in 2005.

Food Poisoning

It includes diarrhoea (American spelling: diarrhea), vomitting and abdominal pain. They occur within 12-24 hours after eating contaminated food. It is an illness from indigestion of food containing toxic substances.

Etiology: Due to the **toxins** produced by bacteria, *Salmonella* and *Campylobacter*. These bacteria live in the intestines of cattle, chicken and duck without causing disease symptoms. Human, however, may develop food poisoning by taking the liquid that escapes during defrosting as frozen meat contains *Salmonela* bacteria. The dishes and utensils while the meat is defrosting must not be allowed to come in contact with any other food.

Symptoms: These include fatigue, dizziness, double vision, headache, nausea, vomitting, diarrhoea and abdominal pain.

Prevention: Basic hygiene should be followed. Avoid unboiled /unbottled water, ice, cubes, salads and peel on fruits. Consume freshly prepared hot food or thoroughly rewarmed food.

> **S.T.S Connections**
> Relate Ulcer, food poisoning and dyspepsia with eating habits of the society.

Treatment: Soft easily digested diet, such as soup, fruits drinks, tea and cold drinks are preferred. Oral rehydration salt (ORS) is given. Antidiarrhoeal agent such as Lepromide, antibiotics are prescribed.

Dyspepsia

Incomplete or imperfect digestion is called dyspepsia. It is not a disease in itself but symptomatic of other diseases. This is characterized by abdominal discomfort, flatulence, heartburn, nausea, vomiting.

Etiology: It may occur due to excessive acidity in stomach or faulty function of stomach and intestine or insufficient quality and quantity of bile secretion.

Prevention: Avoid food that worsens symptoms. Stop smoking, weight reduction, small meals, avoid alcohol, tea, fatty food, heavy lifting, bending specially after meals and late night meals to reduce reflex during sleep.

Treatment: Antibiotics to be given against this disease. Drugs which decrease HCl production such as Cimetidine; stop NSAID (Non-Steroidal Anti Inflammatory Drugs) e.g. Aspirin

Obesity

When a person has abnormal amount of fat on the body it is called obesity. It can be classified according to the number and size of the cells. In hyperplastic obesity a greater than normal number of fat cells occur that are also larger than the normal. Hypertrophic obesity results from a normal number of fat cells that have increased in size. The distribution of fat in obese individual can vary.

Etiology: Obesity can occur for many reasons and obesity in an individual can have more than one cause. Excessive intake of food is responsible for obesity. Emotional disturbances, inherited tendency to obesity, disorder of the thyroid, pituitary or adrenal glands etc, can also cause obesity.

Prevention: Food should be taken according to energy intake and energy expenditure. Diet control, regular exercise can prevent obesity.

Related Disorders: The distribution of fat difference can be clinically significant because upper body obesity is associated with an increased likelihood of diabetes mellitus, cardiovascular disease, and stroke. Many other diseases are associated with obesity like angina, heart failure, anaemia, arthritis etc. Obesity shortens life expectancy.

Q. Write the adverse affects of obesity on health.

Bulimia Nervosa

Symptoms: It is a neurotic disorder in slightly older girls. It is characterized by bouts of over eating fattening food such as fried food or cream cakes. This voracious eating followed immediately by self-induced vomitting, fasting or purging may cause physical effects including serum electrolytes imbalance and frequent recurring infections.

Treatment: Treatment of bulimics is likely to be prolonged. The initial treatment is to overcome the effects of weight loss and malnutrition. It is necessary to undertake the treatment in hospital under strict supervision.

Anorexia Nervosa

It is the loss of appetite due to the fear of becoming obese. Such a feeling is common in human females between the age of 12 and 21 years. Usually just after the onset of puberty.

Symptoms: It includes loss of appetite due to the fear of becoming obese. The anorexic girls over estimate the size of her own body and so insist that she is over weight, when in reality her weight has dropped to a dangerous level. These girls are often not matured psychologically and unable to cope with the challenges of puberty and their emerging sexuality. The losses of feminine characteristics enable the girls to retreat into a child like state in which she feels safe.

Therapy: Psychiatric therapy is usually required to treat anorexic girls. Such patients are fed through any other route other than alimentary canal i.e. intravenously. The recovery is very slow. It may take 2-4 years and in some cases longer.

Exercise

SECTION I : MULTIPLE CHOICE QUESTIONS

Select the correct answer

1. Pepsinogen is activated to pepsin by
   A) active secretin B) hydrochloric acid
   C) active pepsin and HCl D) gastrin
2. Liver secretes bile into the
   A) duodenum B) ileum
   C) jejunum D) peritoneum
3. Emulsification of fat will not occur in the absence of
   A) lipase B) bile pigment
   C) bile sat D) pancreatic juice
4. pH of stomach is 7, which component of food will be digested?
   A) sucrose B) protein
   C) fat D) glucose
5. Fatty acids and glycerol are first absorbed by
   A) lymph vessel B) villi
   C) blood capillaries D) hepatic portal vein

6. The hormone responsible for stimulating secretion of hydrochloroic acid by stomach cells is

A)	pepsin	B)	secretin
C)	gastrin	D)	insulin

7. On removal of pancreas the compound, which remains undigested, is

A)	protein	B)	fat
C)	glucose	D)	lactose

8. Excess intake of the following causes obesity

A)	vitamin	B)	proteins
C)	carbohydrates	D)	mineral

9. Enzyme trypsinogen is changed to trypsin by

A)	gastrin	B)	enterokinase
C)	secretin	D)	hydrochloric acid

10. Cholesterol is synthesized in

A)	liver	B)	pancreas
C)	spleen	D)	gallbladder

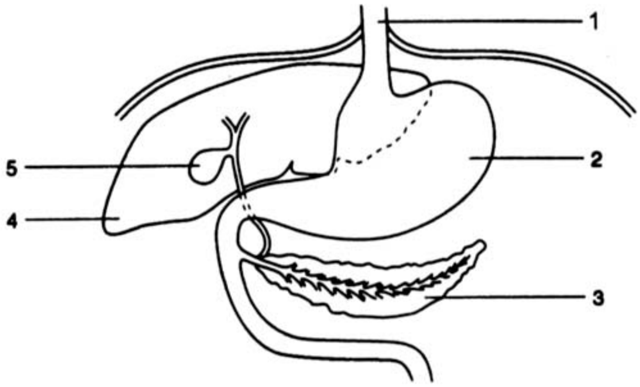
11. Largest gland in human body is

A)	pituitary	B)	thyroid
C)	pancreas	D)	liver

12. Narrow distal part of stomach is

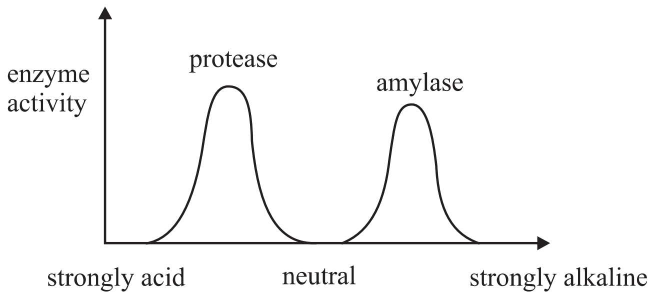
A)	cardiac	B)	pharynx
C)	duodenum	D)	pylorus

13. The diagram shows part of the human alimentary canal. Which two structures produce substances involved in the digestion of fat?



A) 1 and 5 B) 3 and 4 C) 2 and 3 D) 4 and 5

14. The diagram shows the effect of pH on the activity of two enzymes, a protease and an amylase, in the alimentary canal.



In which regions of the alimentary canal would these enzymes be most active?

A	duodenum	colon
B	duodenum	stomach
C	stomach	colon
D	stomach	duodenum

15. If the mucus lining covering the stomach breaks down and stomach tissue is damaged.

A) a peptic ulcer will form

B) appendicitis will result

C) microvilli will invade the stomach

D) absorption of food molecules cananot take place.

SECTION II : SHORT QUESTIONS

1. Why there are villi in the intestine and not in stomach?
2. Bile juice contains no digestive enzymes, yet it is important for digestion. Why?
3. Give one reason as to why some enzymes in stomach and intestine are secreted in inactive form?
4. Name the three intestinal enzymes involved in protein digestion.
5. How could no secretion of HCl in our stomach affect food digestion?
6. Trypsin acts at alkaline pH. What provides the alkalinity?
7. Distinguish between gastrointestinal tract, viscera, accessory digestive organs and gut.
8. Name three eating disorders.
9. How does the stomach protects itself from the damaging effect of HCl?
10. List the functions of large intestine.
11. Name and state the functions of hormones that assist the nervous system in regulating digestive secretions.
12. Is the muscle activity of peristalsis under voluntary control or is it an involuntary process? Does digestion occur in the oesophagus as paristalsis is occurring?
13. How does the absorption of fat differ from absorption of glucose?
14. What happens to ingested cellulose in humans?
15. What would happen to the activity of the intestinal enzymes if the pH in the small intestine remained at 2?

SECTION III : EXTENSIVE QUESTIONS

1. List the organs of the digestive tract and state the contribution of each to the digestive process.
2. Describe the process of chemical digestion in man.
3. Describe the structure, storage and metabolic role of liver of man.
4. Describe with diagram the process of deglutition in man.
5. Outline the structure of pancreas and explain its functions as an exocrine gland.

ANSWER MCQS

1. C 2. A 3. C 4. B 5. A 6. C 7. A 8. C 9. B 10. A
11. D 12. D 13. B 14. C 15. A

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