Name of Unit	Digestive System
Subject/Course Name	Human Anatomy and Physiology-II
Subject/Course ID	BP201T
Class: B. Pharm. Semester	II
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Learning Outcome of Module-2

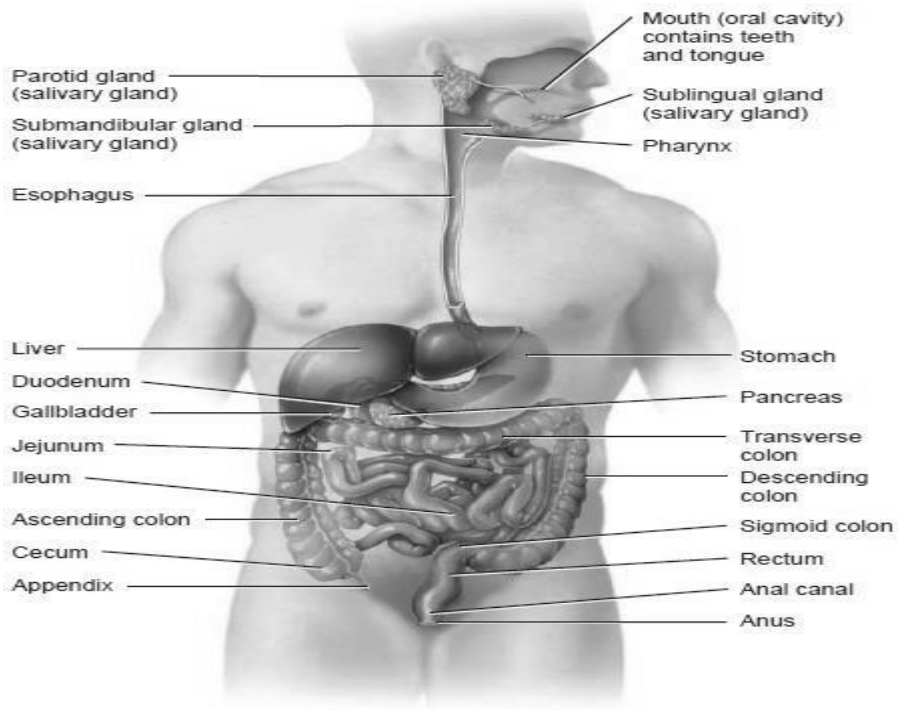
LO	Learning Outcome	Course Outcome Code
LO 1	To understand anatomy and physiology of gastrointestinal tract.	BP201.2
LO 2	To understand physiology of digestion and focus the role of enzymes on digestion.	BP201.2
LO 3	To understand physiology of acid secretion.	BP201.2
LO 4	To understand structure and functions of accessory digestive organ such as Liver, Panaceas, Gall Bladder.	BP201.2

Content Table

Topic
• Anatomy and functions of stomach, (Acid production in the stomach, regulation of acid production through parasympathetic nervous system, pepsin role in protein digestion) small intestine and large intestine. • Anatomy and functions of salivary glands, pancreas and liver, movements of GIT, digestion and absorption of nutrients and disorders of GIT. • Formation and role of ATP, Creatinine Phosphate and BMR. • Understand various disorder related to digestive system

DIGESTIVE SYSTEM

The digestive system is a system of body which breakdown food into forms that can be absorbed and used by body cells. It also absorbs water, vitamins, and minerals, and eliminates wastes from the body. It breakdowns the larger molecules present in food into molecules that are small enough to enter body cells by a process known as digestion. The organs which are involved in the breakdown of food are collectively called the digestive system. The digestive system is a tubular system which extends from the mouth to the anus.



Digestive system

The digestive system can be divided into two parts:

1. The gastrointestinal (GI) tract, or alimentary canal (alimentary = nourishment), is a continuous tube that extends from the mouth to the anus. Organs of the gastrointestinal tract include the mouth, most of the pharynx, esophagus, stomach, small intestine, and large intestine.

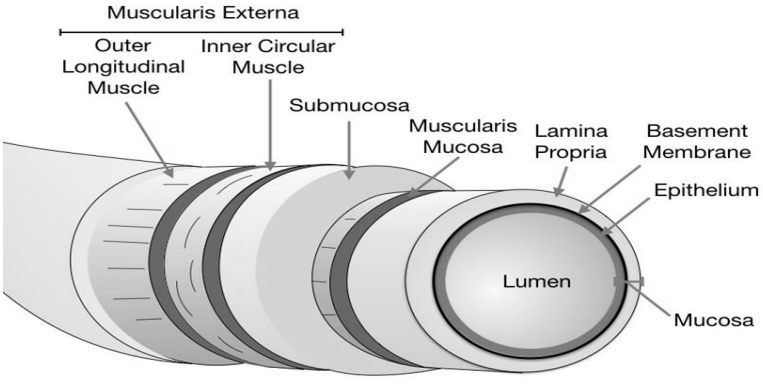
2. The accessory digestive organs are the organs which assist in digestion of food. These include the teeth, tongue, salivary glands, liver, gallbladder, and pancreas. Teeth aid in the physical breakdown of food, and the tongue assists in chewing and swallowing. The other accessory digestive organs never come into direct contact with food but they produce secretions which aid in the chemical breakdown of food.

Functions of digestive system:

1. **Ingestion:** This process involves taking foods and liquids into the mouth (eating).
2. **Secretion:** Cells within the walls of the GI tract and accessory digestive organs secrete about 7 liters of water, acid, buffers, and enzymes into the tract which help in digestion of food.
3. **Mixing and propulsion:** Alternating contractions and relaxations of smooth muscle in the walls of the GI tract mix food and secretions and propel them toward the anus. This capability of the GI tract to mix and move material along its length is called motility.
4. **Digestion:** Digestion is of two types- **Mechanical** and **Chemical** digestion. In mechanical digestion the teeth cut and grind food into smaller pieces. Then smooth muscles of the stomach and small intestine break it into further small pieces and mix it thoroughly with digestive enzymes. In chemical digestion the large carbohydrate, lipid, protein, and nucleic acid molecules in food are split into smaller molecules by hydrolysis and digestive enzymes. Vitamins, ions, cholesterol and water can be absorbed without chemical digestion.
5. **Absorption:** The entrance of ingested and secreted fluids, ions, and the products of digestion into the epithelial cells lining the lumen of the GI tract is called absorption. The absorbed substances pass into blood or lymph and circulate to cells throughout the body.
6. **Defecation:** Wastes, indigestible substances, bacteria, cells sloughed from the lining of the GI tract, and digested materials that were not absorbed in their journey through the digestive tract leave the body through the anus in a process called defecation. The eliminated material is termed feces.

Layers of GI Tract:

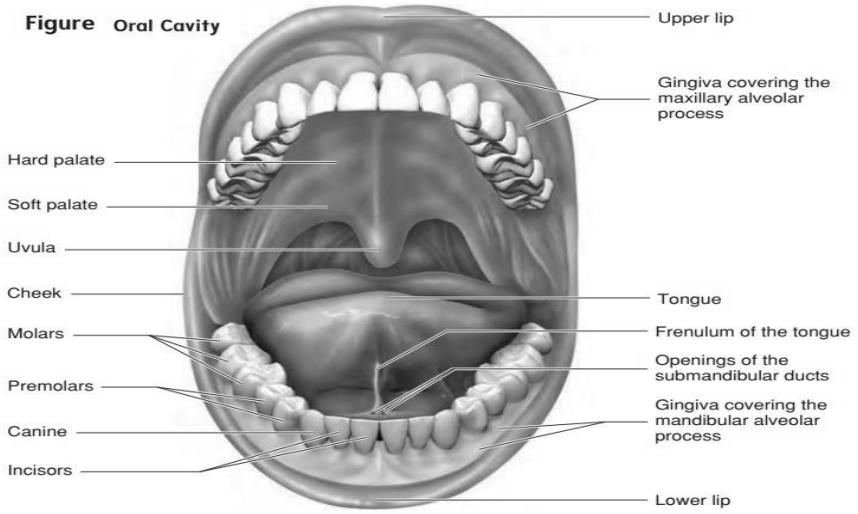
The wall of the GI tract has four layers tissues. These four layers (from deep to superficial) are the mucosa, submucosa, muscularis, and serosa.



Wall of the GI tract

Parts of digestive system:

Mouth Cavity: Mouth is also called Oral cavity or buccal cavity. It is formed by cheeks, hard palate, soft palate and tongue.Cheeks form lateral walls of mouth and is covered by skin from outside and mucous membrane from inside.Hard palate forms anterior portion of roof of mouth. Hard palate is made up of palatine and maxillae bones covered with mucous membrane. Hard palate forms bony partition between oral and nasal cavity.Soft palate forms posterior portion of roof of mouth. It forms partition between oropharynx and nasopharynx. Soft palate is also covered with mucous membrane. Uvula is small muscular process hanging from soft palate. It prevents entrance of swallowed food and liquid into nasal cavity.



Mouth Cavity

Salivary glands:

A salivary gland is a gland that releases a secretion called saliva into the oral cavity. Saliva is secreted to keep the mucous membranes of the mouth and pharynx moist and to cleanse the mouth and teeth. When food enters the mouth, secretion of saliva increases, and it lubricates, dissolves and begins the chemical breakdown of the food. There are 3 pairs of major salivary glands which secrete saliva:

1. **The parotid glands:** (par = near; ot = ear) are located near ears. These secretes saliva into the oral cavity via a parotid duct that open into the vestibule opposite the second maxillary (upper) molar tooth.
2. **The submandibular glands:** (sub = below, mandible = lower jaw bone) are found in the floor of the mouth, below lower jaw. Their ducts open into the oral cavity lateral to the lingual frenulum.

3. **The sublingual glands:** (sub = below, lingual = tongue) are beneath the tongue and superior to the submandibular glands. Their ducts open into the floor of the mouth.
4. Several minor glands are also present in cheeks, palates, tongue and lips etc. which produce small amount of saliva. Process of secretion of saliva is called **salivation**.

Composition and functions of saliva:

Chemically saliva consists of 99.5% water and 0.5% of solutes. Solutes include ions such as chloride ions, sodium, potassium, bicarbonate and phosphate ions.

It also contains various organic substances like urea, uric acid, mucus, immunoglobin A, bacteriolytic enzyme lysozyme and salivary amylase. Water dissolves food and helps to produce taste of food to initiate digestion.Chloride ions in saliva activate salivary amylase which is an enzyme that starts breakdown of starch.Phosphate and bicarbonate ions buffer acidic food so that saliva is only slightly acidic (6.35- 6.85) Mucus lubricates and moistens food for easy swallowing. IgA prevents microbes to enter or attach epithelial cells whereas lysozyme destroys harmful bacteria.

Tongue:

Tongue is an accessory digestive organ composed of skeletal muscle covered with mucous membrane. It helps to taste the food, swallow food and to speak. Tongue and its associated muscles form floor of tongue. Tongue is divided into 2 symmetrical lateral parts by a median septum that extends its whole length. Tongue consists of two types of muscles:

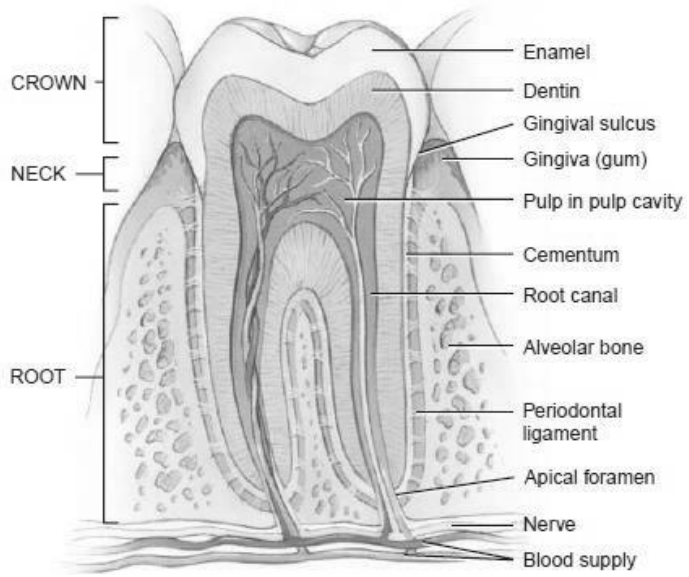
1. The extrinsic muscles move the tongue from side to side and in and out to maneuver food for chewing, shape the food into a rounded mass, and force the food to the back of the mouth for swallowing. They also form the floor of the mouth and hold the tongue in position.

2. The intrinsic muscles alter the shape and size of the tongue for speech and swallowing.

Teeth

Teeth or dentes are the accessory digestive organs which cut, tear and pulverize the solid food to reduce it into smaller particles which makes it easy to swallow and digest. Teeth are located in aveolar processes of mandible and maxillae. Aveolar processes are covered with gingivae (gums) that extend into each socket. Sockets are lined by periodontal ligaments made of dense firbrous connective tissue with anchors teeth into socket.

A tooth has three parts: **crown, root, and neck**. The crown is the visible portion above the level of the gums. Roots are the portion embedded in the socket. The neck is the constricted junction of the crown and root near the gum line.



Anatomy of teeth

There are two types of teeth that are developed in life. The first is called the **deciduous or milk** teeth and the second is called the **permanent teeth**. Basically, there are four types of teeth present in the human body, are incisors, canines, premolar and, molar. The deciduous or milk teeth are number in twenty and the permanent teeth are thirty-two.

Deciduous and permanent teeth

AREA	INCISORS	CANINES	PREMOLARs	MOLARS	TOTAL TEETH
DECIDUOUS TEETH					
Upper jaw	2	1	-	2	20
Lower jaw	2	1	-	2	
PERMANENT TEETH					
Upper jaw	2	1	2	3	32
Lower jaw	2	1	2	3	

Mechanical and Chemical digestion in the mouth:

1. Mechanical digestion: Mechanical digestion starts with mechanical breakdown of food by teeth by **chewing** or **mastication**. After chewing and mixing with saliva, food is converted into soft, flexible and easily swallowed mass called **bolus (lump)**. Small food molecules are dissolved in saliva and water after which they are reacted upon by enzymes.

1. Chemical digestion: It is done by 2 enzymes:

a) **Salivary amylase:** It is secreted by salivary glands. It causes breakdown of starch into simple units of monosaccharides and bisaccharides. Food contains mono, bi and polysaccharides but

only monosaccharides are absorbed. So it starts breakdown of polysaccharides into smaller until it is inactivated by acid present in stomach.

b) **Lingual lipase:** It is secreted by glands in tongue and results in breakdown of triglycerides into diglycerides and fatty acids. It is activated in acidic environment of stomach. So it is inactive in mouth and starts working after swallowing of food.

Pharynx:

Pharynx is funnel shaped tube, covered with mucous and composed of skeletal muscle. It is present in region which extends from internal nares to esophagus. It is divided into 3 parts: **Nasopharynx:** helps in respiration; **Oropharnyx and laryngopharynx:** it helps in respiration as well as swallowing of food.

Esophagus:

It is a collapsible muscular tube (25 cm long) which starts from inferior end of laryngopharynx and it ends at superior portion of stomach. It lies posterior to trachea and anterior to vertebral column. Its main function is to transfer the bolus from mouth to stomach.

At each end of the esophagus a sphincter is present. The upper esophageal sphincter (UES) consists of skeletal muscle and the lower esophageal sphincter (LES) consists of smooth muscle. The upper esophageal sphincter regulates the movement of food from the pharynx into the esophagus and the lower esophageal sphincter regulates the movement of food from the esophagus into the stomach.

The movement of food from the mouth into the stomach is achieved by the act of **swallowing**, or **deglutition**. Deglutition is facilitated by the secretion of saliva and mucus and involves the mouth, pharynx, and esophagus. Swallowing occurs in three stages: (1) the voluntary stage, in which the bolus is passed into the oropharynx; (2) the pharyngeal stage, the involuntary passage of the bolus through the pharynx into the esophagus; and (3) the esophageal stage, the involuntary passage of the bolus through the esophagus into the stomach. During esophageal phase, peristalsis (stalsis = constriction), a progression of coordinated contractions and relaxations of the circular and longitudinal layers of the muscularis, pushes the bolus toward stomach.

Stomach:

Stomach is a ‘J’ shaped enlargement of GI Tract which lies directly inferior to diaphragm. It connect esophagus to duodenum (first part of small intestine). Stomach serves as mixing chamber and holding reservoir for food. When food is ingested, stomach pushes a small quantity of food

into duodenum periodically. As the size of stomach can vary, it can store large amount of food. In stomach, semisolid bolus is converted into liquid, digestion of starch continues, digestion of triglycerides and protein starts and absorption of several substances takes place.

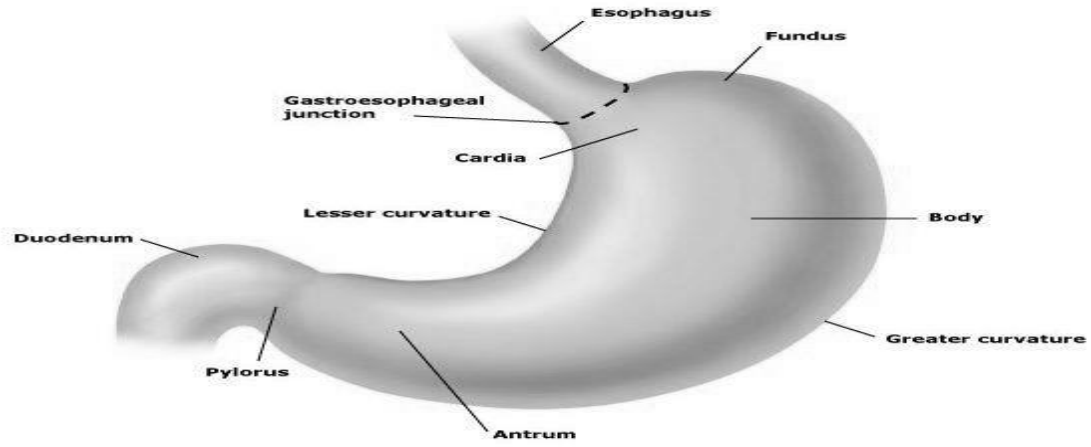
Anatomy of stomach: The stomach has four main regions: the cardia, fundus, body and pylorus. The **cardia** surrounds the superior opening of the stomach.

The **fundus** is the rounded portion superior and left to the cardia.

The **body** is inferior to the fundus and is the large central portion of the stomach.

The **pylorus** is the region of the stomach that connects to the duodenum. (pyl = gate; orus = guard). Pylorus has two parts, the **pyloric antrum** which connects to the body of the stomach, and the **pyloric canal**, which leads into the duodenum.

When the stomach is empty, the mucosa lies in large folds, called rugae (wrinkles) that can be seen with the unaided eye. The pylorus communicates with the duodenum of the small intestine via a smooth muscle sphincter called the **pyloric sphincter**. The concave medial border of the stomach is called the **lesser curvature**, and the convex lateral border is called the **greater curvature**.



Anatomy of stomach

Histology of stomach: The stomach wall is composed of 4 basic layers:

1. Mucosa: Mucosa contains several glands called **gastric glands**. The gastric glands contain three types of exocrine gland cells and one type of endocrine cells that secrete their products into the stomach and bloodstream respectively.

a) **Mucous neck cells:** These cells secrete mucus.

b) **Chief cells:** The chief cells secrete pepsinogen and gastric lipase.

c) **Parietal cells:** Parietal cells produce intrinsic factor (needed for absorption of vitamin B12) and hydrochloric acid. The secretions of the mucous, parietal & chief cells collectively form **gastric juice** (2–3 Lt/day).

d) **G cell:** These are endocrine cells which are located mainly in the mucous of pyloric antrum and secrete the hormone gastrin into the bloodstream

2. Submucosa: is made up of areolar connective tissue.

3. Muscularis: is composed of 3 layers of smooth layers; oblique muscles, circular muscles and longitudinal muscles.

4. Serosa: forms outer most layer of stomach.

Mechanical and chemical digestion in stomach:

1. When food enters the stomach, gentle peristaltic waves pass over the stomach every 15-25 second which is called mixing waves. These waves mix the food with gastric juice and convert it into a soupy liquid called **chyme**.

1. As digestion proceeds more vigorous mixing wave start at body of stomach and intensify as they reach pylorus. At pylorus, each wave periodically pushes little amount of chyme into small intestine thorough pyloric sphincter. This process is called **gastric emptying**.

2. Starch is digested by salivary amylase when food is in fundus. When food moves into body, mixing of chyme with gastric juices starts. The salivary amylase is inactivated and lingual lipase is activated. This stops digestion of starch and starts digestion of triglycerides into diglycerides and fatty acids.

3. Parietal cell present in walls of stomach starts secretion of a strong acid HCl, which kills microbes and denature proteins. HCl also stimulate secretion of hormones which further increases flow of bile and pancreatic juices.

4. Enzymatic digestion of proteins also begins in the stomach. The chief cells in stomach secrete proteolytic (protein-digesting) enzyme in the stomach called **pepsin**. Pepsin breaks peptide bonds to breaking down a large protein chain smaller peptide fragments. Pepsin is most effective in the very acidic environment of the stomach (pH 2); it becomes inactive at a higher pH.

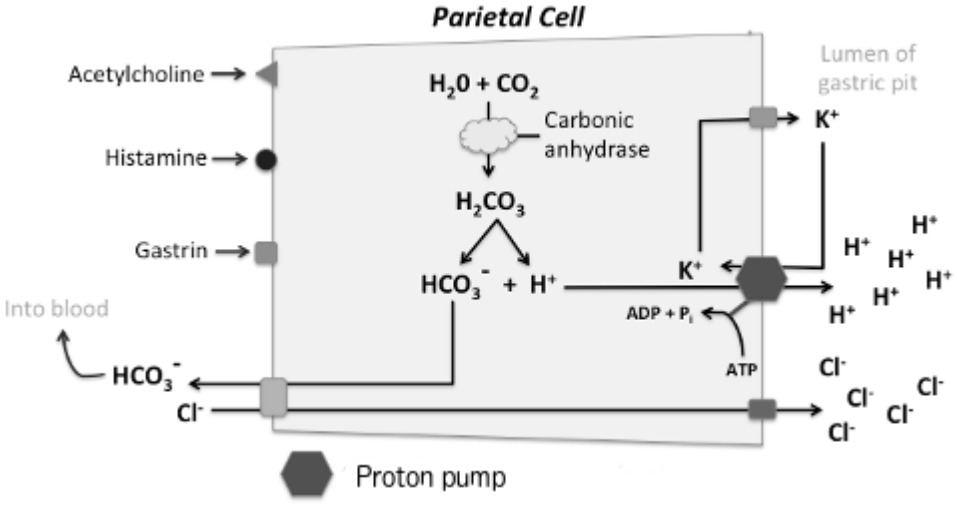
First, pepsin is secreted in an inactive form called pepsinogen; in this form, it cannot digest the proteins in the chief cells that produce it. Pepsinogen is not converted into active pepsin until it comes in contact with hydrochloric acid secreted by parietal cells or active pepsin molecules.

Second, the stomach epithelial cells are protected from gastric juices by a 1–3 mm thick layer of alkaline mucus secreted by surface mucous cells and mucous neck cells.

Another enzyme of the stomach is gastric lipase, which splits the short-chain triglycerides in fat molecules.

Only a small amount of nutrients are absorbed in the stomach *e.g.* water, ions, and short- chain fatty acids, as well as certain drugs (especially aspirin) and alcohol.

Mechanism of HCl secretion by parietal cells: Parietal cells secrete H+ and Cl- separately into stomach lumen but net effect is secretion of HCl. Proton pumps actively transport H+ into lumen and bring K+ ion back into cell. At same time Cl- and K+ diffuse out into lumen through Cl- and K+ channels in apical membrane. Carbonic anhydrase enzyme present in parietal cell produces carbonic acid from CO2 and H2O. H2CO3 dissociates into H+ and HCO3-.H+ moves into lumen by H+/K+ ATPase pump and HCO3- moves into bloodstream. HCl secretion in parietal cells can be stimulated by Gastrin, Acetylcholine and Hisatmaine.



Mechanism of HCl secretion by parietal cells

Pancreas:

Pancreas (Pan = all, creas = flesh) is a retroperitoneal (behind peritoneum) gland, which lies posterior to greater curvature of stomach. It is 12-15cm long and 2-3cm thick. Anatomically it is divided into 3 parts:

a) **Head:** It is expanded portion and lies near to curve of duodenum

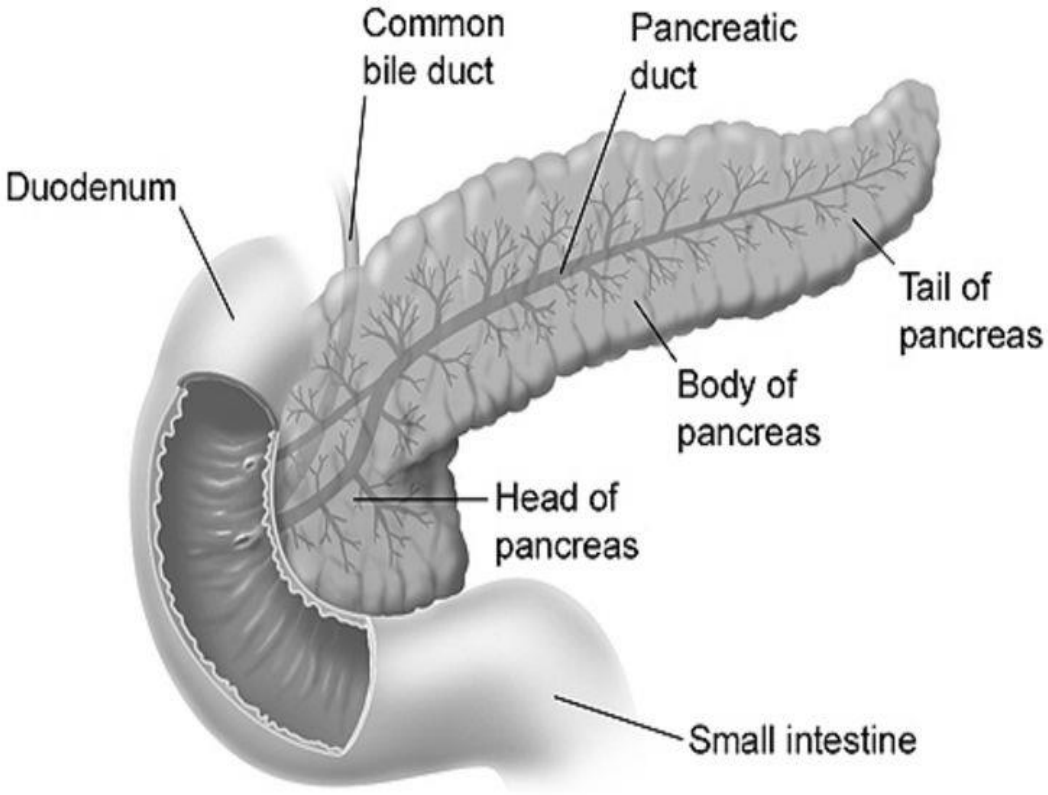
b) Body: It is central part and is left and superior to head.

c) Tail: It is last tapering portion of pancreas.

Pancreas has two ducts that open into duodenum and these ducts carry pancreatic juices into duodenum:

1. Pancreatic duct: It is larger in size. It combines with common bile duct from liver and forms hepatopancreatic ampulla which opens into duodenum.

2. Accessory duct: It is smaller and also opens into duodenum.



Anatomy of Pancreas

Histology of Pancreas:

Pancreas is made up of small clusters of glandular epithelial cells known as **acini**. 99% of acini are exocrine cells which secrete mixture of fluid and digestive enzymes called ***pancreatic juice***. 1% of acini are endocrine cells which are called ***Pancreatic Islets*** or ***Islet of Langerhans*****.** These pancreatic islets secrete 4 types of hormone:

Glucagon: It increases blood sugar level.

Insulin: It decreases blood sugar level.

Somatostatin: It maintains Gluacagon and Insulin level in body.

Pancreatic polypeptide: It controls somatostatin secretion.

Composition and functions of pancreatic juice:

1. Pancreatic juice is a clear, colorless liquid is consisting of water, salts, sodium bicarbonate and several enzymes. Each day 1200-1500 ml pancreatic juice is produced.
2. Sodium bicarbonate makes pancreatic juice slight alkaline (7.1-8.2) and stops action of pepsin from stomach and creates pH for action of digestive enzyme in small intestine.
3. Enzymes secreted in pancreatic juices are:

a) **Pancreatic amylase:** It is starch digesting enzyme.

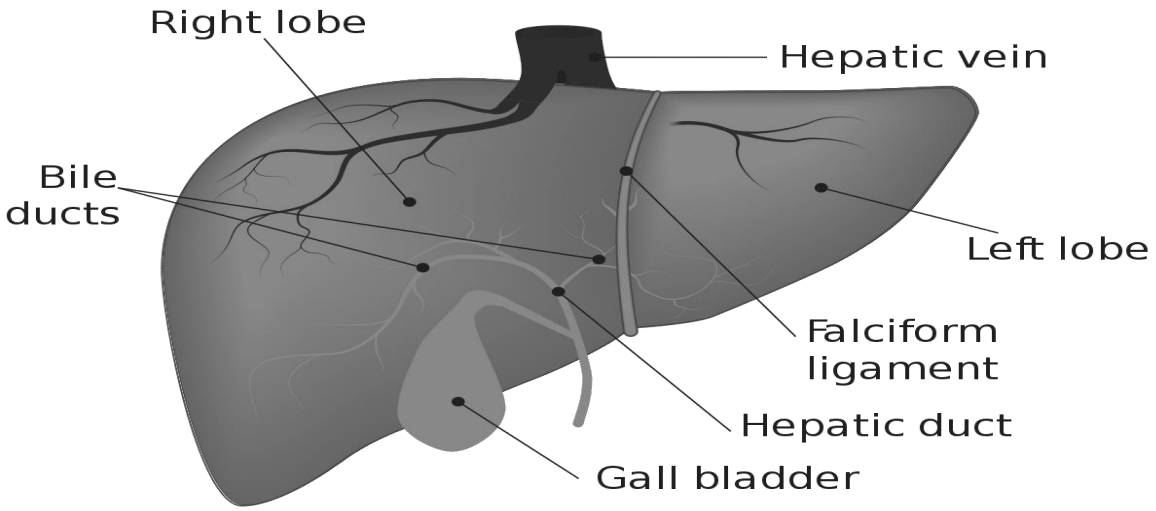
b) **Trypsin, Chymotrypsin, Carboxypeptidase, Elastase:** These are protein digesting enzymes.

c) **Pancreatic lipase:** This is major triglyceride digesting enzyme.

d) **Ribonuclease and deoxyribonuclease:** Nucleic acid digesting enzyme.

Liver and Gall bladder:

- Liver is the 2nd largest organ in body, located inferior to diaphragm.
- Gall bladder is pear shaped sac located inferiorly and posteriorly to liver.Liver is divided into 2 lobes; Right lobe (larger) and left lobe (smaller).
- Right and left lobes are separated by falciform ligament.
- Gall bladder has 3 portions. The inferior broad portion is called fundus, the middle portion is called body and the upper taper portion is called neck.



Anatomy of Liver

Histology of liver and Gall bladder:

Liver is made up of lobes. Lobes are made up of lobules (small functional units). Lobules are further made up of specialized cells called hepatocytes (hepato = liver, cytes = cells). Lobules contain highly permeable capillaries which supply blood to hepatocytes. These capillaries contain **stellate reticuloendothelial cells** also called **Kupffer cells**. These Kupffer cells act as phagocytes and destroy worn out RBC, WBC, bacteria and other foreign materials.

Hepatocytes secret bile into bile canaliculi.Bile canaliculi carry bile into bile ductules which transfers it into left hepatic duct or right hepatic duct. These left and right hepatic ducts combines to form common hepatic duct which further combines with cystic duct (from gall bladder) to form common bile duct.

Gall bladder: is made up of simple epithelial cells. Contraction of smooth muscles ejects the content of gall bladder into cystic duct. Functions of gall bladder are to store and concentrate the bile until required in duodenum. Concentration is done by the absorption of water and ions.

Role and composition of bile: Each day, hepatocytes secrete about 1 lt of bile, a yellow, brownish, or olive-green liquid. It has a pH of 7.6–8.6 and consists mostly of water, bile salts, cholesterol, a phospholipid called lecithin, bile pigments, and several ions.

1. Bile salts (sodium and potassium salts of bile acid) play role in emulsification. Emulsification is process of breakdown of large lipids into small lipid gloubules. These small gloubules are easily digested by pancreatic lipase.

2. Bile salts also play important role in absorption of lipids.

Functions of liver:

1. Carbohydrate metabolism: Liver maintains normal blood glucose level. When blood glucose level is low, it starts breakdown of glycogen (storage form of glucose) to glucose. It also converts lactic acid and amino acid into glucose. It can also convert fructose, galactose and other sugars into glucose. When blood sugar level rises, it converts glucose into glycogen and triglycerides for storage.

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

3. Protein metabolism: Hepatocytes remove amino group (NH_2) from amino acids so that amino acids can be used for ATP production or can be converted into carbohydrates or fats. The harmful free amino group (NH_2) is converted into urea which can be excreted out of body in urine.

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

5. Excretion of billirubin: Bilirubin, derived from the heme of aged red blood cells, is absorbed by the liver from the blood and secreted into bile. Most of the bilirubin in bile is metabolized in the small intestine by bacteria and eliminated in feces.

6. Synthesis of bile salts: Bile salts are used in the small intestine for the emulsification and absorption of lipids.

7. Storage: In addition to glycogen, the liver is a prime storage site for certain vitamins (A, B12, D, E, and K) and minerals (iron and copper).

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

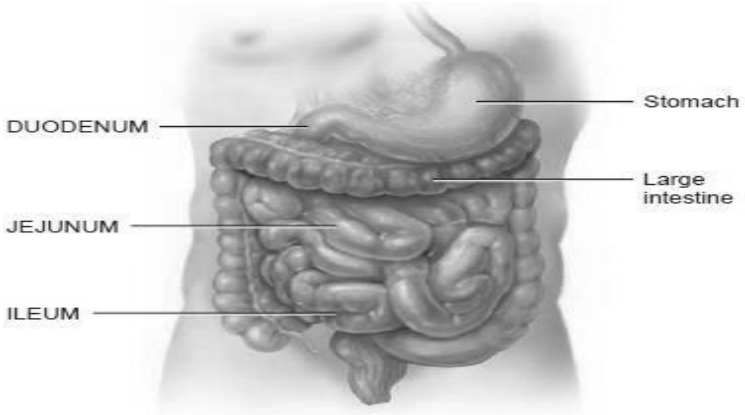
9. Activation of vitamin D: Liver along with skin and kidneys participate in synthesizing the active form of vitamin D.

Small Intestine:

Small intestine starts from pyloric sphincter of stomach, coils through central and inferior part of abdominal cavity and ends at large intestine. It has major role in digestion and absorption of nutrients.

Anatomy: It has 3 major parts

a) **Duodenum:** This is first part of small intestine. It starts from pyloric sphincter, extends up to 25 cm and merges into jejunum.
b) **Jejunum:** It is middle part and extends up to ileum.
c) **Ileum:** It is last part of small intestine and ends at ileocecal junction of large intestine.



Anatomy of Small Intestine

Histology: Small intestine is composed of same basic 4 layers:
1. Muscosa: The mucosa of small intestine contains many types of cells:

a) **Absorptive cells:** These cells digest and absorb nutrients.

b) **Goblet cells:** These cells secrete mucus.

c) **Paneth cells:** These secrete bactericidal enzyme lyzozyme. Lyzoyme play role in phagocytosis.

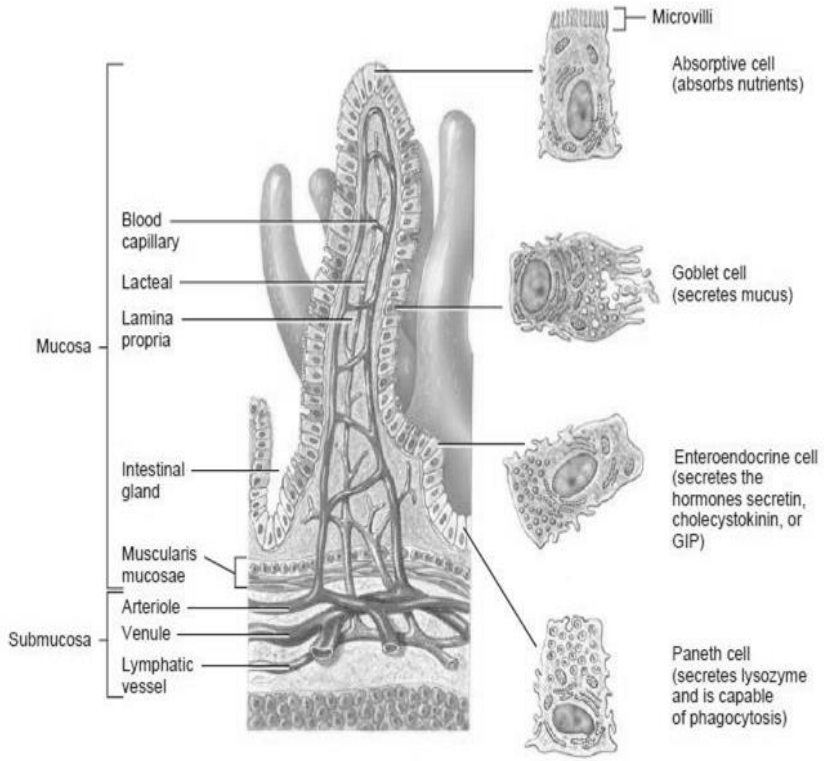
d) **Endocrine cells:** These cells secrete hormones into blood stream. These include:

S cells: secrete secretin

CCK cells: secrete cholecystokinin or CCK

K cells: secrete Glucose dependent insulinotropic peptide or GIP

Mucosas of small intestine also contain some special structural feature which facilitates digestion and absorption



Histology of Small Intestine

a) **Circular folds:** These are folds of mucosa and submucosa. These folds increase surface area and cause the chime to move spiral than straight as it passes through small intestine.

b) **Villi:** These are fingerlike projections of mucosa which vastly increases surface area for absorption and digestion. (20-40 sq. mm.)

c) **Microvilli:** These are projections from free membrane of absorptive cells. These are too small to see individually under microscope. Instead they form a fuzzy line called brush border. This brush border also contains several enzymes called brush border enzyme that have digestive function.

2. Submucosa: The submucosa of the duodenum contains duodenal which secrete alkaline mucus that helps neutralize gastric acid in the chyme.

3. Muscularis: The muscularis of the small intestine consists of two layers of smooth muscle *i.e.* The outer longitudinal and inner circular muscles.

4. Serosa: The serosa (or visceral peritoneum) completely surrounds the small intestine.

Role of intestinal juice and brush border enzyme:

About 1-2 Lt of intestinal juice (pH 7.6) is secreted every day which contained water and mucous. Intestinal juice mixes with pancreatic juices and provides the liquid medium for absorption of substance from chime into small intestine.

Brush border enzymes secreted from absorptive cells in small intestine contain following types of enzymes:

Four carbohydrate-digesting enzymes called α-dextrinase, maltase, sucrase and lactase Two Protein-digesting enzymes called peptidases (aminopeptidase and dipeptidase) Two types of nucleotide-digesting enzymes, nucleosidases and phosphatases.

Mechanical and chemical digestion in small intestine:

Mechanical Digestion: Two types of movements occur in small intestine which results in mechanical digestion:

1. **Segmentation:** These are localized mixing contractions that occur in portions of small intestine distended with large volume of chime. Segmentation helps in mixing and absorption of chyme, but it does not push chyme forward.
2. **Migrating motality complex (MMC):** This is a type of peristaltic movement which occurs when volume of chyme in distended portion of small intestine decreases. This pushes the chyme forward. Chyme remains in small intestine for 3-5 hours.

Chemical digestion: Chyme entering the small intestine contains partially digested carbohydrates, proteins, and lipids by the enzymes in mouth and stomach. The completion of the digestion of carbohydrates, proteins, and lipids occurs in small intestine and it is a collective effort of

pancreatic juice, bile, and intestinal juice.

1. Digestion of carbohydrates: Starches are broken into maltose, maltriose and α-dextrin units by **pancreatic amylase**. Following brush border enzymes act on these and convert it even smaller units.

a) **α-Dextrinase** acts on α-dextrin to produce glucose.
b) **Maltase** splits maltose and maltriose into 2-3 units of glucose.
c) **Lactase** digests lactose into a glucose and galactose.
d) **Sucrase** breaks sucrose into molecule of glucose and fructose.
e) Cellulose (a polysaccharide) is not digested by amylase enzymes and hence it is called roughage.

3. **Digestion of proteins:** Trypsin, chymotrypsin, carboxypeptidase and elastase convert proteins into peptide units. These peptides are converted into small amino acids by two enzymes **aminopeptidase** and **Dipeptidase** which break amino acids into single amino acids.

4. **Digestion of lipids:** Most of triglycerides in food are broken into long chain or short chain fatty acids and monoglycerides by pancreatic lipase. Long chain fatty acids are emulsified into short chain fatty acid by bile salts in small intestine.

5. **Digestion of nucleic acids:** Pancreatic juice contains two nucleases (nucleic acid digesting enzymes) **ribonuclease** (digests RNA) and **deoxyribonuclease** (digests DNA) into nucleotides. These nucleotides are further digested by brush-border enzymes called **nucleosidases** and **phosphatases** into pentoses, phosphates, and nitrogenous bases.

Absorption in small intestine: All chemical and mechanical phases of digestion convert large molecule into smaller one which can be easily absorbed. For example Carbohydrates are converted into monnosacchride *i.e.* glucose, fructose and galactose. Proteins are converted into single amino acids, dipeptides and tripeptides. Triglycerides are converted into fatty acids, glycerol and monoglycerides.

Passage of these digested nutrients from GIT into blood or lymph is called **absorption**. Nutrients move from lumen into absorptive cells and then pass to blood or lymph capillaries or lacteals in villi. **Lacteals** are network of blood and lymph capillaries which absorb fat. This absorbed fat

gives them milky appearance and hence they are called lacteals (lact = milky). 90% of all absorption of nutrients occurs in small intestine. Absorption is done by diffusion, fascilitated diffusion, osmosis and active transport.

1. Absorption of monosaccharides: All carbohydrates are absorbed as monosaccharides. Fructose is absorbed by fascilitated diffusion; glucose and galactose are absorbed by secondary active transport into absorptive cells. Monosacchrides move out of absorptive cells via facilitated diffusion.

2. Absortion of amino acids, dipeptides and tripeptides: Most of proteins are absorbed as amino acid via active transport. Dipeptides and tripeptides which enter absorptive cells are broken into to single amino acid. Amino acids move out of absorptive cells via diffusion.

3. Absorption of lipids: All dietary lipids are absorbed by simple diffusion. Triglycerides are broken into monoglycerides and fatty acids (long chain and short chain). Short chain fatty acids are absorbed easily. Long chain fatty acids and monoglycerides are absorbed with the help of bile salts. Bile salts form tiny spheres called micelles which carry fatty acids and monoglycerides to the absorptive cells for absorption. Micelles also help to solubilize and absorb other large hydrophobic molecules such as Vit. A, D, E, K and cholesterol.

4. Absorption of electrolytes: Electrolytes absorbed in small intestine come from ingested food, liquids and from gastrointestinal sescretions. Most of the electrolytes including Na^{+} , Ca^{2+} , negatively charged ions like bicarbonate, chloride, iodide, nitrate, other electrolytes like iron, potassium, magnesium and phosphate etc. are absorbed by active or passive transport.

5. Absorption of vitamins: Fat soluble vitamins like Vit. A, D, E, K are absorbed by simple diffusion by micelle formation. Water soluble vitamins Vit. B and C are also absorbed by simple diffusion. Vit B_{12} combines with intrinsic factor produced by stomach and and is absorbed in ileum via active transport.

6. Absorption of water: All water absorption in the GI tract occurs via osmosis. Because water can move across the intestinal mucosa in both directions, the absorption of water from the small intestine depends on the absorption of electrolytes and nutrients to maintain an osmotic balance with the blood.

Large Intestine:

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

Anatomy of large intestine: Large intestine is about 1.5 m long and extends from ileum to anus. The joining of small and large intestine occurs at ileocecal sphincter which controls movement of material from small intestine to large intestine. Large intestine consists of 4 major regions ***cecum, colon, rectum*** and ***anal canal***.

a) **Cecum** is a small pouch like organ which is present next to ileocecal sphincter. Attached to cecum is a coiled and twisted tube called appendix or vermiform appendix.
b) **Colon** is a long tube which is present next to cecum. The open end of cecum attaches with colon. Colon is divided into 4 portions *i.e.* ascending colon, transverse colon, descending colon and sigmoid colon.
c) **Rectum** is approximately last 20 cm of GI tract. Terminal 2-3 cm of rectum is called anal canal. Opening of anal canal to exterior is called anus which is guarded by internal sphincter of smooth muscles and external sphincter of skeletal muscles.

Histology of large intestine:

Walls of large intestine consist of same basic 4 layers:

a) **Mucosa:** Mucosa mainly consists of absorptive and goblet cells. The absorptive cells function in water absorption and the goblet cells secrete mucus that lubricates the passage of the colonic contents. Villi and circular folds are absent in large intestine.
b) **Submucosa:** Submucosa is similar to that of rest of GIT.
c) **Muscularis:** Muscularis consists of circular and longitudinal muscles. Tonic contraction of circular muscles divide colon into series of pouches called huastra.
d) **Serosa:** consist of visceral peritoneum.

Mechanical digestion in large intestine: As food passes through ileocecal sphincter, it fills the cecum and accumulates in ascending colon. The haustral churning occurs in colon. In this process, huastra remain relaxed and becomes distended when filled up. After a certain point, the walls contract and squeeze the content into next haustrum. Peristalsis occurs at slow rate. A final movement *i.e.* **mass peristalsis** which is a strong peristaltic wave, starts from middle of transverse colon and drives the colonic contents into rectum (3-4 times a day).

Chemical digestion in large intestine: Chemical digestion in large intestine is done by bacteria and no enzyme is secreted.

a) Bacteria ferments any remaining carbohydrate and releases hydrogen, CO_2 and methane gas. If excessive, these gases cause flatulence.

b) Bacteria also convert remaining protein to amino acids and amino acids into simple substances like indole, hydrogen sulphide which are further converted to less toxic substances by liver.

c) Bacteria also decompose bilirubin to simple pigment like stercobilin which gives brown color to fecal material.

d) Certain vitamins like Vitamin B and K are produced by bacteria which are absorbed in colon.

Absorption and feces formation in large intestine: Chyme remains for 3–10 hours in large intestine and it becomes solid or semisolid because of water absorption and then it is called feces. Chemically, feces consist of water, inorganic salts, sloughed-off epithelial cells from the mucosa of the gastrointestinal tract, bacteria, and products of bacterial decomposition, unabsorbed digested materials, and indigestible parts of food.

Although 90% of all water absorption occurs in the small intestine, the large intestine absorbs enough to make it an important organ in maintaining the body's water balance. The large intestine also absorbs ions, including sodium and chloride, and some vitamins.

Phases of Digestion:

Digestive activities occur in three overlapping phases: the cephalic phase, the gastric phase, and the intestinal phase.

1. Cephalic phase: During this phase, smell, sight, thought or initial taste of food activates neural centers in different parts of brain. The brain parts stimulate salivary glands and gastric glands to secrete saliva and gastric juices respectively. This phase of digestion prepare mouth and stomach for food that is about to be eaten.

2. Gastric phase: Once food reaches the stomach, the gastric phase of digestion begins. Neural and hormonal mechanisms regulate the gastric phase of digestion to promote gastric secretion and gastric motility.

3. Intestinal phase: When food come into the duodenum is moderate gastric activity via hormonal and neuronal reflexes.

Very Short Answer Type Question (2Marks)

1. Write short note on
    a. Salivary glands
    b. Teeth formula
    c. Different parts of stomach
    d. Listed layers of GIT

Short Answer Type Question (5 Marks)

1. Write short note on salivary glands and also mention function saliva.
2. Give the structure and functions of stomach.
3. Give anatomy and functions of small intestine.
4. Give anatomy and functions of large intestine.
5. Define digestion. Explain various phases involved in digestion.

Long Answer Type Question (10 Marks)

1. Draw a well-labled diagram of the digestive tract. Mention functions of the digestive system.
2. What mechanism is behind for secretion of HCl from the stomach?
3. Give structure and functions of pancreas.
4. Give structure and functions of liver.