The digestive system

The digestive system is the collective name used to describe the alimentary canal, some accessory organs and a variety of digestive processes that take place at different levels in the canal to prepare food eaten in the diet for absorption. The alimentary canal begins at the mouth, passes through thorax, abdomen and pelvis and ends at the anus (Fig.4.1). The digestive processes gradually breakdown the food eaten, until they are in a form suitable for absorption. Chemical substances or enzymes that effect these changes are secreted into the canal by specialized glands, some of which are in the walls of the canal and some outside the canal, but with ducts leading into it. The activities in the digestive system can be grouped under five main headings;

1) Ingestion: This is the taking of food into the alimentary tract, i.e. eating and drinking
2) Propulsion: This mixes and moves the contents along the alimentary tract.
3) Digestion: This consists of :
   - Mechanical breakdown of food by mastication or chewing
   - Chemical digestion of food into small molecules present in secretions produced by glands and accessory organs of the digestive system.
4) Absorption: This is the process by which digested food substances pass through the walls of some organs of the alimentary canal into the blood and lymph capillaries for circulation and use by body cells.
5) Elimination: Food substances that have been eaten but cannot be digested and absorbed are excreted from the alimentary canal as faeces by the process of defaecation.

General outline of the digestive system/tract

The human digestive canal is a long muscular tube consisting of the following parts from above downwards:

Mouth guarded by lips and teeth, tongue, pharynx, oesophagus, stomach, small intestine, large intestine, rectum and anal canal. Various secretions are poured into the alimentary tract by the accessory organs of digestion and their secretions pass through ducts to enter the duct and consist of three pairs of salivary glands, the pancreas, the liver and the biliary tract. The ducts of the salivary gland open into the mouth. The proximal end of the stomach is guarded by the cardiac sphincter. The distal end of the stomach is guarded by the pyloric sphincter. Small intestines begin after the pyloric sphincter and consist of the following sub divisions:

Duodenum, jejunum and ileum.

Duodenum receives food from the stomach. The bile duct and the pancreatic duct jointly open in it through "Ampulla of vater". Small intestine is very long (5-7m), the great length of the small intestine provides enough time and surface area, so that digestion and absorption of food may get completed. The small intestine opens into the next part, i.e. large intestine. The opening between them is guarded iliocolic sphincter. In the large intestine water is absorbed followed by the formation of faeces. The large intestine opens into the last part rectum and anal canal that opens outside.

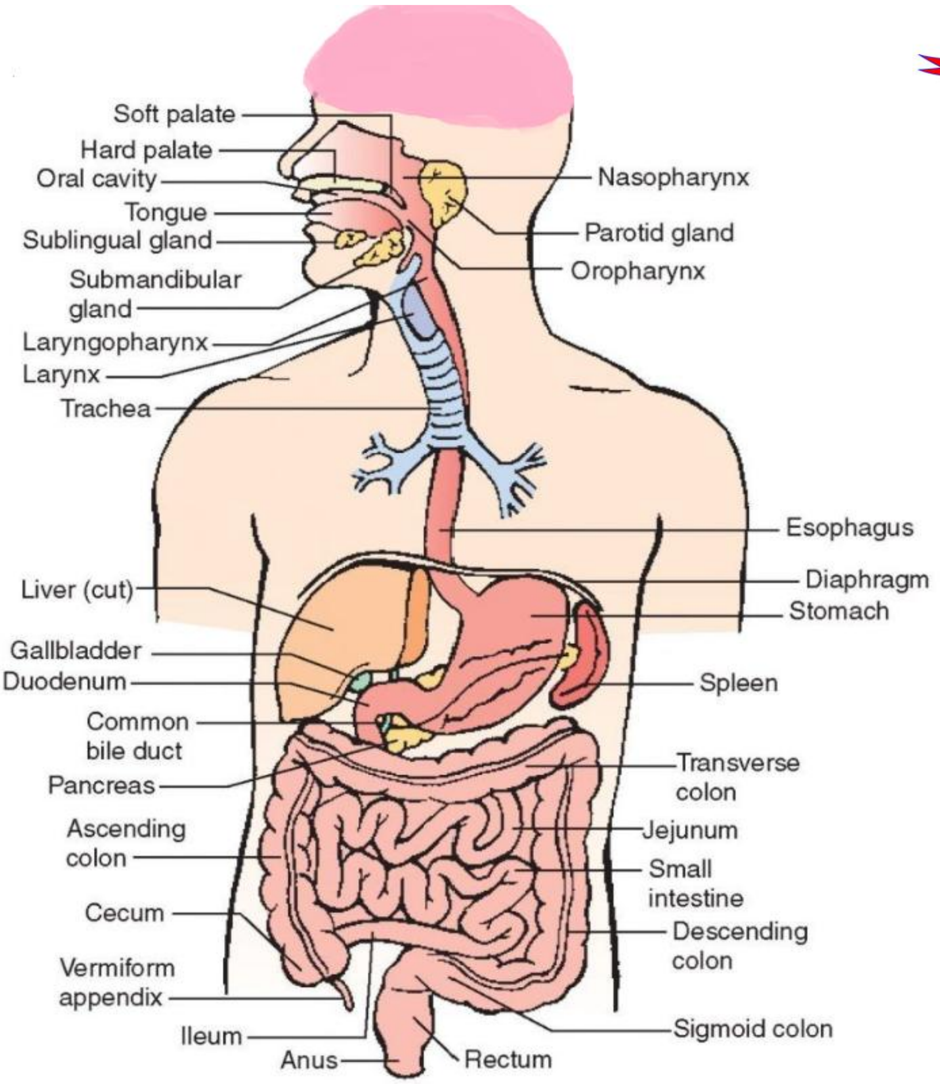

Fig.4.1.The digestive system

Basic structure of the alimentary canal (Histology)

The layers of the walls of the alimentary canal follow a consistent pattern from the oesophagus onwards. This basic structure does not apply so obviously the mouth and the pharynx. The walls of the alimentary tract area formed by four layers of tissue (Fig 4.2):

- Adventitia or serosa –outer covering
- Muscle layer
- Sub-mucosa
- Mucosa.

Adventitia or serosa

This is the outer most layer. In the thorax it consists of loose fibrous tissue and in the abdomen the organs are covered by a serous membrane (serosa) called peritoneum. Peritoneum is the largest serous membrane of the body. It consists of a closed sac, containing a small amount of serous fluid, within the abdominal cavity. It has two layers; the parietal layer, which lines the abdominal wall and the visceral layer which covers the organs (viscera) within the abdominal and pelvic cavities. The two layers of peritoneum are actually in contact, and friction between them is prevented by the presence of a serous fluid secreted by peritoneal cells, thus peritoneal cavity is only a potential cavity.

Muscle layer

With some exceptions it consists of two layers of smooth (involuntary) muscles. The muscle fibers of the outer layer are arranged longitudinally and those of the inner layer encircle the wall of the tube. Between these two muscle layers are blood vessels, lymph vessels and a plexus (network) of sympathetic and parasympathetic nerves, called the myentric or auerbach' plexus. These nerves supply the adjacent smooth muscle and blood vessels. Contraction and relaxation of these muscle layers occur in waves, which push the contents of the tract onwards. This type of contraction of smooth muscles is called as peristalsis.

Sub-mucosa

This layer consists of loose connective tissue collagen and some elastic fibres. Within it are plexuses of blood vessels and nerves, lymph vessels and varying amount of lymphoid tissue. The blood vessels are arterioles, venules and capillaries. The nerve plexus is the sub-mucosal or meissener's plexus, containing sympathetic and parasympathetic nerves that supply the mucosal lining.

Mucosa

This consists of three layers of tissues;

- Mucus membrane formed by the columnar epithelium is the innermost layer. And has three main functions: protection, secretion and absorption.
- Lamina propria. Consisting of loose connective tissue, which supports the blood vessels that nourish the inner epithelial layer and varying amount of lymphoid tissue that has a protective function.
- Muscularis mucosa, a thin outer layer of smooth muscle that provides involutions of mucosa layer. E.g. gastric gland and villi.

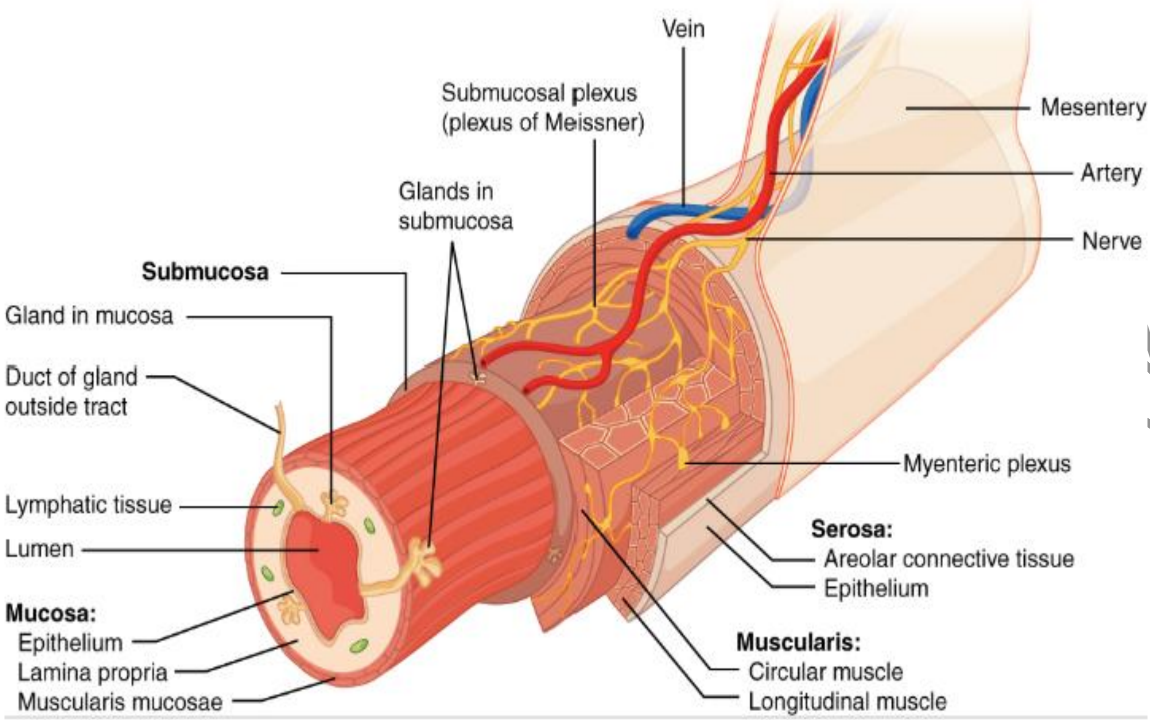

Fig 4.2 Basic structure of the alimentary canal (Histology)

Organs of the digestive system

The mouth

The mouth or oral cavity is the first part of the alimentary tract and is bound by muscles and bones. The mouth is throughout lined by mucus membrane consisting of stratified squamous epithelium, containing small mucus secreting glands. The mouth has two parts: the vestibule and the oral cavity. Vestibule is the part between the gums and the cheeks and the remainder of the cavity is the oral cavity. The palate forms the roof of the mouth and is divided into the anterior hard palate and the posterior soft palate (Fig 4.1). The maxilla and the palatine bones form the hard palate and the soft palate is made up of muscle tissue. The soft palate joins the walls of the pharynx at the sides. The uvula is a curved fold of muscle covered with mucus membrane hanging down from the free border of soft palate. The posterior folds, one on each side, are the palatopharyngeal arches and the two anterior folds are the palatoglossal arches. On each side, between the arches, is a collection of lymphoid tissue called the palatine tonsil (fig 4.3).

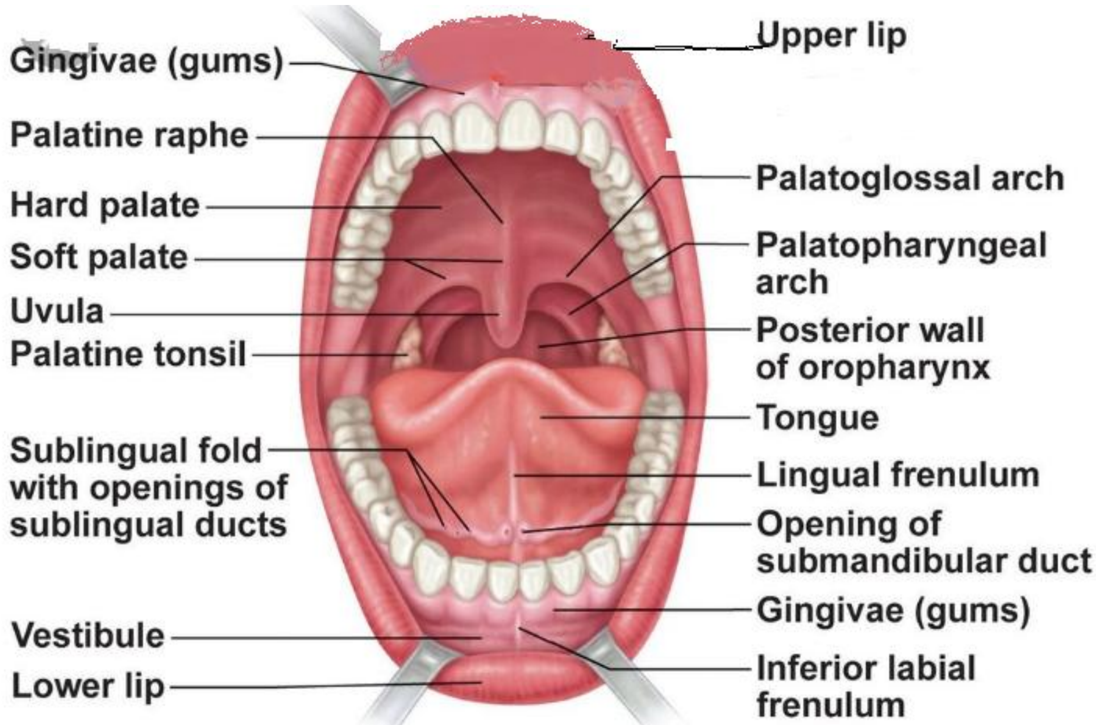

Fig 4.3 The Mouth

Lips

Lips are fleshy folds lined externally by skin and internally by mucus membrane.

Gums

Gums are the soft tissues which cover the alveolar processes of the upper and lower jaws and surround the necks of the teeth. The gums are made up of dense fibrous tissue, covered by stratified squamous epithelium.

Cheeks

Cheeks are flashy flaps, forming a large part of each side of the face. The cheeks are composed of skin, buccinators muscle, parotid duct, vessels and nerves, mucus glands and mucosa.

Tongue

The tongue is a highly mobile muscular structure, situated on the floor of the mouth. It is attached to the hyoid bone at its base and by frenulum (fold of mucus membrane covering) to the floor of the mouth. There are numerous papillae (small projections) on the upper surface of the tongue, which contain sensory receptors for the sense of taste in the taste buds. There are three varieties of papillae (Fig 4.4 A and Fig. 4.4 B).

1) Vallate papillae: These are present at the base of the tongue in the shape of an inverted V, usually 8-12 together.
2) Fungiform papillae: These are present at the tip and the sides of the tongue. They are more in number than the vallate papillae.
3) Filliform papillae: These are smallest among the three types and are most abundant at the anterior two-thirds of the tongue.

Histology

The tongue is covered by a mucus membrane. It has a stratified squamous non keratinizing epithelium and lamina propria (the connective tissue layer.)There are three different types of papillae-filiform, fungiform and circumvallate (vallate) . The fungiform and circumvallate papillae have taste buds.

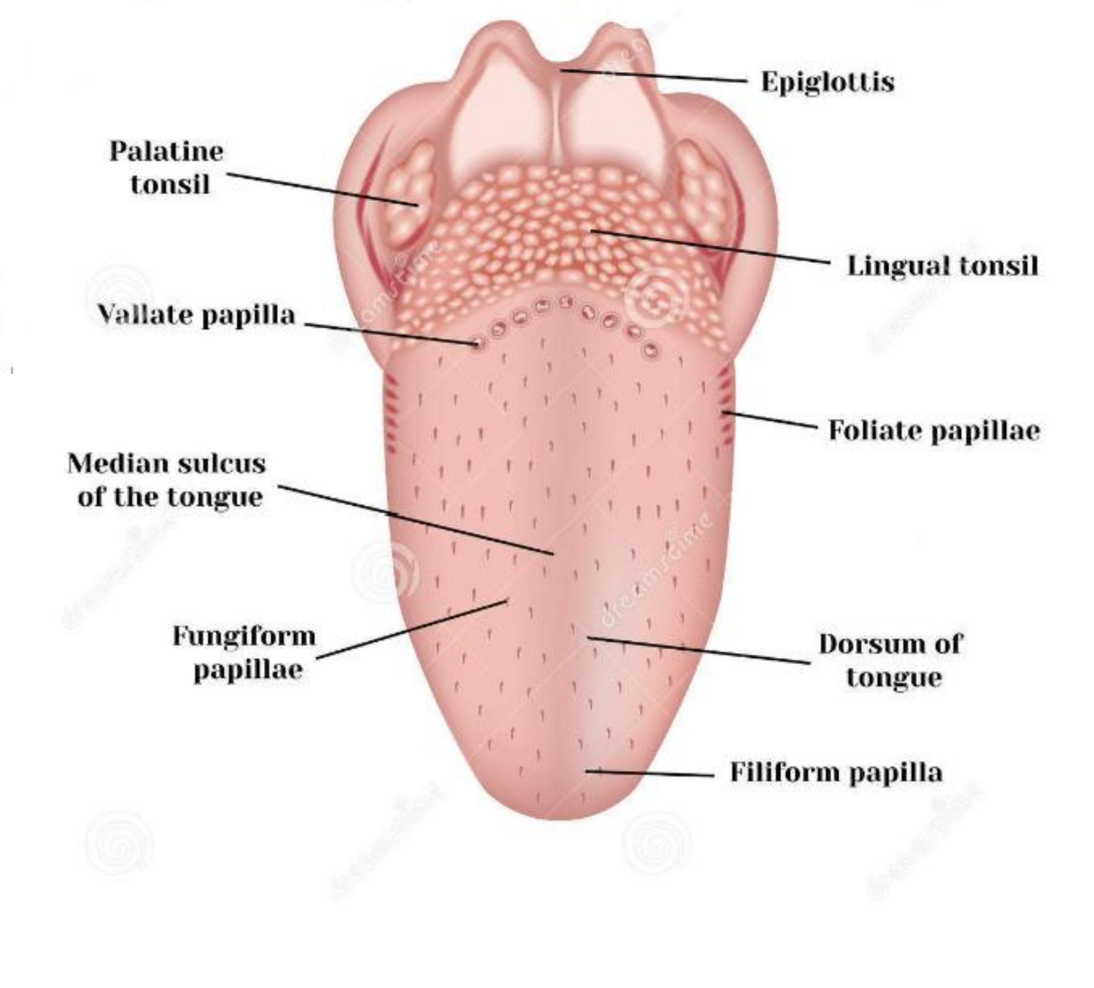

Fig 4.4 A. The tongue

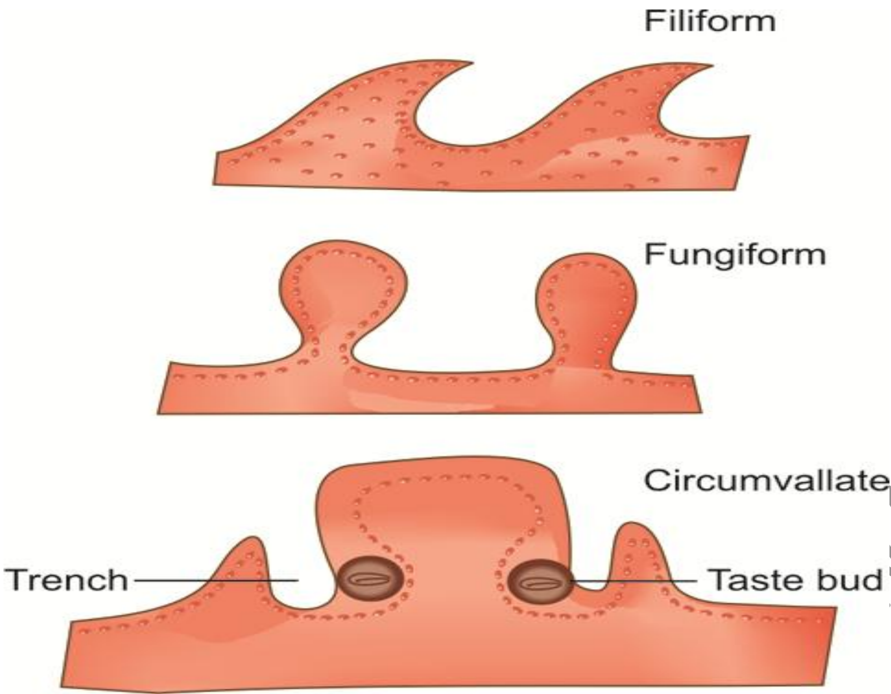

Fig 4.4 B The papillae and the taste buds

Taste buds

They are small, barrel-shaped structures, arranged along the sides of the grooves that surround the vallate or fungiform papillae(Fig 4.5). Any substance to be tasted gets dissolved in saliva and passes through the taste pore into the pit of the taste bud, where, it stimulates the hairs of neuroepithelial cells; these cells are richly innervated. So, a nerve impulse is set up.

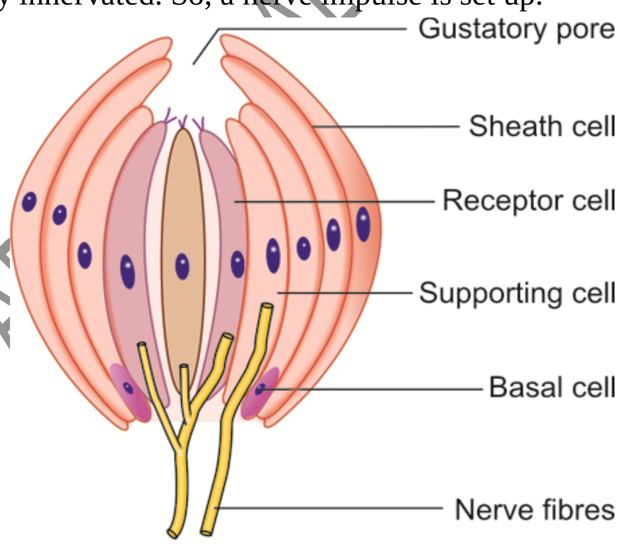

Fig 4.5 the taste bud

Blood supply to the tongue

The lingual branch of the carotid artery provides the main arterial blood supply to the tongue and the lingual vein, which joins the internal jugular vein is concerned with the venous drainage.

Nerve supply to the tongue

The nerves involved are; the hypoglossal nerves, the lingual branch of the mandibular nerves, the facial nerves and the glossopharyngeal nerves.

Functions of the tongue

The main functions of the tongue are

- ✓ Mastication (chewing)
- ✓ Deglutition(swallowing)
- ✓ Articulation(speech)
- ✓ Taste
- ✓ Oral cleansing.

Salivary glands

Salivary glands release their secretion into ducts that lead to the mouth. There are three main pairs; the parotid glands, the submandibular glands and the sub-lingual glands.

The parotid glands

These are situated one on each side of the face just below the external acoustic meatus. Each gland has a parotid duct opening into the mouth.

Sub-mandibular glands

These lye one on each side of the face under the angle of the jaw. The two sub mandibular ducts open on the floor of the mouth, one on each side of the frenulum of the tongue.

Sub-lingual glands

These glands lie under the mucus membrane of the floor of the mouth in front of the submandibular glands. They have numerous small ducts that open into the floor of the mouth.

Structure of salivary glands

The glands are all surrounded by a fibrous capsule. They consist of a number of lobules made up of small acini, lined with secretary cells. The secretions are poured into small ductioles that join up to form large ducts leading into the mouth.

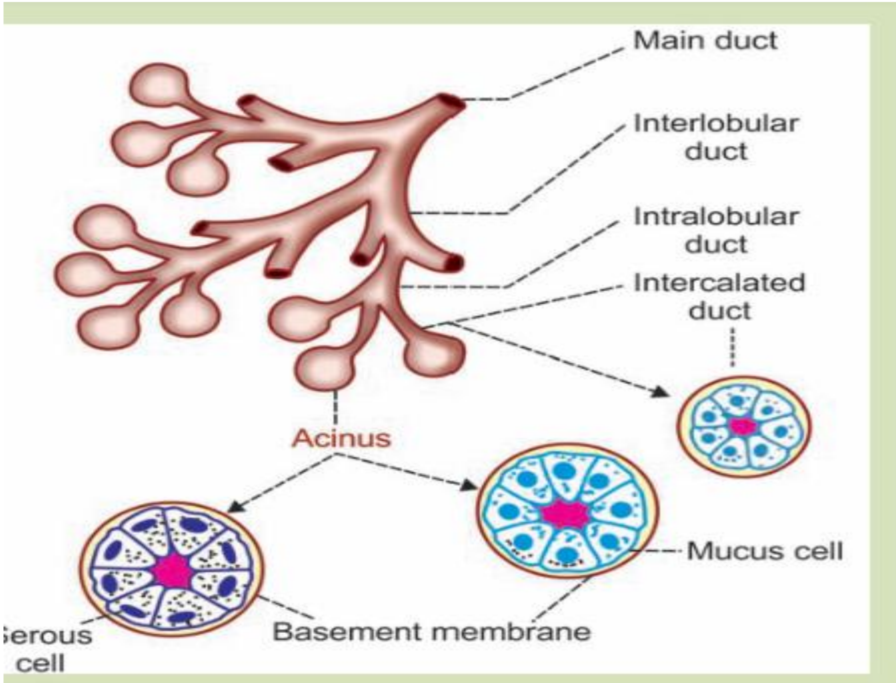

Fig 4.5 Structure of the salivary gland

Composition of saliva

Saliva is the combined secretion from the salivary glands and the small mucus-secreting glands of the oral mucosa. About 1.5 liters of saliva are produced daily and it consists of;

- Water
- Mineral salts
- An enzyme; salivary amylase
- Mucus
- Lysozyme
- Immunoglobulims
- Clotting factors

Functions of saliva:

1) Chemical digestion of polysaccharides
2) Lubrication of food
3) Cleaning and lubricating the oral cavity
4) Non-specific defence
5) taste

The teeth

The teeth form the part of the chewing or masticatory apparatus and are fixed to the jaw. In man teeth are replaced only once. The teeth are embedded in the alveoli or sockets of the alveolar ridges of the mandible and the maxilla. Babies are born with two sets of dentition, the temporary or deciduous teeth and the permanent teeth. At birth the teeth of both dentitions are present, in immature form, in the mandible and maxilla.

Eruption of teeth

There are 20 temporary teeth, 10 in each jaw. When a child reaches the age of 6 months, these temporary teeth begin to erupt and should all be present by 2 years of age. The permanent teeth begin to replace the deciduous teeth when in the 6th year of child's life. The permanent teeth consisting of 32 teeth completes at 24 years of life, normally.

Structure of the tooth:

Different types of teeth have different shapes (fig. 4.6) but the basic structure is same and consists of the following parts;

- The crown: this projects above the gum.
- Neck: the narrow point where root and crown merges.
- Root: the part embedded in the bone

The tooth consists of a pulp cavity at the center surrounded by a hard substance called as dentine (Fig 4.7) . The blood vessels, lymph vessels and the nerves are present in the pulp cavity. The crown of the dentine is surrounded by a thin covering of a very hard substance called as enamel; however the root part is covered with a substance that resembles bone and is called as cement. At the apex of each tooth the blood vessels and nerves enter the tooth.

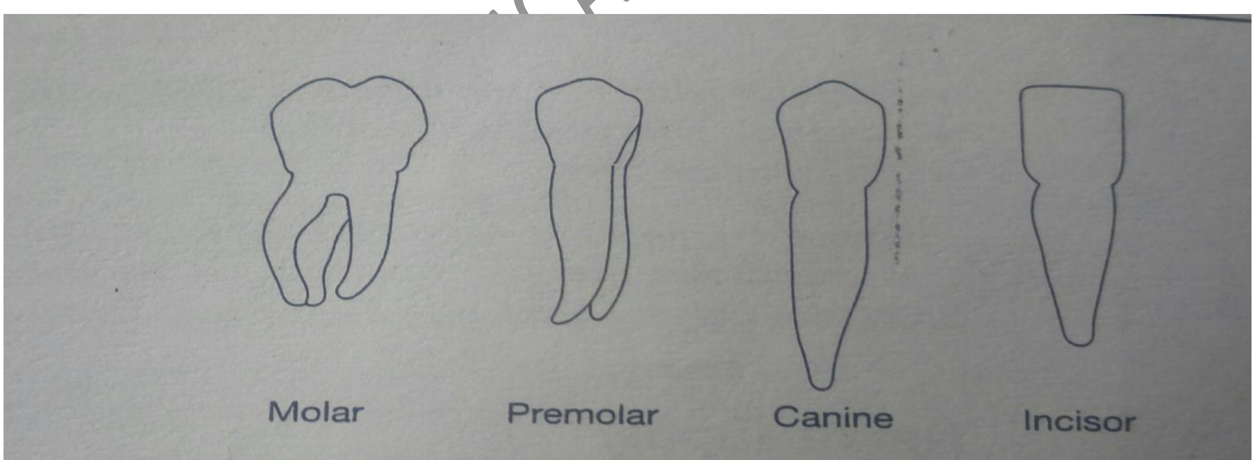

Fig 4.5 shapes of the teeth

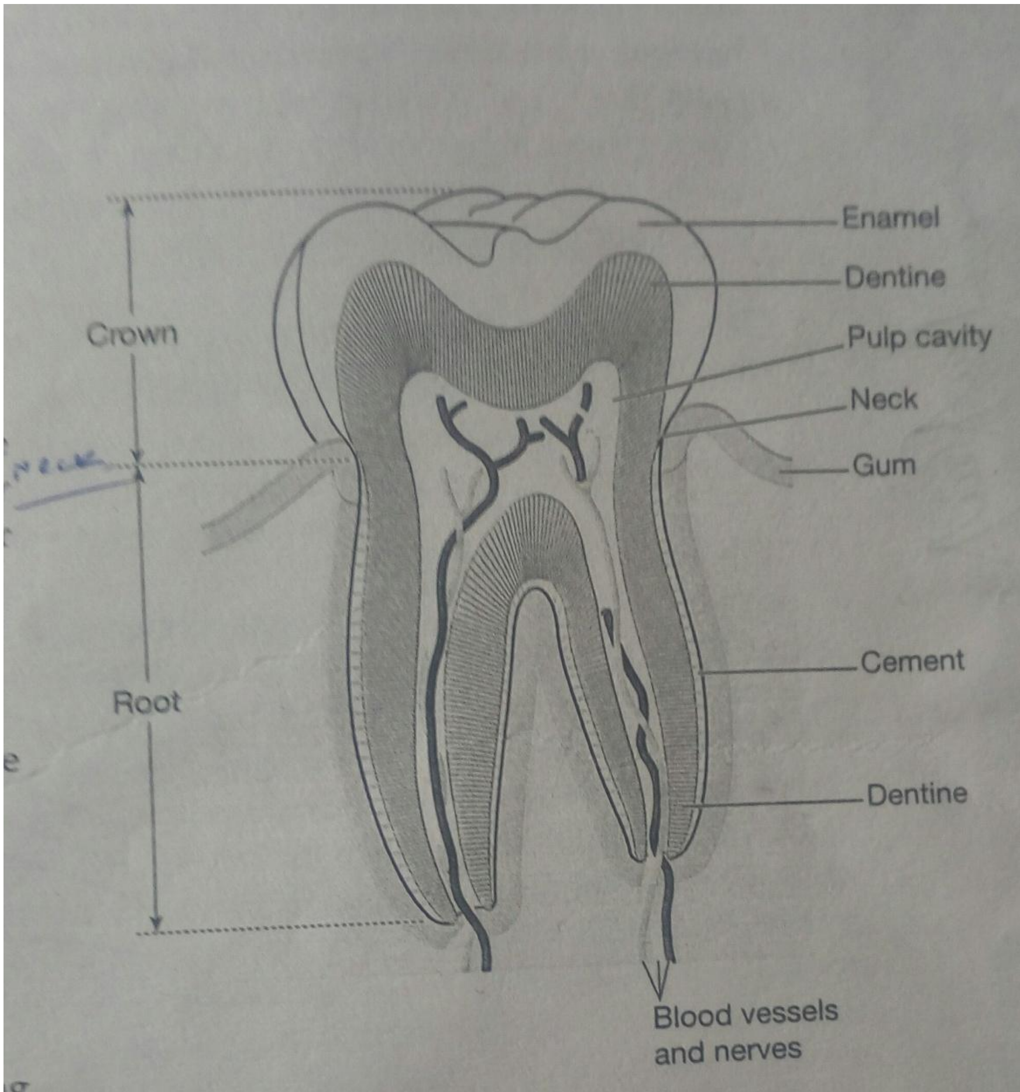

Fig 4.6 structure of the tooth

Blood supply of the tooth

Maxillary arteries carry the arterial supply and the venous drainage is by a number of veins that finally drain into the internal jugular veins.

Nerve supply:

Different branches of the trigeminal nerves supply the upper teeth(maxillary nerves) and lower teeth(mandibular nerves)

Functions of the teeth:

- Cutting and biting off pieces of food (by incisors and canines)
- Grinding and chewing of food (by flat surfaced molar and premolar teeth).

Pharynx

There are three main parts of the pharynx, i.e. nasopharynx, oropharynx and laryngopharynx (Fig. 4.7). The nasopharynx is concerned with the respiration ,while as the oropharynx and the laryngopharynx are the common passages for both the respiration and the digestion. From the mouth foods passes into the oropharynx and then to oesophagus, with which it is continuous.

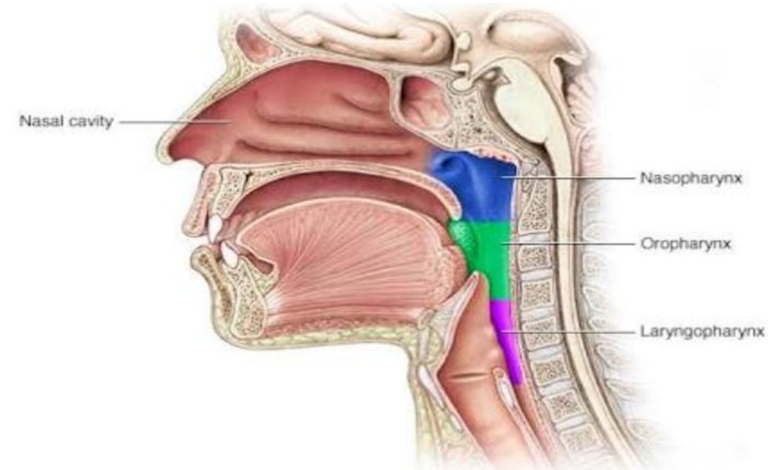

Fig 4.7 the pharynx

Structure

The walls of the pharynx consist of three layers of the tissue:

- ✓ The lining membrane or mucosa is made up of stratified squamous epithelium.
- ✓ The middle layer consists of fibrous tissue.
- ✓ The outer layer consists of different involuntary muscles, involved in swallowing.

Blood supply: Several branches of the facial arteries supply the pharynx. Venous drainage is by the facial and inter-jugular veins.

Waldeyer's Ring

This is a ring of lymphoid tissue in relation to the oropharyngeal isthmus. The rings is formed mainly by the right and left palatine tonsils. The other aggregations involved in the formation of the weldeyer's ring are tubal tonsils, pharyngeal tonsils and the lingual tonsils (fig 4.8)

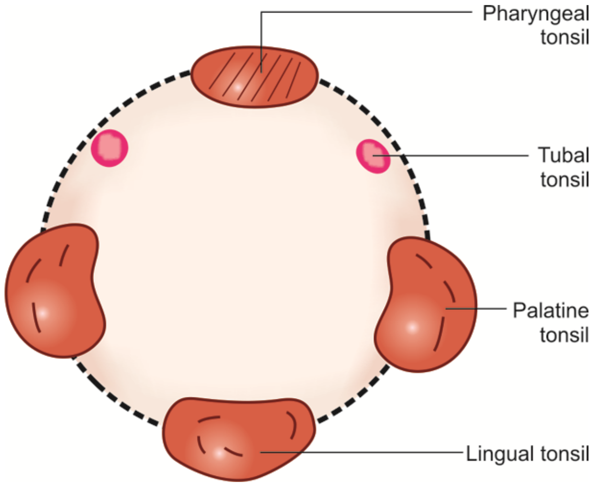

Fig 4.8 the weldeyer's ring

The oesophagus

The oesophagus is a muscular tube, 25cm long and about 2cm in diameter. It lies in the median plane in the thorax. It lies in front of the vertebral column, behind the trachea and the heart(Fig 4.9). It enters the abdomen through the oesophageal opening of the diaphragm and joins the stomach. It is controlled by two sphincters one on upper end (cricopharyngeal or upper oesophageal sphincter) and one on lower end (cardiac or lower oesophageal sphincter). The upper sphincter prevents the passage of air into the oesophagus during inspiration and prevents the aspiration of oesophageal contents. The lower sphincter prevents the reflux of gastric contents into the oesophagus

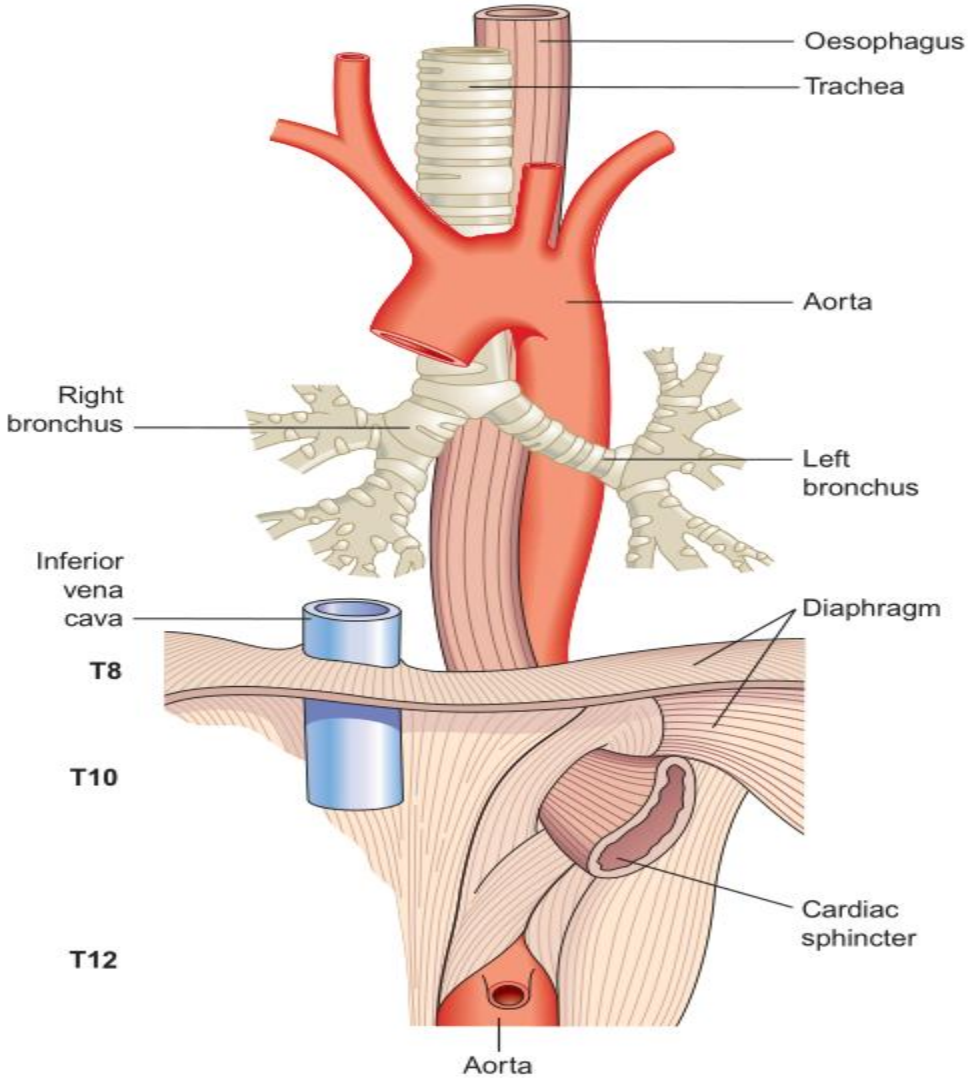

Figure 4.9 The oesophagus and some related structures.

Structure: There are four layers of tissues(Fig 4.10) as discussed below;

1) Innermost mucosa: it consists of stratified squamous, non-keratinizing epithelium. Inner to the epithelium is the connective tissue (lamina propria) , under which is the muscularis mucosa.
2) Sub-mucosa : it contains the large blood vessels and mucus secreting glands.
3) Outer muscular coat: It consists of two muscle layers, outer one is longitudinal and inner one is circular. The muscle layers are smooth at the lower end,striated at the upper side and in the middle it is mixed.
4) Outermost fibrous coat(adventitia): it consists of the elastic fibrous tissue and on the lower end is covered by peritoneum.

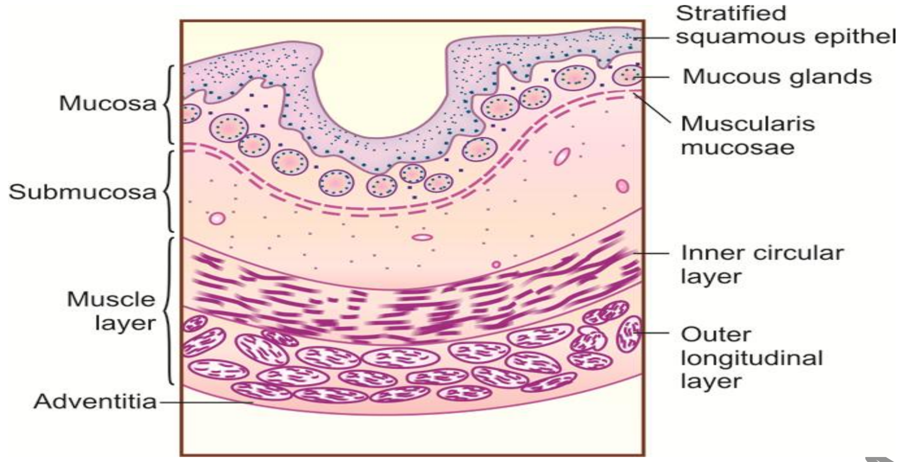

Fig 4.10 histology of the oesophagus

Functions of the mouth, pharynx and oesophagus (The bolus formation and the deglutition)

Formation of the bolus:

When food is taken into the mouth, the teeth chew or masticate it and the tongue in combination with muscles of the cheeks move it round the oral cavity. These movements mix the saliva with the finely chewed food and convert it into a soft round mass. This soft mass is ready for swallowing and is called as 'bolus'.

Deglutition or swallowing: once the mastication is completed and the bolus is formed, the next step involved is the swallowing of this bolus. It is a voluntary action and occurs in three stages.

1) Stage 1st: It involves the closing of the lips and raising the tongue above against the palate. Once the mouth is closed the voluntary muscles of the tongue and the cheeks force the bolus back into the oropharynx.
2) Stage 2nd : a reflex generated in the walls of the oropharynx, stimulates the muscles of the pharynx and as a result these muscles propel the bolus downwards into the oesophagus involuntarily. At the same time the entry of bolus into any other route is prevented. The soft palate closes the nasopharynx by rising up, back entry into the mouth is prevented by the tongue and the pharyngeal folds that block the way back and the larynx is lifted upwards and forwards, so that it is blocked by the overhanging epiglottis there and the entry of bolus into the trachea is prevented.
3) The presence of bolus in the oesophagus initiates a wave of peristalsis in its muscles, that propels the bolus through the oesophagus into the stomach. This completes the whole process of swallowing.

Regions of the abdomen

For descriptive purposes the abdominal cavity is divided into 9 regions (Fig 4.11) by the two lateral vertical planes (mid inguinal and mid clavicular) and two horizontal planes(transpyloric plane and the transtubercular plane). The nine regions are as under;

1) Epigastric or epigastrium
2) Right hypochondrium
3) Left hypochondrium
4) Umbilical
5) Right lumbar
6) Left lumbar
7) Hypogasrium or suprapubic
8) Right iliac fossa or right inguinal region
9) Left iliac fossa or left inguinal region

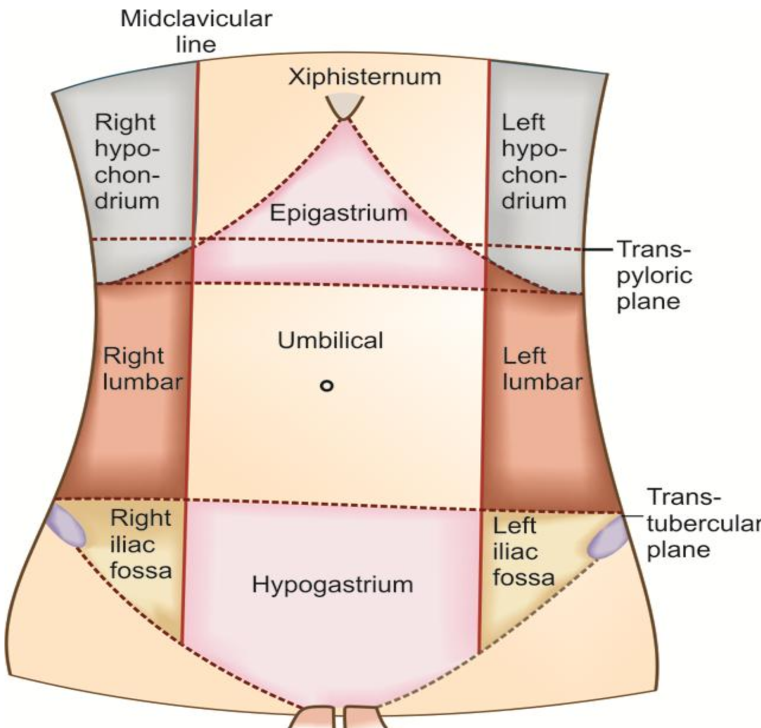

Fig 4.11 the regions of the abdomen

The stomach

The stomach is a J-shaped most dilated portion of the alimentary tract, situated in the parts of the Epigastric, umbilical and left hypochondriac regions of the abdominal cavity. The capacity of the stomach increases with the increasing age, it is about 30ml in a newborn, 1000ml at puberty and about 1500 ml in an adult.

The stomach bed: It is a combination of organs that hold the stomach and includes; left kidney, left supra-renal gland, anterior surface of pancreas, transverse colon, splenic artery, diaphragm and gastric surface of spleen(Fig 4.12.)

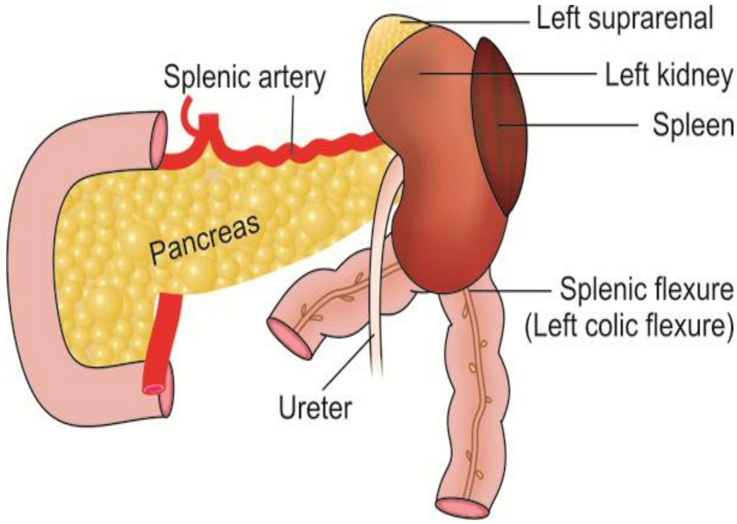

Fig 4.12 the stomach bed

Histology or structure of the stomach

The stomach is continuous with the oesophagus by cardiac sphincter and with the duodenum at the pyloric sphincter. It has two curvatures; the lesser curvature and the greater curvature. The lesser curvature is the downward continuation of the posterior wall of the oesophagus and the greater curvature is formed, when the anterior region angles acutely upwards and then curves downwards, at a point where the oesophagus joins the stomach.

Walls of the stomach:

The walls of the stomach are made up of the same four layers of the tissue that comprise the basic structure of the alimentary canal but there are some modifications. They are as(Fig 4.13);

Muscle layer: It has three layers of muscles instead of two, they are an outer layer of longitudinal muscles, a middle layer of circular muscles and an inner layer of oblique fibres.

Mucosa: when empty the mucus membrane folds of the stomach are scattered in longitudinal folds, called rugae and when full these folds are ironed out smoothly. The mucus membrane here contains gastric glands consisting of specialized cells that secret gastric juice.

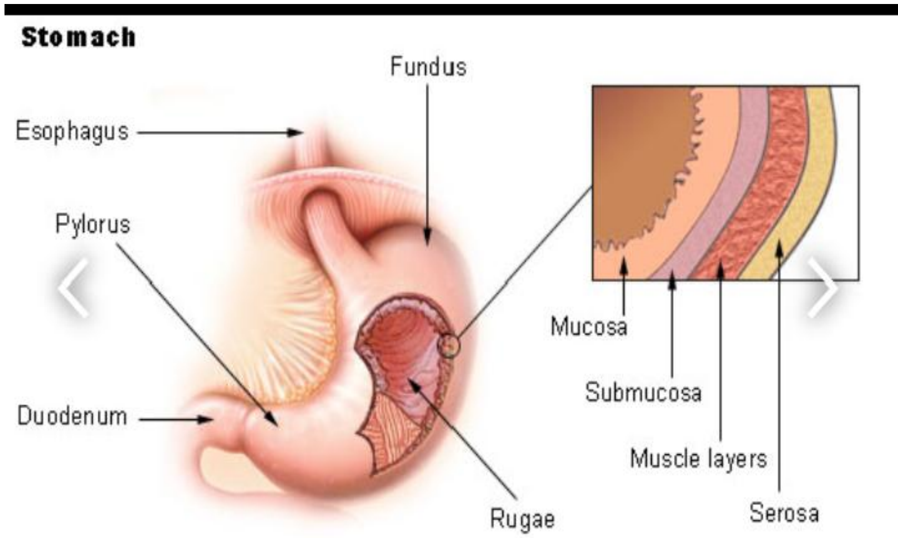

Fig 4.13 layers of the stomach

Parts of the stomach

The stomach is divided into three parts; the body, the fundus and the antrum(Fig 4.14).

Fundus: it is the dome shaped upper part lying to the left of the cardiac sphincter. This is the most superior part of the stomach. It usually contains a bubble of gas which can be seen in X-rays.

Body of the stomach: it is the main part of the stomach. It includes the major portion of the stomach and lies between the fundus and the pyloric antrum.

Pyloric antrum: There is a sharp angulation of the lesser curvature of the stomach called as 'incisura angularis' (angular notch), which indicates the junction of the body and pyloric part of the stomach. It has two parts- a wide part called the pyloric antrum and a narrow part called the pyloric canal.

Blood supply to the stomach:

Arterial supply is by the left and right gastric arteries. Venous drainage is by the corresponding veins into the portal vein.

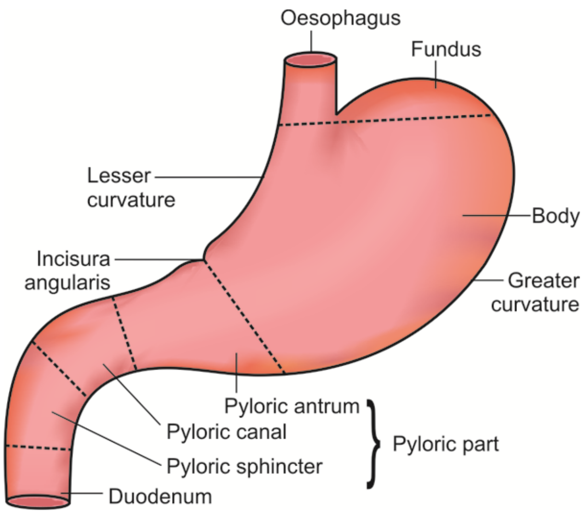

Fig 4.14 the parts of the stomach

Functions of the stomach:

1) Temporary storage allowing time for the digestive enzymes, pepsin to act.
2) Mechanical breakdown: The three smooth muscle layers enable the stomach to act as churn, gastric juice is added and the contents are liquefied to chime.
3) Chemical digestion: pepsin converts proteins to polypeptides
4) Absorption: limited absorption of water, alcohol and some lipid soluble drugs.
5) Non-specific defence against microbes provided by hydrochloric acid in gastric juice.
6) Preparation of iron for absorption further along the tract- the acid environment of the stomach solublizes iron salts, which are required before iron can be absorbed.
7) Production and secretion of intrinsic factor needed for absorption of Vit.B_{12} in the terminal ileum.
8) Regulation of passage of gastric contents into the duodenum.
9) Secretion of hormone gastrin.

Gastric juice

A specialized type of secretary glands presents in the mucosa secret about two liters of gastric juice daily. The gastric juice thus secreted contains following constituents;

- ✓ Water(secreted by gastric glands)
- ✓ Mineral salts(secreted by gastric glands)
- ✓ Mucus(secreted by goblet cells in the glands and on the stomach wall)
- ✓ Hydrochloric acid(secreted by parietal cells in the gastric glands)
- ✓ Intrinsic factor(secreted by parietal cells in the gastric glands)
- ✓ Inactive enzyme precursors; pepsinogens secreted by chief cells in the glands.

Secretion of gastric juice: Even if stomach is empty, there always a little amount of gastric juice present in it, this is known as 'fasting juice'. The gastric juice secretion is highest after an hour of taking a meal and declines back to fasting level after 4 hours of taking a meal. There are three phases of secretion of gastric juice (Fig 4.15) and they are as;

1) **Cephalic phase:** This phase involves the flow of gastric juice due to the vagus nerve stimulation by the smell, sight or taste of food, therefore occurs before the food reaches the stomach.
2) **Gastric phase:** once the food reaches the pyloric antrum, it stimulates the enteroendocrine cells there and in duodenum, which secret gastrin (a hormone). The gastrin enters the circulation and its presence in the circulating blood stimulates the gastric glands to produce more and more gastric juice. As a result of this the gastric juice secretion continues even after the completion of a meal. The secretion of gastrin is suppressed when the pH in pyloric antrum falls to 1.5.
3) **Intestinal phase:** the partially digested contents of the stomach reach the small intestine and cause the secretion of two hormones; secretin and cholecystokinin by the endocrine cells of intestinal mucosa. These hormones are responsible for slowing down the secretion of gastric juice and decreasing the gastric motility. This phase of gastric secretion is most marked after having a high fat meal.

The emptying of the stomach is dependent on the type of food eaten, as a carbohydrate meal leaves the stomach in 2-3 hours, protein rich meal remains for longer time while as the fat rich meal stays the longest.

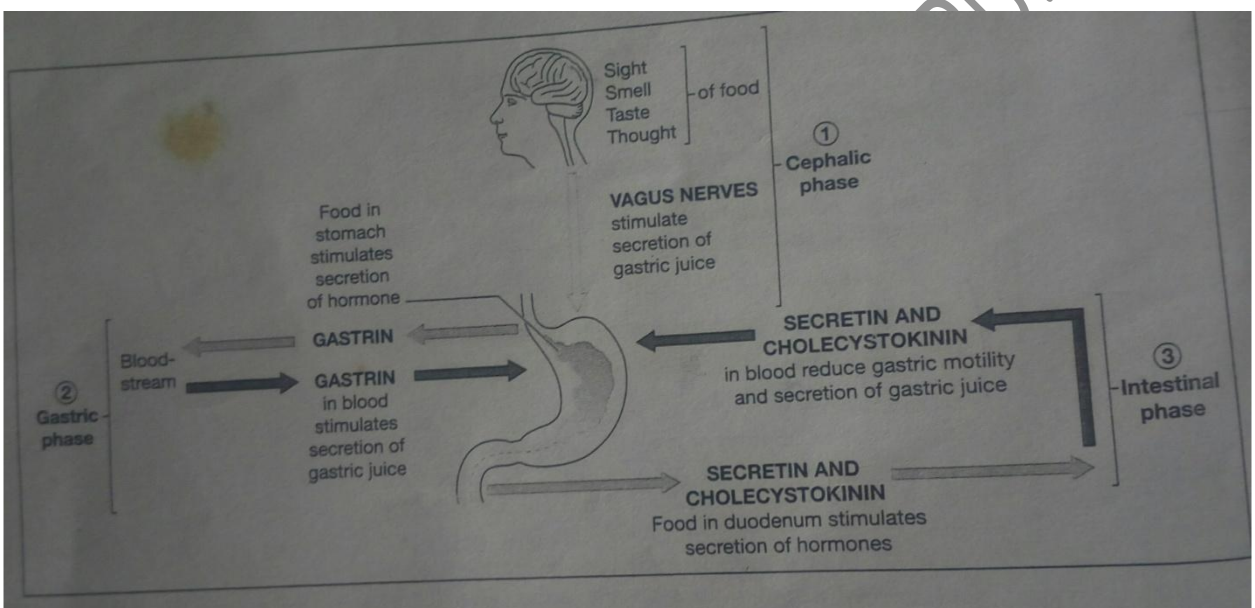

Fig 4.15 the phases of gastric secretion

Small intestine

The stomach joins the small intestine at the pyloric sphincter and the ileocaecal valve connects the small intestine with the large intestine. The small intestine is about 5-7 meters long and lies in the abdominal cavity surrounded by the large intestine. Small intestine is the site where most of the absorption of the nutrients occurs and the chemical digestion of the food completes.

Parts of the small intestine

The small intestine is divided into two main parts; (a) an upper fixed part called as the duodenum and (b) and a lower or distal mobile part. The proximal $2/5^{th}$ part of this mobile part is continuous with the duodenum and is called as jejunum and the distal $3/5^{th}$ part is called as the ileum.

Duodenum: It is about 25 cm long and curves around the head of the pancreas. The secretions from the pancreas and the gall bladder are released into the duodenum through a common structure, the hepatopancreatic ampulla and the opening there is guarded by the hepatopancreatic sphincter of oddi.

Jejunum: It is about 2cm long and is the middle section of the small intestine.

Ileum: it is the last part of the small intestine and is about 3 meters long. It joins the large intestine at ileocaecal valve; the valve controls the flow of material from the ileum to the caecum and prevents the regurgitation of it.

Structure of the small intestine (histology)

The walls of the small intestine consist of the four layers of tissue as are present in basic structure of the alimentary canal but there are some modifications of the peritoneum and the mucosa as described below;

Peritoneum: The jejunum and the ileum are attached to the posterior abdominal wall by a double layer of peritoneum called as mesentery.

Mucosa: the surface area of the small intestinal mucosa is greatly increased by the permanent circular folds villi and microvilli. The villi are small finger like projections about 0.5- 1 mm long. Their walls contain enterocytes with tiny microvilli on their free border. Goblet cells are also present between the enterocytes. It also contains the intestinal glands which are tubular . Numerous lymph nodes are present in the mucosa and the nodes present on the distal side are called as aggregated lymphatic follicles (Peyer's patches).

Blood supply to the small intestine:

Arterial supply is by the superior mesenteric artery and the venous drainage is by the superior mesenteric vein that joins the other veins to form the portal vein.

Functions of the small intestine

- Onward movement of its constituents by peristalsis.
- Secretion of intestinal juice.
- Completion of chemical digestion of food.
- Protection against microbes by lymph follicles
- Secretion of the hormones- cholecystokinin (CCK) and secretin.
- Absorption of nutrients

Intestinal juice: The glands of the small intestine secrete intestinal juice daily (about 1500ml). This juice contains water, mucus and mineral salts and has a pH between 7.8- 8.0.

Chemical digestion of food:

When acidic chyme enters the small intestine, pancreatic juice, bile and intestine juice mixes with it. This mixture comes in contact with the enterocytes of the villi. In the small intestine digestion of all the nutrients gets completed. The principle constituents of intestinal secretions are water, mucus and mineral salts. The larger molecules are broken down into absorbable form, i.e. carbohydrates to monossacharides, proteins to amino acids and fats to fatty acids and glycerol. The enzymes that are associated with the completion of chemical digestion are peptidases, lipase, sucrase, maltase and lactase.

Absorption of nutrients in the small intestine:

Two main processes are involved in the absorption of nutrients in the small intestine they are **diffusion** and **active transport**. Monossacharides, amino acids, fatty acids and glycerol are absorbed by the process of diffusion. Disaccharides, dipeptides, and tripeptides are actively transported into the enterocytes of the villi, monossacharides, amino acids, fatty acids and glycerol may also be actively transported through villi. The monossacharides and amino acids enter the capillaries of the villi and the fatty acids into the lacteals and extent of protein absorption is believed to be limited. Other nutrients (vitamins, mineral salts and water) are also absorbed from the small intestines. The rate of absorption is increased in the small intestine by the increased surface area of small intestine (by the villi, microvilli and the circular folds of mucus membrane). Every day a large amount of fluid enters the digestive tract which is absorbed by the small intestine except 1500ml which is passed to the large intestine.

The large intestine

Large intestine starts at caecum and ends at the rectum and anal canal. It is about 1.5 meters long with a lumen of 6.5cm. It has been divided into the caecum, ascending colon, transverse colon, descending colon, sigmoid colon, rectum and anal canal.

The caecum: it is the first part of the large intestine and is continuous with the ascending colon superiorly. The vermiform appendix is a fine tube, closed from one end and leads from the caecum.

The ascending colon: this passes upwards from the caecum, reaches the level of the liver and then curves towards the left at hepatic flexure to form the transverse colon.

The transverse colon: it is the part of the colon that extends through the abdominal cavity and at the level of the spleen it forms splenic flexure. Then it curves downwards to continue as the descending colon.

The descending colon: It passes down from the left side of the abdominal cavity and curves towards the midline. When it reaches the pelvis it is called as sigmoid colon.

The sigmoid colon: it is an S-shaped curve in the pelvis that continues downwards to form rectum.

The rectum: it is a dilated part of the colon and is 13 cm long. It continues with the anal canal.

The anal canal: it is a short canal of about 3.8cm length and leads from the rectum to the external. It is controlled by two sphincters. The internal sphincter is involuntary and the external sphincter is under voluntary control.

Structure of the large intestine:

The colon, rectum and the anal canal are made up of the same layers as are present in the basic structure of the alimentary canal; however the longitudinal muscle is modified in the colon. Instead of forming a smooth continuous layer the muscle fibres are arranged in three bands called as 'taeniae coli'.

Great quantity of lymphoid tissue is found in the sub-mucosal layer of the colon, more than the rest alimentary tract. This lymphoid tissue provides non-specific defence to the colon against the resident and other microbes.

Large numbers of goblet cells are found in the mucosal layer of the colon and rectum, which secret mucus. The lining membrane of the anal canal contains stratified squamous epithelium which is continuous with the mucus membrane lining of the rectum.

Blood supply to the large intestine: Arterial supply is by the superior and inferior mesenteric arteries and the venous drainage is by the corresponding veins that join the splenic and gastric veins to form the portal vein.

Functions of the large intestine, rectum and anal canal

Absorption: absorption of water by osmosis, mineral salts, vitamins and some drugs are also absorbed from the large intestines into the blood capillaries.

Microbial activity: certain types of bacteria are found in colonies in the large intestine, which synthesize Vit. K. These include; E. coli, streptococcus faecalis, clostridium perfringes etc.

Mass movement: There are no peristaltic movements in the larger intestine as are found in the other parts of the alimentary canal. At some intervals (30 min intervals) a wave of strong peristalsis occurs in the transverse colon that forces its contents towards the descending and sigmoid colon, this is known as mass movement.

Defaecation: The nerve endings in the rectum are stimulated by the stretch of the mass movement, which causes the muscles of the rectum to cause relaxation of internal anal sphincter. The external anal sphincter is under conscious control through the pudendal nerve. There occurs contraction of the abdominal muscles and lowering of the diaphragm, which increases the abdominal pressure and aids in defecation. The faeces consists of a semisolid brown mass (brown colour is due to the presence of stercobilin). Water is the main constituent of faeces (60-70%), the other constituents include; fibres, dead and live microbes, epithelial cells, fatty acids and mucus.

The pancreas

The pancreas is a pale yellow grey gland weighing about 60 gm; it has a length of 12-15 cm and is situated in the Epigastric and left hypochondriac regions of the abdominal cavity. The pancreas is divided into a broad head, neck, body and a tail (Fig 4.17)

The head: it is the right rounded portion of the pancreas. It lies in the curvature of the II, III part of duodenum. It lies on the right surface of the bodies of lumbar vertebrae (L1 and L2). It is globular but flattened antereoposteriorly.

The neck: it is 2cm long extending upwards and to the left from the head, up to the body of pancreas.

Body: It consists of three surfaces, (a) anterior surface, (b) posterior surface and (c) inferior surface. It has three borders, superior , anterior and inferior. It lies behind the stomach.

The tail: it is the tapering left end of the pancreas. It rests on the visceral surface of the spleen just below the hilum and above the colic area. It lies within the line renal ligament along with the splenic vessel.

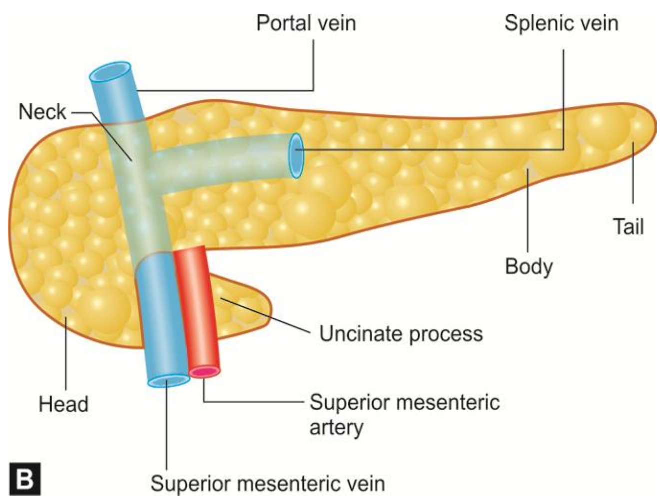

Fig 4.17 the pancreas

The pancreas is both an endocrine and an exocrine gland.

The exocrine part: The exocrine part consists of a number of lobules, which are made up of small alveoli, having secretary cells in their walls. Each lobule has a tiny duct and all these tiny ducts unite to form a large duct called as pancreatic duct, which opens into the duodenum. Before opening into the duodenum the pancreatic duct joins the common bile duct(fig 4.18) to form the 'hepatopancreatic ampulla' (controlled by sphincter of oddi). The exocrine pancreas secretes the pancreatic juice containing enzymes that digest carbohydrates, proteins and fats.

The endocrine part: throughout the pancreas, there are groups of specialized cells called as pancreatic islets (islets of langerhans). These islets are ductless and their hormonal secretions are diffused directly into the blood. The hormones secreted by endocrine part are insulin and glucagon, which are concerned with maintenance of blood glucose levels.

Blood supply to the pancreas: the arterial supply is by the splenic and mesenteric veins and the venous drainage is by the corresponding veins of same names.

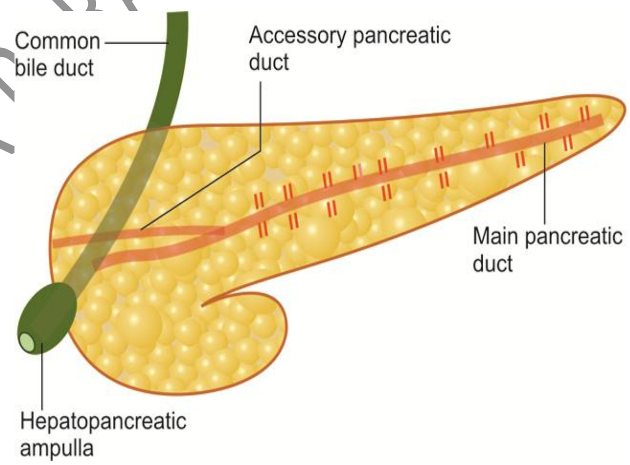

Fig 4.18 the ducts of pancreas

The pancreatic juice:

The pancreatic juice(from exocrine part) enters the duodenum at the hepatopancreatic sphincter and has following constituents;

- Water
- Mineral salts
- Enzymes (amylase and lipase)
- Inactive enzyme precursors(trypsinogen, chymotrypsinogen, procarboxypeptidase)

The pancreatic juice is alkaline in nature (due to the presence of bicarbonate ions) with a pH of 8.0. Since the gastric contents are acidic in nature, when they mix with the alkaline pancreatic juice the pH is increased to 6-8, this is the suitable pH for the pancreatic enzymes to act.

Functions of the pancreatic juice

1) Digestion of proteins: trypsin and chymotrypsin convert the polypeptides to tripeptides, dipeptides and amino acids.
2) Digestion of carbohydrates: All the polysaccharides that have not been acted upon by salivary amylase are converted to disaccharides by pancreatic amylase.
3) Digestion of fats: lipase converts fats to fatty acids and glycerol. Bile salts emulsify the fat that aids the functioning of the lipase.

Regulation or control of pancreatic secretion

The endocrine cells in the walls of the duodenum secrete secretin and CCK, which are responsible for stimulation of pancreatic juice. Intern the secretion of these hormones is secreted by the presence of acidic chyme in the duodenum.

The liver

The liver is reddish brown in colour and is the largest gland in the body, weighing about 1-2.3 kg. It is believed that the weight of the liver varies in accordance with the total body weight of a person, it is $1/36^{th}$ part of the body weight in adults and $1/18^{th}$ in children. The liver is situated in the upper part of the abdominal cavity occupying a great part of the right hypochondriac region, a part of the epigastric region and the left hypochondriac region. It is a wedge shaped organ with its base towards the right. The liver is partially covered by a layer of peritoneum and enclosed in a thin inelastic capsule. The liver is attached to the diaphragm by the fold of peritoneum.

Dimensions of the liver:

- Transversely- 15-20 cm
- Vertically at the right lateral surface- 17cm

Support:

- Tonicity of the abdominal muscle

- Hepatic vein draining to the inferior vena cava.
- Intra abdominal pressure
- Some sources mention the role of peritoneal folds in support whilw as others believe they have no role in the support.

Features of the liver: Liver has 5 letters, and most of the features of liver are 5 in number.

- 5-surfaces: superior, inferior, anterior, posterior and right lateral.
- 5-borders: borders are not defined except for the inferior border, which starts from the left triangular ligament and then extends up to the lower border of left and right lobes of the liver and the right triangular ligament. The other borders are posterior, superior and posterior inferior.
- 5-base areas: the base area, the groove for the inferior vena cava, potahepatis, fossa for gallbladder, triangular area on the superior surface between the two layers of filiform ligaments.
- 5-fissures: Fisher for ligamentum teris, fisher for ligamentum vansum, groove for the inferior vena cava, fossa for gall bladder and potahepatis.
- S-peritoneal ligaments(the filiform ligaments)

Histology or structure of the liver:

The liver has four lobes(fig 4. 19 A and fig 4.19 B), among which only two are most obvious and they are the right lobe(larger) and the left lobe(smaller). The other two lobes are the caudate and the quadrate lobe, situated on the posterior surface. The structure of the liver is discussed below;

1) The liver is covered by Glisson's capsule(a connective tissue capsule)
2) The two lobes are composed of a large number of hexagonal lobules.
3) The hepatocytes are arranged in a unique fashion forming plates or cords.
4) Between these plates there are blood filled spaces, the sinusoids. These sinusoids are lined with endothelium and the special type of phagocytes called as 'the kupffer cells'.
5) At the periphery of each lobule, branches of hepatic artery, portal vein and the bile duct are found. These branches are surrounded and held by the connective tissue and constitute the **portal triad.**
6) The hepatocytes are in close contact with the sinusoids and absorb nutrients from them. These cells secrete bile into the biliary canaliculi, that join together to form the large ducts that emerge as right and left hepatic ducts.

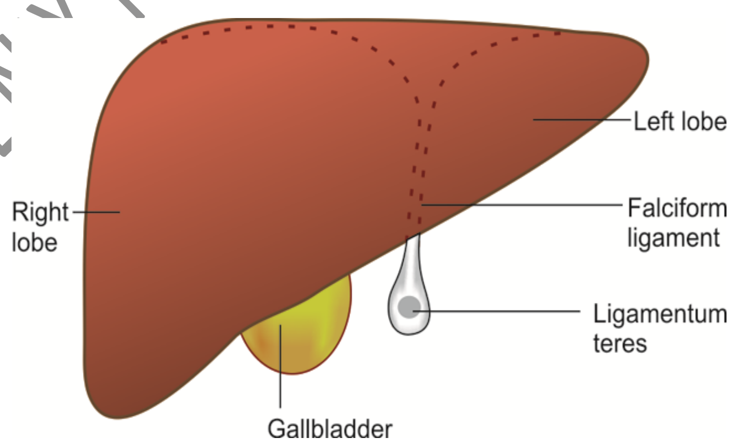

Fig 4.19 A the anterior view of liver

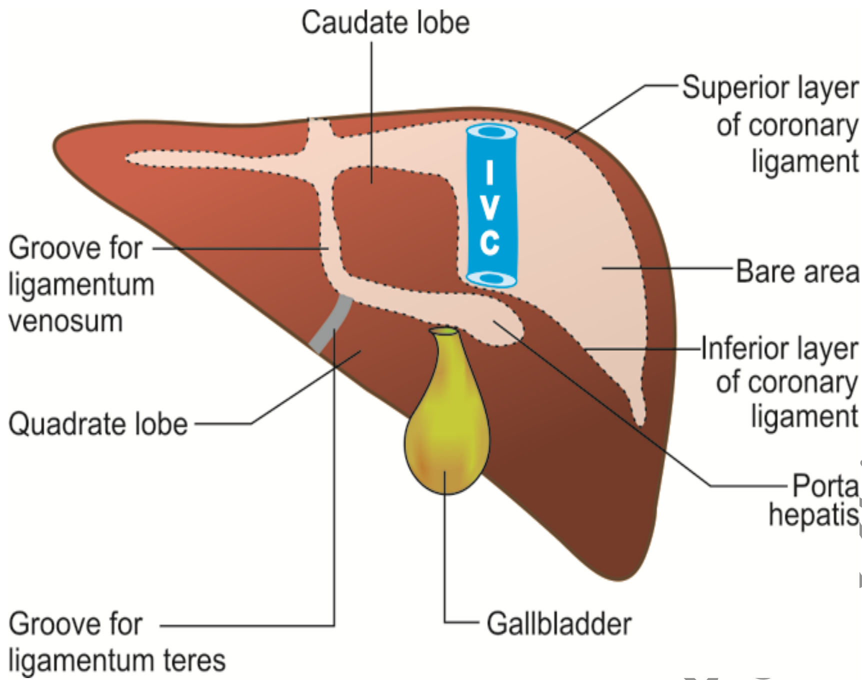

Fig 4.19 B the posterior view of liver

Functions of the liver

- Carbohydrate metabolism: maintenance of plasma glucose levels is extremely important for an individual and livers plays a pivotal role in maintaining these levels. After having a meal normally the glucose levels increase and the liver is the main organ that converts the extra glucose to the glycogen(under the influence of the hormone insulin)for storage and when the glucose levels in blood fall, this glycogen is reconverted into glucose(under the influence of the hormone glucagon) to keep the plasma glucose levels in normal range always.
- Liver also converts the stored fat into a form that can be used by the tissues for energy production.
- Protein metabolism: liver is responsible for the deamination of amino acids and synthesis of plasma proteins and most of the blood clotting factors from them.
- Breakdown of erythrocytes and provides defence against the microbes (by kupffer cells- the hepatic macrophages).
- Detoxification of drugs and noxious substances.
- Inactivation of hormones, including insulin, glucagon, cortisol, aldosterone, thyroid and sex hormones.
- Production of heat: Due to the great metabolic rate, high energy is used by the liver and intern generates a great deal of heat. Liver is considered to be the main heat producing organ of the body.
- Secretion of bile: the hepatocytes of the liver are responsible for synthesizing the constituents of bile from the mixed arterial and venous blood. These include bile salts, bile pigments and the cholesterol.
- Storage for various substances: the substances that are stored in the liver include; glycogen, iron, copper, fat soluble vitamins (A,D,E and K)and some water soluble vitamins, e.g. vitaminB_{12}.

The bile

The bile is synthesized in the hepatocytes and about 500- 1200 ml of bile is secreted by the liver daily. Small amount of bile is always stored in gall bladder, where it is concentrated. During the interdigestive period the bile cannot enter the duodenum as the sphincter of oddi is very high at that period, therefore after a meal the bile that enters the duodenum is from the gall bladder.

Composition of the bile: The bile consists of the following constituents;

- Water
- Mineral salts
- Mucus
- Bile pigments(mainly bilirubin)
- Bile salts
- Cholesterol

In the gall bladder the bile is concentrated by the absorption of water, sodium chloride and other inorganic constituents.

Bilirubin: The hepatic macrophages (kupffer cells) and the other macrophages in the spleen and bone marrow cause the hemolysis of erythrocytes and bilirubin is released. In the original form bilirubin is insoluble in water and is bound to albumin in the blood. In the hepatocytes bilirubin is in the conjugated form with glucuronic acid and is converted into a water soluble form before being secreted into the bile. Bilirubin is acted upon by the intestinal bacteria and most of it is excreted as **stercobilin** with the faeces. Small amount of bile is reabsorbed that is later excreted with the urine as urobilinogen.

When there occurs excessive bilirubin concentration in the blood it causes yellow discoloration of the skin called as **jaundice.**

Functions of the bile

- Emulsification of fats
- Cholesterol and fatty acids are converted into soluble form by the bile salts, as a result they are absorbed easily.
- Conversion of fat soluble vitamins (A, D, E and K) to water soluble forms, hence promote their absorption.
- Stercobilin a product of bile metabolism colours and deodorizes the faeces.

Gall bladder

It is a pear-shaped sac and is attached to the liver by connective tissue. The gall bladder has three parts; the fundus- an expanded part, body- the main part and a neck. The neck is continuous with the cystic duct.

Structure (histology)

The gall bladder shows same histology as is found in the basic structure of the alimentary tract, but with some modifications.

Here only the inferior surface is covered by the peritoneum and the position of the gall bladder is supported by the visceral peritoneum of the liver. The muscular layers here contain an additional layer of oblique muscle fibers. The mucus membrane here has small rugae, that appear only when the gall bladder is empty.

Blood supply: the gall bladder is supplied by the cystic artery(a branch of hepatic artery) and the venous drainage is by the cystic vein.

Functions of the gall bladder

- Reservoir for bile
- Concentrating the bile by about 10-15 fold by absorption of water.
- Release of stored bile during interdigestive period by the contraction of gall bladder as a response to the stimulation by the hormone cholecystokinin and presence of fat and acid chyme in the duodenum.

Digestion and absorption of nutrients

Mechanism of digestion and absorption

Digestion of food in the mouth: the food is chewed and masticated by the teeth and moved round the mouth by the tongue and the muscles of the cheeks. It is mixed nicely with saliva and formed into a soft mass or bolus for swallowing. These secretions of the salivary glands contain enzyme ptyalin, which converts starch to maltose. These secretions lubricate and moisten the food, clean the mouth and keep the structures within the mouth soft and pliable. The bolus of food is pushed back into the pharynx by the upward movement of the tongue. The muscles of pharynx further propel it down into the oesophagus. The walls of the pharynx get stimulated by the presence of bolus in it and a wave of peristalsis is generated that propels the bolus via the oesophagus to the stomach. The walls of the oesophagus also aid in propulsion of food by peristaltic movements.

Digestion of food in stomach: The stomach acts as a temporary reservoir of food, thus allowing the digestive juice to act upon it. It also produces gastric juice which contains, H_2O, mineral salts, mucus, hydrochloric acid and some enzymes (pepsinogen, renin, and the intrinsic factors. The water further liquefies the swallowen food, the Hcl acidifies the food and stops the action of the salivary ptyalin. It also converts pepsinogen to the active enzyme pepsin and kills many microbes, which may be harmful to the body. Pepsin converts proteins to peptones and renin converts the soluble caseinogens to insoluble kesine, which inturn is converted by pepsin into peptones. The intrinsic factor is necessary for the absorption of vitamin B_{12}. The mucus in the gastric juice prevents mechanical injury to the stomach wall by lubricating the contents. It also prevents chemical injury by acting as a barrier between the stomach wall and the other constituents of the gastric juice. Muscular action of the stomach mixes the food with the gastric juice and moves the food in the stomach. To a limited extent some water, glucose, alcohol and some drugs are absorbed through the walls of the stomach into the venous circulation.

Digestion of food in the small intestine: The small intestine further progress the movement of the contents by its peristaltic, segmental and pendular movements. It also secretes intestinal juice which consists of water, mucus and various enzymes. The enzymes in the intestinal juice perform many functions, the enteropeptidase converts inactive pancreatic trypsinogen and chymotrypsinogen to active trypsin and chymotrypsin, which further convert peptones to peptides and polypeptides. Intestinal and pancreatic amylase converts polysaccharides to disaccharides. Peptidase converts peptides and polypeptides to amino acids. Lipase converts fat to fatty acids and glycerol. Sucrase, maltase and lactase act on corresponding disaccharides to convert them to monossacharides. The intestinal juice thus completes digestion of carbohydrates, fats and proteins. The end products of digestion of carbohydrates, proteins and fats are monossacharides, amino acids and fatty acids and glycerol, respectively. The glucose is absorbed into the capillaries of the villi and transported into the portal circulation to the liver. Amino acids also follow the same path. Fatty acids and glycerol are absorbed into the lacteals of the villi and are transported via the thoracic duct to the left sub-clavian vein, then they are carried to the liver. The solitary and aggregated lymph follicles in the villi of small intestine provide protection against the invasion of microbes.

Absorption in the large intestine: the food passing through the small intestine enters the large intestine. In the large intestine absorption of water continues till semi-solid consistency of the contents is achieved. Mineral salts and some drugs are also absorbed into the blood capillaries from the large intestine. The large intestine exhibits a wave of strong peristalsis only at certain intervals (mass movement) that force the faeces towards the anal canal.

The digestion and absorption sites of different nutrients are summarized in the table below

Table 12.2 Summary showing the sites of digestion and absorption of nutrients

	Mouth	Stomach	Small intestine: Digestion	Small intestine: Absorption	Large intestine
Carbohydrate	*Salivary amylase*: digestible starches to disaccharides	*Acid* denatures and stops action of salivary amylase	*Pancreatic amylase*: digestible starches to disaccharides *sucrase, maltase, lactase* (in enterocytes): disaccharides to monosaccharides (mainly glucose)	Into blood capillaries of villi	–
Proteins	–	*Acid*: pepsinogen to pepsin *Pepsin*: proteins to polypeptides	*Enterokinase* (in enterocytes): chymotrypsinogen and trypsinogen (from pancreas) to chymotrypsin and trypsin *Chymotrypsin and trypsin*: polypeptides to di- and tripeptides *Peptidases* (in enterocytes): di- and tripeptides to amino acids	Into blood capillaries of villi	–
Fats	–	–	*Bile* (from liver): bile salts emulsify fats *Pancreatic lipase*: fats to fatty acids and glycerol *Lipases* (in enterocytes): fats to fatty acids and glycerol	Into the lacteals of the villi	–
Water	–	Small amount absorbed here	–	Most absorbed here	Remainder absorbed here
Vitamins	–	Intrinsic factor secreted for vitamin B_{12} absorption	–	Water-soluble vitamins absorbed into capillaries; fat-soluble ones into lacteals of villi	Bacteria synthesise vitamin K in colon; absorbed here