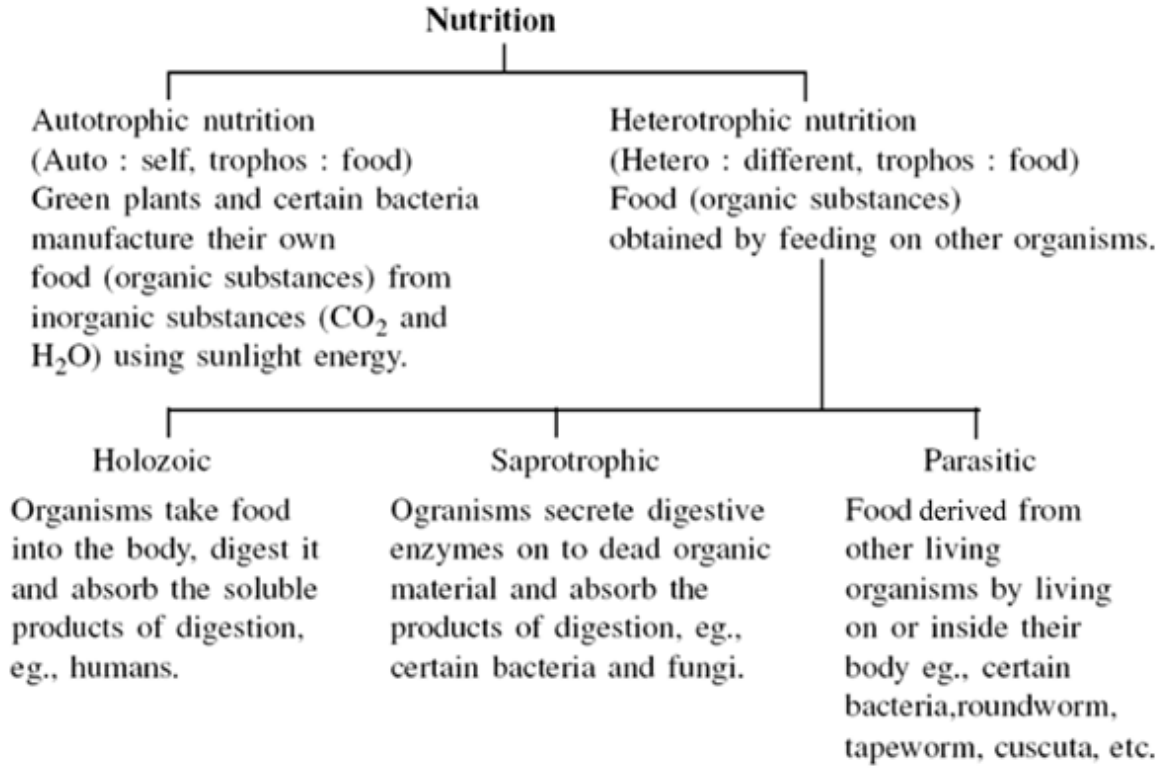
DIGESTION AND ABSORPTION

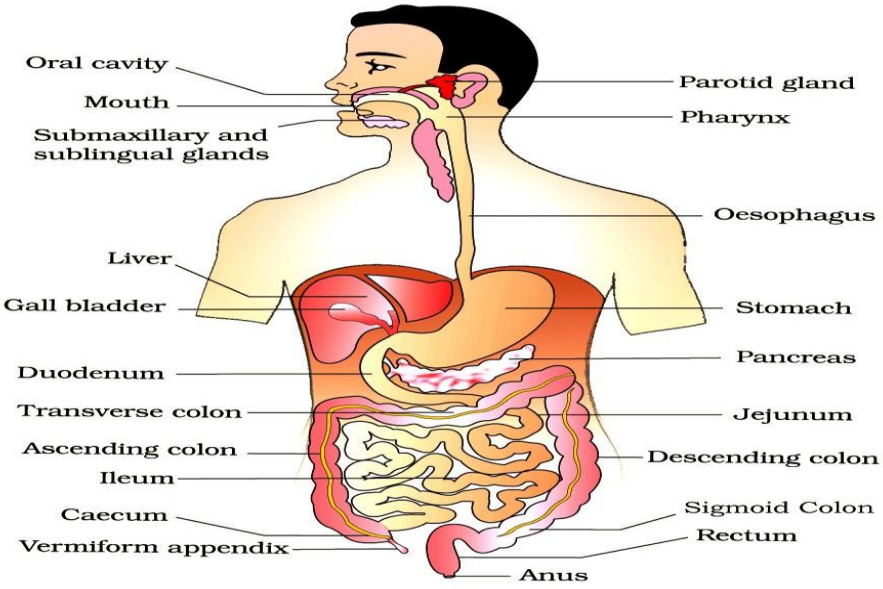
Nutrition is a process by which animal obtain essential and non-essential substances called nutrients. The way by which organisms derive their nutrients is called mode of nutrition.



The major components of our food are carbohydrates, proteins and fats. Vitamins and minerals are also required in small quantities. Food provides energy and organic materials for growth and repair of tissues. The water we take in, plays an important role in metabolic processes and also prevents dehydration of the body. Biomacromolecules in food cannot be utilised by our body in their original form. They have to be broken down and converted into simple substances in the digestive system.

Digestion is the process of conversion of complex food substances to simple absorbable forms. Digestion is carried out by our digestive system by mechanical and biochemical methods.

- Human digestive system consists of the alimentary canal and the associated glands. The main organs that make up the digestive system (in order of their function) are the mouth, oesophagus, stomach, small intestine, large intestine, rectum and anus. Helping them along the way are the pancreas, gall bladder and liver.



The alimentary canal begins with an anterior opening – the mouth, and it opens out posteriorly through the anus. The mouth leads to the buccal cavity or oral cavity. The oral cavity has a number of teeth and a muscular tongue etc., Upper surface of tongue has small projections called **papillae**, some of which contain taste buds. The tongue is a freely movable muscular organ attached to the floor of the oral cavity by the frenulum.

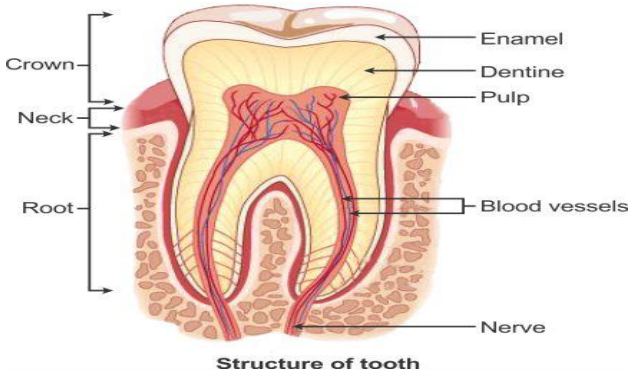
Types of dentitions in humans:

1. Heterodont dentition: presence of different types of teeth, namely incisors, canines, premolars and molars.
2. Thecodont dentition: Each tooth is embedded in a socket of jaw bone.
3. Diphyodont dentition: Majority of mammals including human being forms two sets of teeth during their life, a set of temporary milk or deciduous teeth replaced by a set of permanent or adult teeth.
   Note: . An adult human has 32 permanent teeth. Arrangement of teeth in each half of the upper and lower jaw in the order I, C, PM, M is represented by a dental formula which in human is 2123/2123 (and for the child is 2102/2102)

$$\text{Dental formula of humans} = \frac{2,1,2,3}{2,1,2,3} \times 2 = 32$$

$$\text{or} \quad \frac{\text{I, C, Pm, M}}{\text{I, C, Pm, M}} \times 2 = 32$$

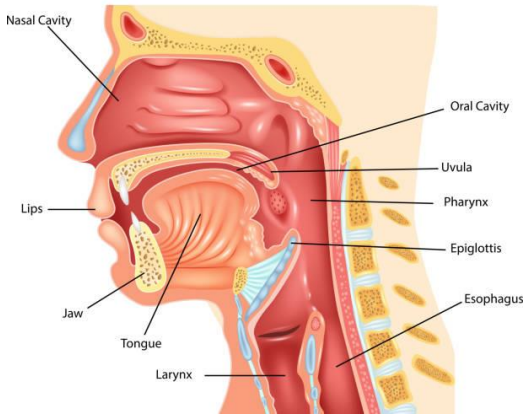
Structure of tooth



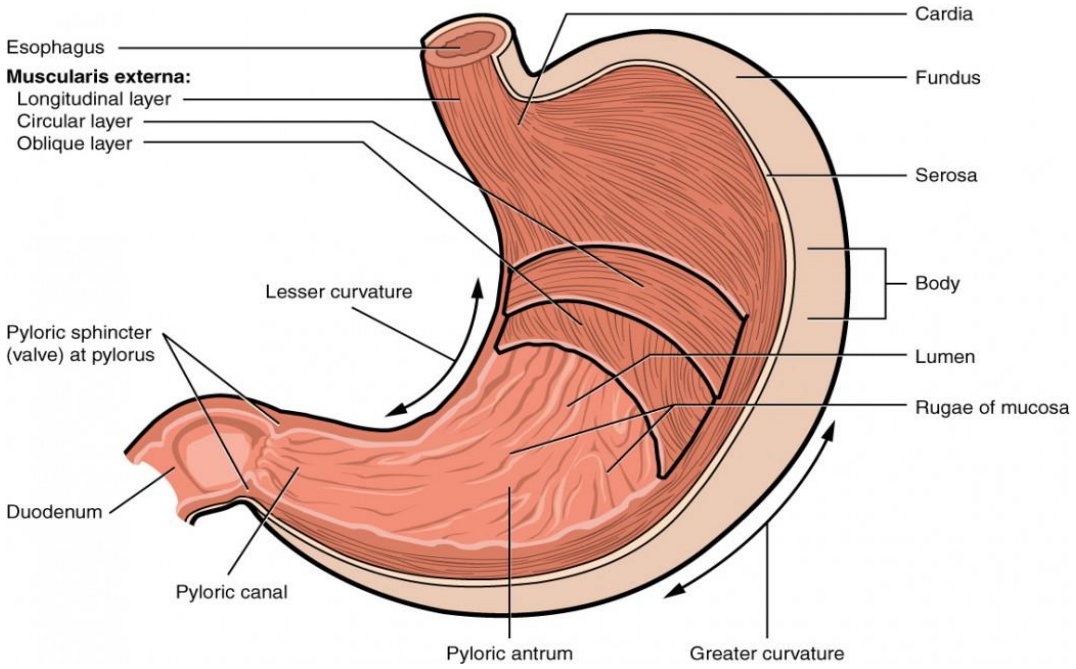
Structure of tooth

The oral cavity leads into a short pharynx which serves as a common passage for food and air. The oesophagus and the trachea (wind pipe) open into the pharynx. A cartilaginous flap called epiglottis prevents the entry of food into the glottis – opening of the wind pipe – during swallowing.

HUMAN DIGESTIVE SYSTEM



The oesophagus is a thin, long tube which extends posteriorly passing through the neck, thorax and diaphragm and leads to a 'J' shaped bag like structure called stomach. A muscular sphincter (gastro-oesophageal) regulates the opening of oesophagus into the stomach. The stomach, located in the upper left portion of the abdominal cavity, has four major parts – a cardiac portion into which the oesophagus opens, a fundic region, body (main central region) and a pyloric portion which opens into the first part of small intestine. The stomach stores the food for 4-5 hours. The food mixes thoroughly with the acidic gastric juice of the stomach by the churning movements of its muscular wall and is called the chyme.



Additional information:

1. Parietal cells or Oxyntic cells —Located primarily in the middle region of the gastric glands are parietal cells, produce both gastric juice (pH 1.8) or hydrochloric acid (HCl) and Castles intrinsic factor. HCl is responsible for the high acidity of the stomach contents and is needed to activate the protein-digesting enzyme, pepsin.

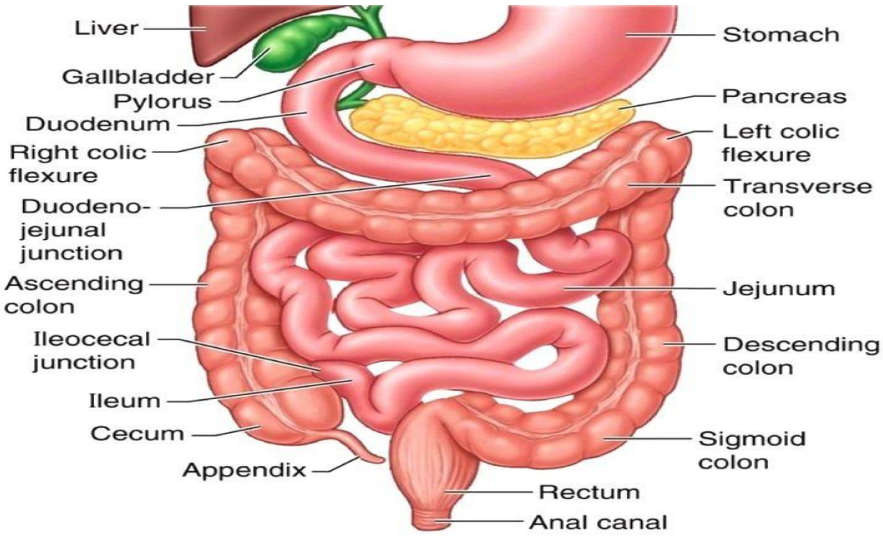
Note: The acidity also kills much of the bacteria you ingest with food and helps to denature proteins, making them more available for enzymatic digestion. Intrinsic factor is a glycoprotein necessary for the absorption of vitamin B_{12} in the small intestine.

2. Chief cells or peptic cells —Located primarily in the basal regions of gastric glands are chief cells, which secrete pepsinogen, the inactive proenzyme form of pepsin. HCl is necessary for the conversion of pepsinogen to pepsin.

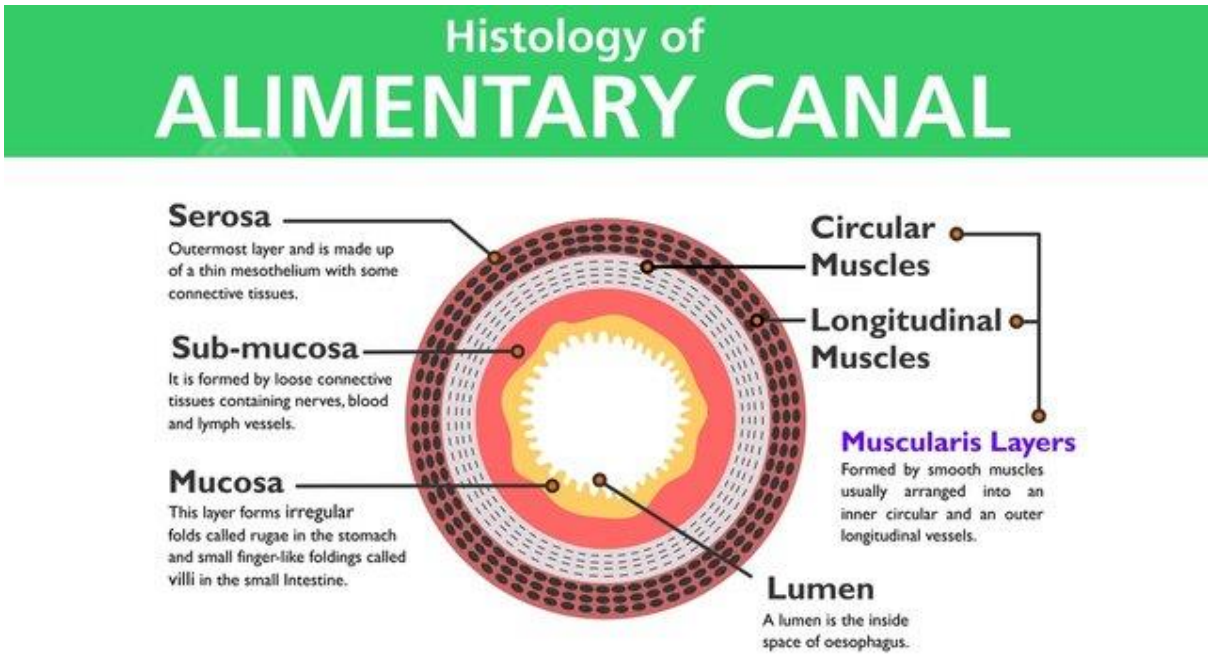
3. Mucous neck cells or Goblet cells —Gastric glands in the upper part of the stomach contain mucous neck cells that secrete thin, acidic mucus that is much different from the mucus secreted by the goblet cells of the surface epithelium.

4. Enteroendocrine cells—e.g., G cells secrete Gastrin stimulates the release of gastric juice etc.,

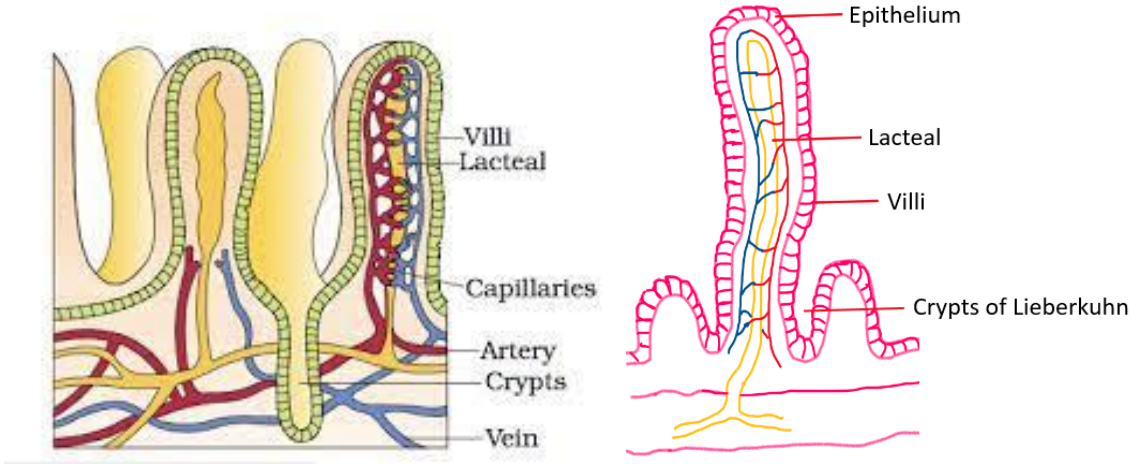
Small intestine is distinguishable into three regions, a 'C' shaped duodenum, a long coiled middle portion jejunum and a highly coiled ileum. The opening of the stomach into the duodenum is guarded by the pyloric sphincter. Ileum opens into the large intestine. It consists of caecum, colon and rectum. Caecum is a small blind sac which hosts some symbiotic micro-organisms. A narrow finger-like tubular projection, the vermiform appendix which is a vestigial organ, arises from the caecum. The caecum opens into the colon. The colon is divided into four parts – an ascending, a transverse, descending part and a sigmoid colon. The descending part opens into the rectum which opens out through the anus. The intestinal mucosal epithelium has goblet cells which secrete mucus. The secretions of the brush border cells of the mucosa along with the secretions of the goblet cells constitute the intestinal juice or succus entericus. This juice contains a variety of enzymes like disaccharidases (e.g., maltase), dipeptidases, lipases, nucleosidases, etc. The mucus along with the bicarbonates from the pancreas protects the intestinal mucosa from acid as well as provide an alkaline medium (pH 7.8) for enzymatic activities. Sub-mucosal glands (Brunner's glands) also help in this.



Histology of alimentary canal



The wall of alimentary canal from oesophagus to rectum possesses four layers namely serosa (outermost), muscularis, sub-mucosa and mucosa (innermost). Serosa is the outermost layer and is made up of a thin mesothelium (epithelium of visceral organs) with some connective tissues. Muscularis is formed by smooth muscles usually arranged into an inner circular and an outer longitudinal layer. An oblique muscle layer may be present in some regions. The submucosal layer is formed of loose connective tissues containing nerves, blood and lymph vessels. In duodenum, glands are also present in sub-mucosa. The innermost layer lining the lumen of the alimentary canal is the mucosa. This layer forms irregular folds (rugae) in the stomach and small finger-like folding's called villi in the small intestine.



The cells lining the villi produce numerous microscopic projections called microvilli giving a brush border appearance. These modifications increase the surface area enormously. Villi are supplied with a network of capillaries and a large lymph vessel called the lacteal. Mucosal epithelium has goblet cells which secrete mucus that help in lubrication. Mucosa also forms glands in the stomach (gastric glands) and crypts in between the bases of villi in the intestine (crypts of Lieberkuhn). All the four layers show modifications in different parts of the alimentary canal.

Note: Intestinal glands are of two types namely, crypts of Lieberkuhn and Brunner's glands. 1. Crypts of Lieberkuhn (mucosa): They are tubular structure that occur throughout the small intestine between the villi. They secrete digestive enzymes etc.,

2. The Brunner's glands are found in the duodenum and are located in the submucosa. They secrete mucus etc.,

The intestinal mucosal epithelium has goblet cells which secrete mucus. The secretions of the brush border cells of the mucosa along with the secretions of the goblet cells constitute the intestinal juice or succus entericus

No significant digestive activity occurs in the large intestine. The functions of large intestine are:

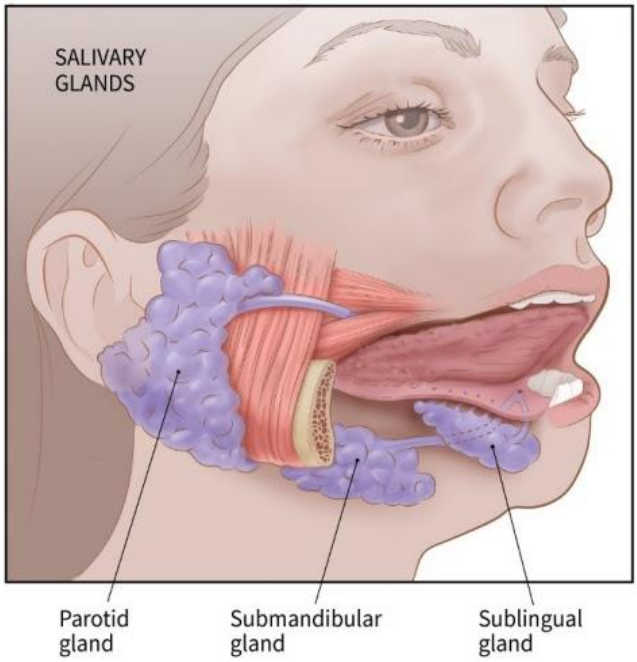
(i) absorption of some water, minerals and certain drugs;

(ii) secretion of mucus which helps in adhering the waste (undigested) particles together and lubricating it for an easy passage.

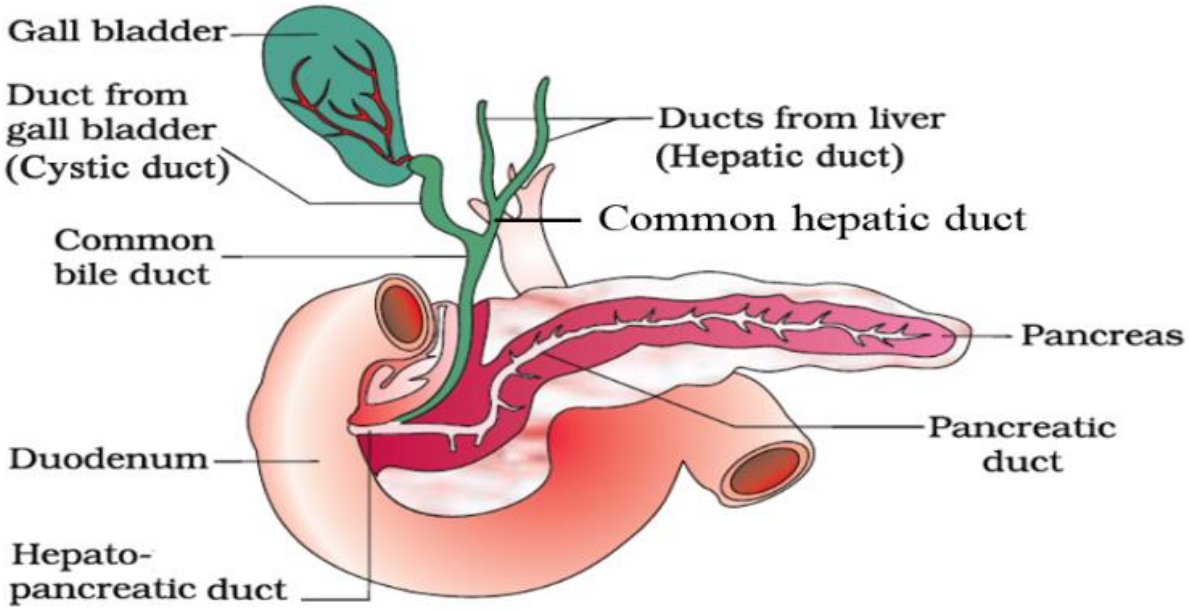
Digestive Glands:

The digestive glands associated with the alimentary canal include the salivary glands, the liver and the pancreas.

1. Saliva is mainly produced by three pairs of salivary glands, the parotids (cheek), the submaxillary/sub-mandibular (lower jaw) and the sub- linguals (below the tongue). These glands situated just outside the buccal cavity secrete salivary juice into the buccal cavity.



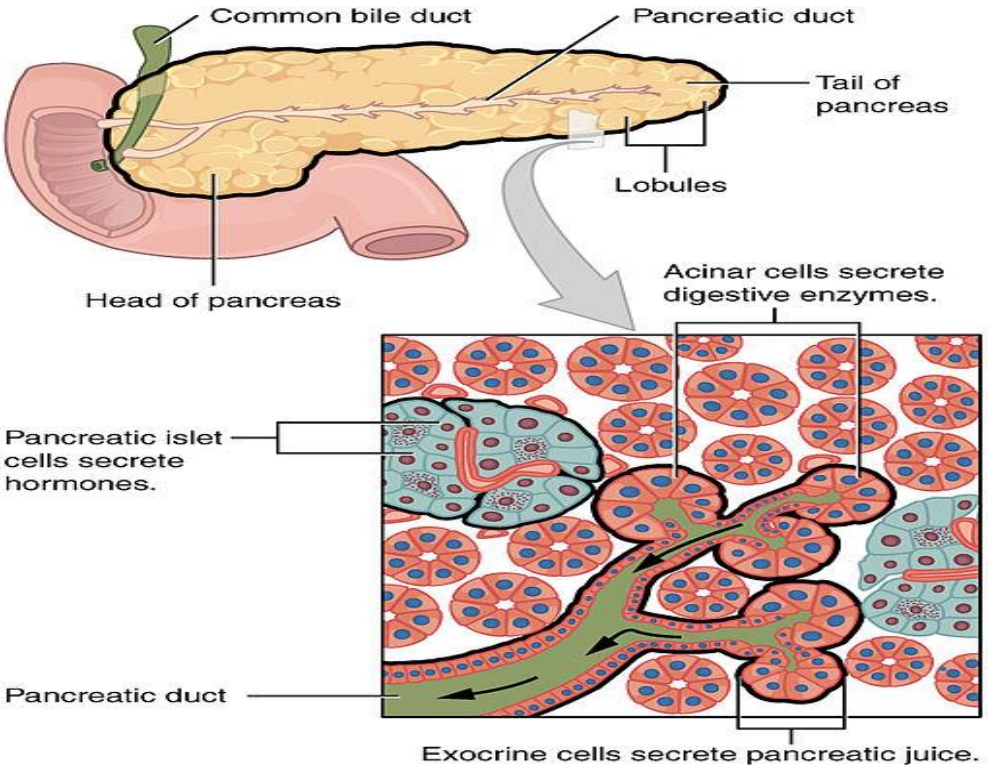
2. Liver is the largest gland of the body weighing about 1.2 to 1.5 kg in an adult human. It is situated in the abdominal cavity, just below the diaphragm and has two lobes. The hepatic lobules are the structural and functional units of liver containing hepatic cells arranged in the form of cords. Each lobule is covered by a thin connective tissue sheath called the Glisson's capsule. The bile secreted by the hepatic cells passes through the hepatic ducts and is stored and concentrated in a thin muscular sac called the gall bladder. The duct of gall bladder (cystic duct) along with the hepatic duct from the liver forms the common bile duct (Figure 16.6). The bile duct and the pancreatic duct open together into the duodenum as the common hepato-pancreatic duct which is guarded by a sphincter called the sphincter of Oddi.



Additional information:

1. Bile production: Bile helps the small intestine break down and absorb fats etc., Bile consists of bile salts, cholesterol, bilirubin, electrolytes, and water.
2. Fat metabolization: Bile breaks down fats and makes them easier to digest.
3. Metabolizing carbohydrates: Carbohydrates are stored in the liver, where they are broken down into glucose and siphoned into the bloodstream to maintain normal glucose levels. They are stored as glycogen and released whenever a quick burst of energy is needed.
4. Vitamin and mineral storage: The liver stores vitamins A, D, E, K, and B12. It keeps significant amounts of these vitamins stored.
5. Immunological function: The liver is part of the mononuclear phagocyte system. It contains high numbers of Kupffer cells that are involved in immune activity.
6. Production of albumin: Albumin is the most common protein in blood serum. It transports fatty acids and steroid hormones to help maintain the correct pressure and prevent the leaking of blood vessels.
7. Synthesis of angiotensinogen: This hormone raises blood pressure by narrowing the blood vessels when alerted by production of an enzyme called renin in the kidneys.
8. Formation of urea (by Ornithine cycle)

The pancreas is a compound (both exocrine and endocrine) elongated organ situated between the limbs of the 'C' shaped duodenum. The exocrine portion secretes an alkaline pancreatic juice containing enzymes and the endocrine portion secretes hormones, insulin and glucagon.



Pancreatic juice and bile are released through the hepato-pancreatic duct. The pancreatic juice contains inactive enzymes – trypsinogen, chymotrypsinogen, procarboxypeptidases, amylases, lipases and nucleases. Trypsinogen is activated by an enzyme, enterokinase, secreted by the intestinal mucosa into active trypsin, which in turn activates the other enzymes in the pancreatic juice.

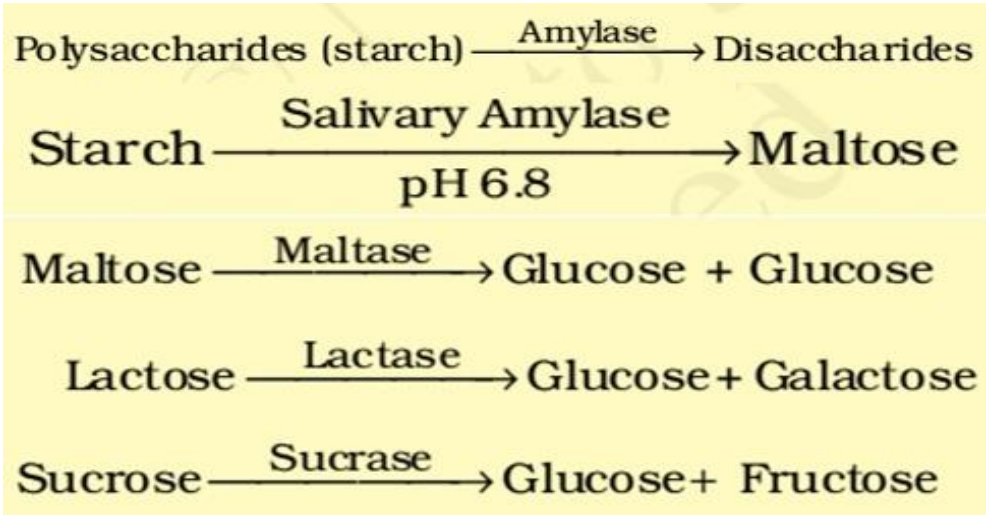
The process of digestion is accomplished by mechanical and chemical processes. The buccal cavity performs two major functions, mastication of food and facilitation of swallowing. The teeth and the tongue with the help of saliva masticate and mix up the food thoroughly. Mucus in saliva helps in lubricating and adhering the masticated food particles into a bolus. The bolus is then conveyed into the pharynx and then into the oesophagus by swallowing or deglutition. The bolus further passes down through the oesophagus by successive waves of muscular contractions called peristalsis. The gastro-oesophageal sphincter controls the passage of food into the stomach. The saliva secreted into the oral cavity contains electrolytes and enzymes, salivary amylase and lysozyme. The chemical process of digestion is initiated in the oral cavity by the hydrolytic action of the carbohydrate splitting enzyme, the salivary amylase.

For reference:

1. Saliva – Salivary amylase and lysozyme
2. Gastric juice – Pepsin and Rennin (in infants) and lipase (small amount)
3. Pancreatic juice - trypsin, chymotrypsin, carboxypeptidase, amylases, lipases and nucleases.
4. Succus entericus (or intestinal juice) - contains a variety of enzymes like disaccharidases (e.g., maltase, sucrase, lactase), dipeptidases, lipases, nucleosidases, etc.

Digestion of carbohydrates

The chemical process of digestion is initiated in the oral cavity by the hydrolytic action of the carbohydrate splitting enzyme, the salivary amylase. About 30 per cent of starch is hydrolysed here by this enzyme (optimum pH 6.8) into a disaccharide – maltose. Pancreatic amylase acts on polysaccharides (e.g., starch) and convert them to disaccharide (e.g., maltose). Maltase, lactase and sucrase of succus entericus convert disaccharides to monosaccharides.



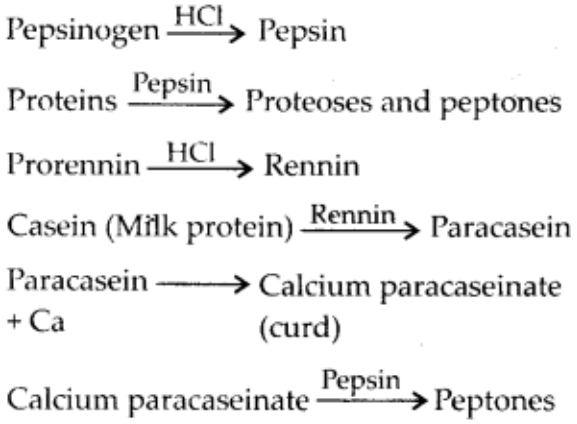
Digestion of Proteins (starts from stomach)

The proenzyme pepsinogen, on exposure to hydrochloric acid gets converted into the active enzyme pepsin, the proteolytic enzyme of the stomach. Pepsin converts proteins into proteoses and peptones (peptides).

Note: The food mixes thoroughly with the acidic gastric juice of the stomach by the churning movements of its muscular wall and is called the chyme. The proenzyme pepsinogen, on exposure to

hydrochloric acid gets converted into the active enzyme pepsin, the proteolytic enzyme of the stomach. Pepsin converts proteins into proteoses and peptones (peptides). The mucus and bicarbonates present in the gastric juice play an important role in lubrication and protection of the mucosal epithelium from excoriation by the highly concentrated hydrochloric acid. HCl provides the acidic pH (pH 1.8) optimal for pepsins. Rennin is a proteolytic enzyme found in gastric juice of infants which helps in the digestion of milk proteins. Small amounts of lipases are also secreted by gastric glands.

Note: Small amounts of lipases are also secreted by gastric glands



The bile, pancreatic juice and the intestinal juice are the secretions released into the small intestine.

Note: Trypsinogen is activated by an enzyme, enterokinase, secreted by the intestinal mucosa into active trypsin, which in turn activates the other enzymes in the pancreatic juice. Proteins, proteoses and peptones (partially hydrolysed proteins) in the chyme reaching the intestine are acted upon by the proteolytic enzymes of pancreatic juice.

Dipeptidase in succus entericus converts dipeptides into amino acids

Digestion and absorption of lipids

1. The bile released into the duodenum contains bile pigments (bilirubin and biliverdin), bile salts, cholesterol and phospholipids but no enzymes. Bile helps in emulsification of fats, i.e., breaking down of the fats into very small micelles. Bile also activates lipases.
   Note: Fat emulsification is the process of increasing the surface area of fats in the small intestine by grouping them into small clusters. This is the responsibility of bile, a liquid

created by the liver and stored in the gallbladder. Actual digestion of the fats is then accomplished by lipase, an enzyme from the pancreas etc.,

2. Fats are broken down by lipases with the help of bile into di-and monoglycerides.

   Fats --→Diglycerides---→ Monoglycerides

3. In succus entericus

   Di and Monoglycerides ---→Fatty acids + Glycerol

4. Fatty acids and glycerol being insoluble, cannot be absorbed into the blood. They are first incorporated into small droplets called micelles which move into the intestinal mucosa. They are re-formed into very small protein coated fat globules called the chylomicrons which are transported into the lymph vessels (lacteals) in the villi. These lymph vessels ultimately release the absorbed substances into the blood stream.

   Digestion of nucleic acid

   1. Nucleases in the pancreatic juice acts on nucleic acids to form nucleotides and nucleosides

   Nucleic acids -→Nucleotides →Nucleosides

   2. In succus entericus

   Nucleotides---→ Nucleosides →Sugars + Bases

   ABSORPTION OF DIGESTED PRODUCTS

1. Absorption is the process by which the end products of digestion pass through the intestinal mucosa into the blood or lymph. It is carried out by passive, active or facilitated transport mechanisms.
2. Small amounts of monosaccharides like glucose, amino acids and some electrolytes like chloride ions are generally absorbed by simple diffusion. The passage of these substances into the blood depends upon the concentration gradients.
3. However, some substances like glucose and amino acids are absorbed with the help of carrier proteins. This mechanism is called the facilitated transport.

4. Transport of water depends upon the osmotic gradient.
5. Active transport occurs against the concentration gradient and hence requires energy. Various nutrients like amino acids, monosaccharides like glucose, electrolytes like Na+ are absorbed into the blood by this mechanism.

Note: CALORIFIC VALUE OF PROTEIN, CARBOHYDRATE AND FAT

1. The energy requirements of animals, and the energy content of food, are expressed in terms of measure of heat energy because heat is the ultimate form of all energies. This is often measured to as calorie (cal) or joule (J), which is the amount of heat energy required to raise the temperature of 1 g of water by 1 °C.
2. Since this value is tiny amount of energy, physiologists commonly use kilocalorie (kcal) or kilo joule (kJ). One kilo calorie is the amount of energy required to raise the temperature of 1 kg of water by 1 °C. Nutritionists, traditionally refer to kcal as the Calorie or Joule (always capitalised).
3. The amount of heat liberated from complete combustion of 1 g food in a bomb calorimeter (a closed metal chamber filled with oxygen) is its gross calorific or gross energy value.
4. The actual amount of energy combustion of 1 g of food is the physiologic value of food. Gross
5. Calorific values of carbohydrates, proteins and fats are 4.1 kcal/g, 5.65 kcal/g and 9.45 kcal/g,
6. Physiologic values are 4.0 kcal/g, 4.0 kcal/g and 9.0 kcal/g.

Nutrient	Caloric value	Physiological fuel value
Carbohydrate	4.1 Kcal/gm	4.0 Kcal/gm
Protein	5.6 Kcal/gm	4.0 Kcal/gm
Fat	9.45 Kcal/gm	9.0 Kcal/gm

Note: Absorption of substances takes place in different parts of the alimentary canal, like mouth, stomach, small intestine and large intestine. However, maximum absorption occurs in the small intestine.

Mouth	Stomach	Small Intestine	Large Intestine
Certain drugs coming in contact with the mucosa of mouth and lower side of the tongue are absorbed into the blood capillaries lining them.	Absorption of water, simple sugars, and alcohol etc. takes place.	Principal organ for absorption of nutrients. The digestion is completed here and the final products of digestion such as glucose, fructose, fatty acids, glycerol and amino acids are absorbed through the mucosa into the blood stream and lymph.	Absorption of water, some minerals and drugs takes place.

Note: The absorbed substances finally reach the tissues which utilise them for their activities. This process is called assimilation. The digestive wastes, solidified into coherent faeces in the rectum initiate a neural reflex causing an urge or desire for its removal. The egestion of faeces to the outside through the anal opening (defaecation) is a voluntary process and is carried out by a mass peristaltic movement.

DISORDERS OF DIGESTIVE SYSTEM

Note: The inflammation of the intestinal tract is the most common ailment due to bacterial or viral infections. The infections are also caused by the parasites of the intestine like tapeworm, roundworm, threadworm, hookworm, pin worm, etc.

1. Jaundice: The liver is affected; skin and eyes turn yellow due to the deposit of bile pigments. Note: Jaundice is a condition in which the skin, whites of the eyes and mucous membranes turn yellow because of a high level of bilirubin, a yellow-orange bile pigment. Jaundice has many causes, including hepatitis, gallstones and tumours etc.,
2. Vomiting: It is the ejection of stomach contents through the mouth. This reflex action is controlled by the vomit centre in the medulla. A feeling of nausea precedes vomiting.
3. Diarrhoea: The abnormal frequency of bowel movement and increased liquidity of the faecal discharge is known as diarrhoea. It reduces the absorption of food. Constipation: In
4. Constipation, the faeces are retained within the colon as the bowel movements occur irregularly.

5. Indigestion: In this condition, the food is not properly digested leading to a feeling of fullness. The causes of indigestion are inadequate enzyme secretion, anxiety, food poisoning, over eating, and spicy food.
6. Protein Energy Malnutrition (PEM) – Marasmus and Kwashiorkar.
    a. Marasmus is produced by a simultaneous deficiency of proteins and calories.
        i. It is found in infants less than a year in age, if mother's milk is replaced too early by other foods which are poor in both proteins and caloric value.
        ii. This often happens if the mother has second pregnancy or childbirth when the older infant is still too young.
        iii. In Marasmus, protein deficiency impairs growth and replacement of tissue proteins; extreme emaciation of the body and thinning of limbs results, the skin becomes dry, thin and wrinkled.
        iv. Growth rate and body weight decline considerably. Even growth and development of brain and mental faculties are impaired.
    b. Kwashiorkar is produced by protein deficiency unaccompanied by calorie deficiency.
        i. It results from the replacement of mother's milk by a high calorie, low protein diet in a child more than one year in age.
        ii. Like marasmus, kwashiorkor shows wasting of muscles, thinning of limbs, failure of growth and brain development.

    Note: But unlike marasmus, some fat is still left under the skin; moreover, extensive oedema and swelling of body parts are seen.