DIGESTION AND ABSORPTION

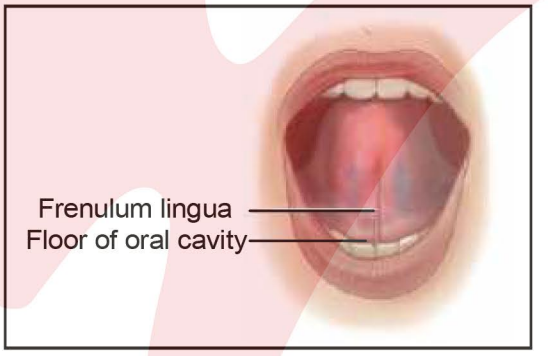
Food is one of the basic requirements of all living organisms. The major components of our food are carbohydrates, proteins and fats. Vitamins and minerals are also required in small quantities. Food provides energy and organic materials for growth and repair of tissues. The water we take in, plays an 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. This process of conversion of complex food substances to simple absorbable forms is called digestion and is carried out by our digestive system by mechanical and biochemical methods.

The human digestive system consists of the alimentary canal and the associated glands.

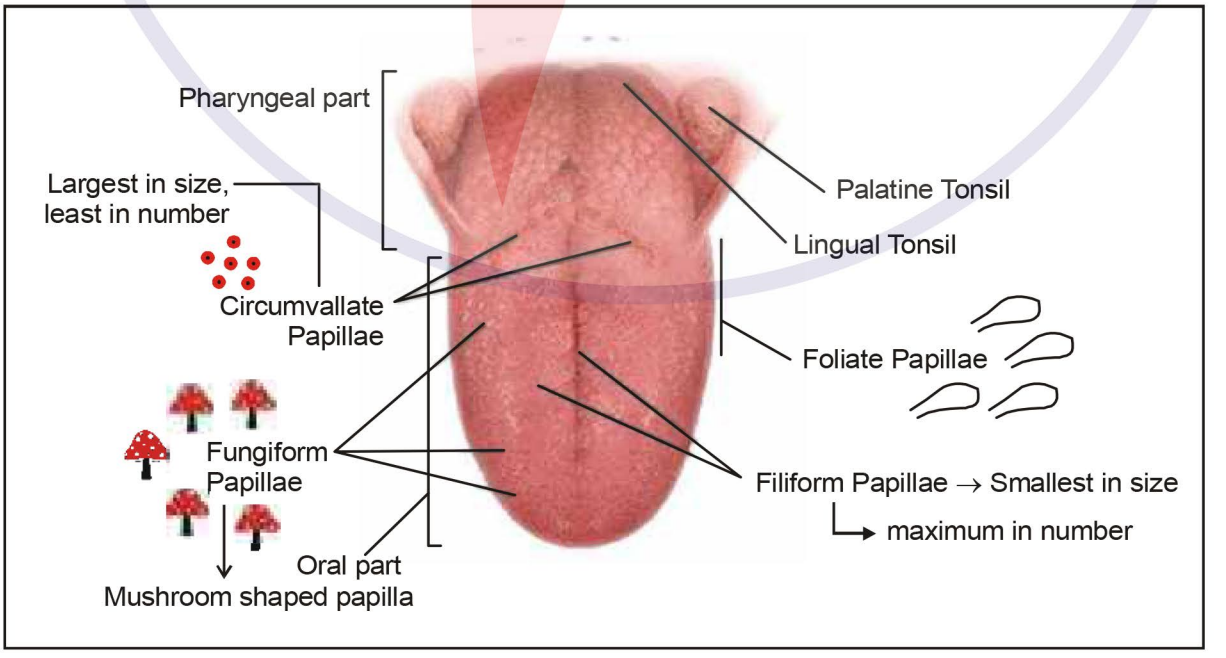
ALIMENTARY CANAL

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.

Tongue is highly muscular organ attach to the floor of oral cavity with the help of filamentous fold called frenulum lingua

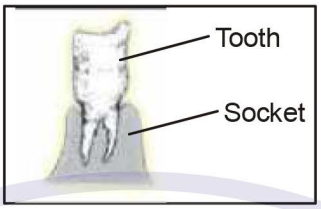


The upper surface of the tongue has small projections called papillae, some of which bear taste buds.

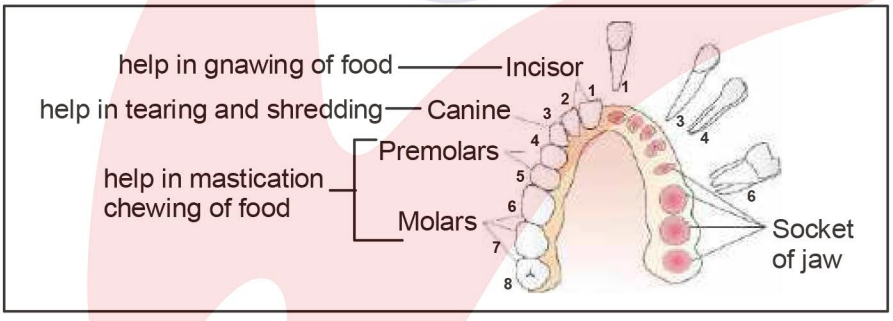


TEETH

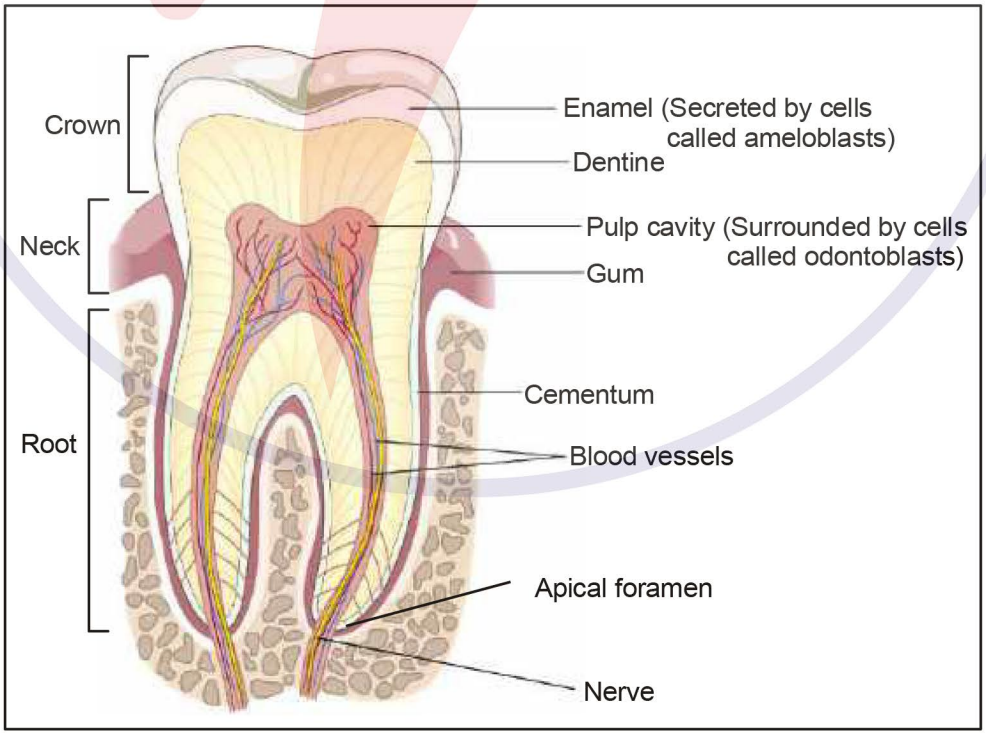
The oral cavity has a number of teeth and a muscular tongue. Each tooth is embedded in a socket of jaw bone. This type of attachment is called thecodont.



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. This type of dentition is called diphyodont. An adult human has 32 permanent teeth which are of four different types (Heterodont dentition), namely, incisors (I), canine (C), premolars (PM) and molars (M). 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 . (Diphyodont - 20 in number - 8 incisors, 4 canines, 6 molars) (monophyodont - 12 in number - 8 premolars, 4 last molars)



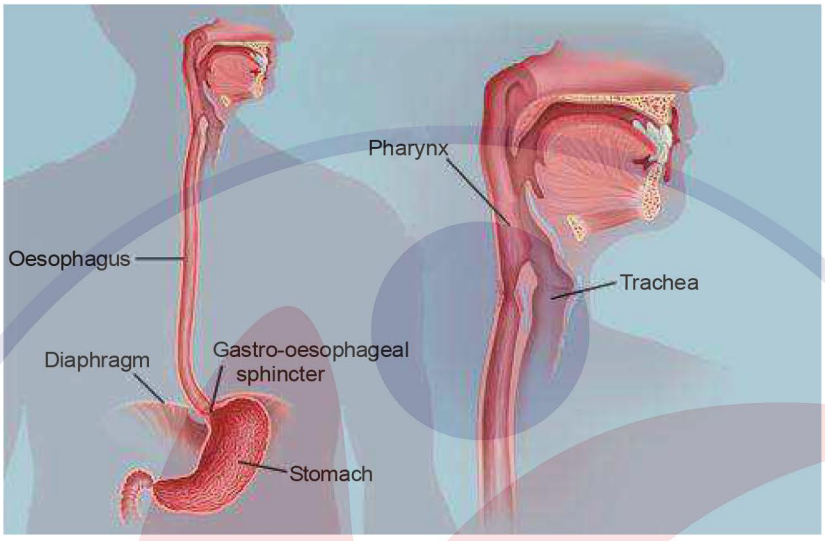
The hard chewing surface of the teeth, made up of enamel, helps in the mastication of food.



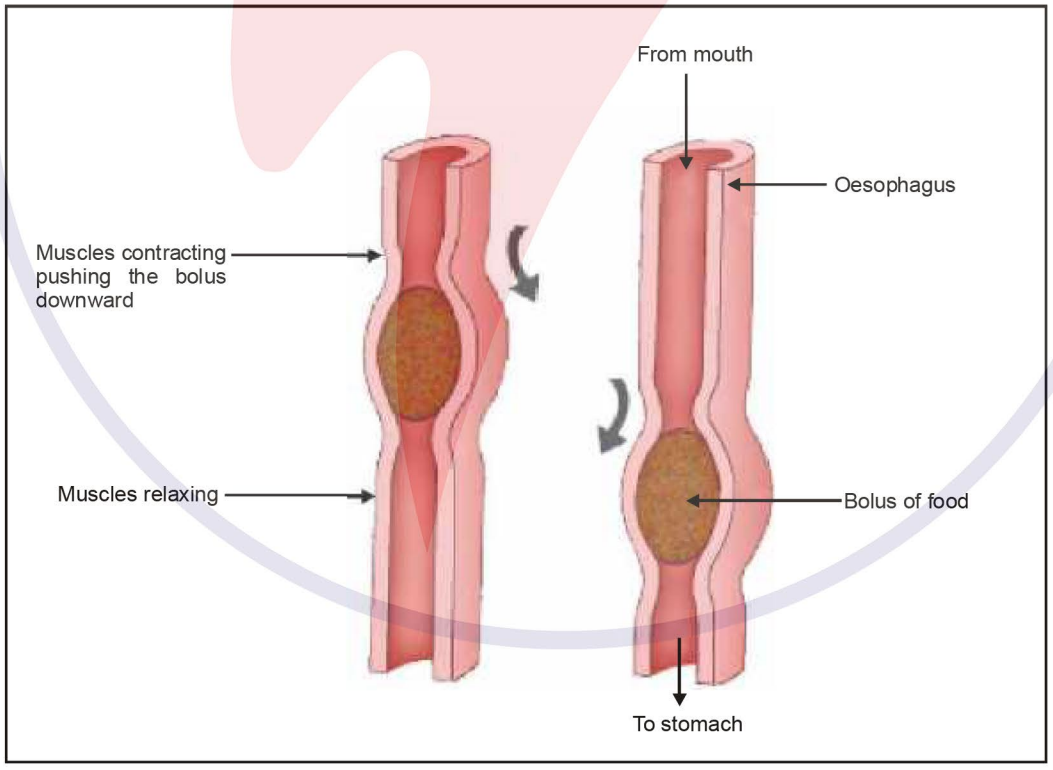
Enamel is the hardest substance of animal kingdom because it contains maximum amount of inorganic substances (96%). Dentine is the main part of tooth. Dentine contain 69% of inorganic substances.

OESOPHAGUS

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. 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.

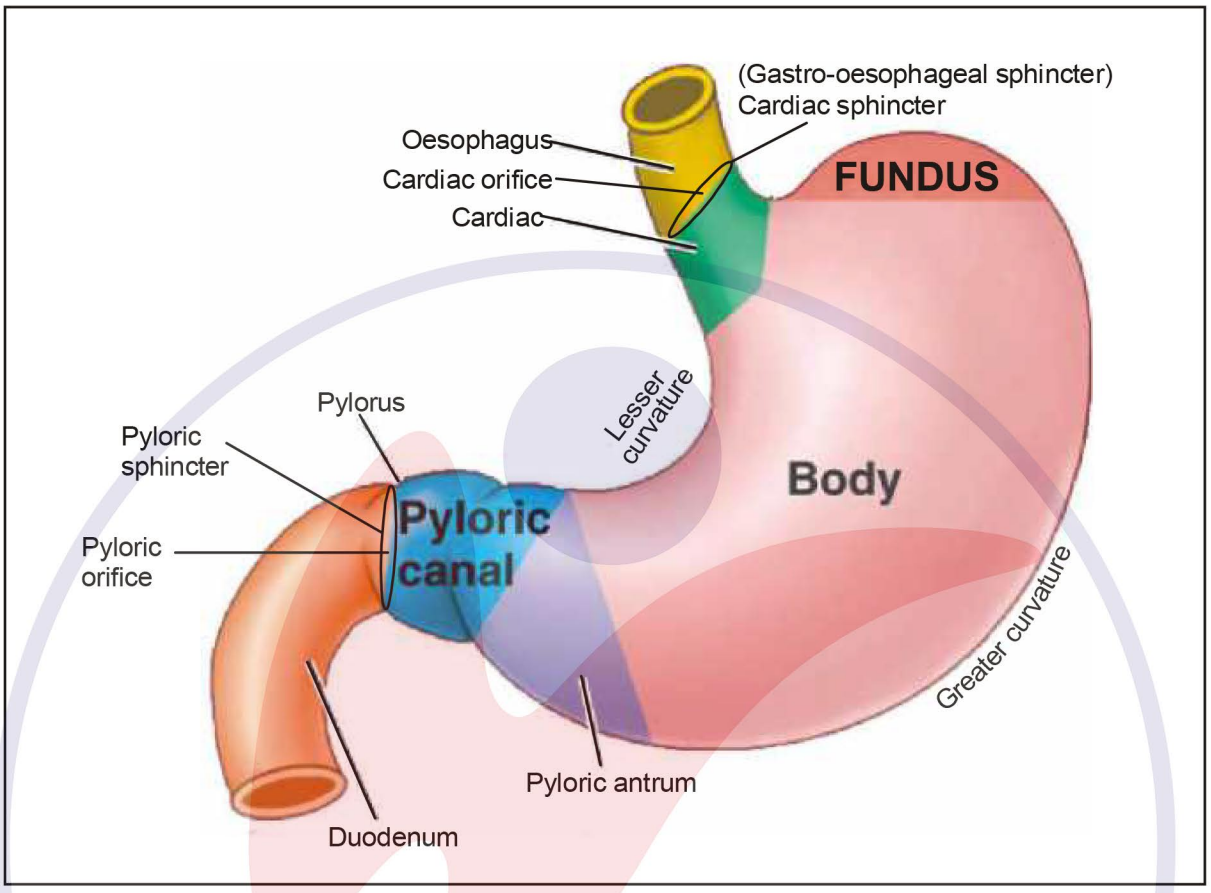


The bolus (mixture of food and saliva) passes down through the oesophagus by successive waves of muscular contractions called peristalsis. The gastro-oesophageal sphincter controls the passage of food into the stomach.



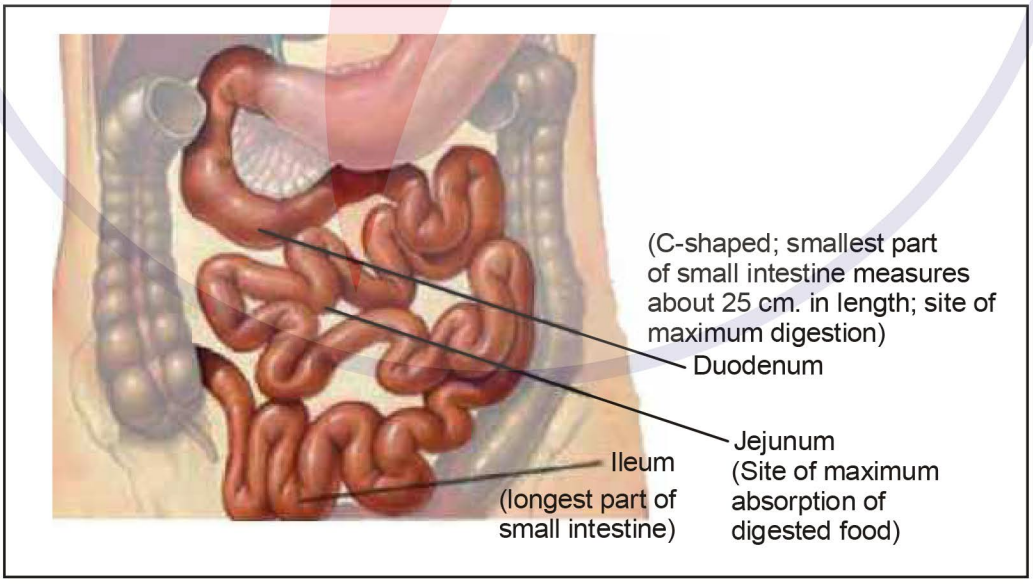
STOMACH

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 parts : cardiac, fundus, body and pylorus (cardiac portion in which the oesophagus opens, whereas the pyloric portion which opens into the first part of small intestine). The opening of the stomach into the duodenum is guarded by the pyloric sphincter.



SMALL INTESTINE

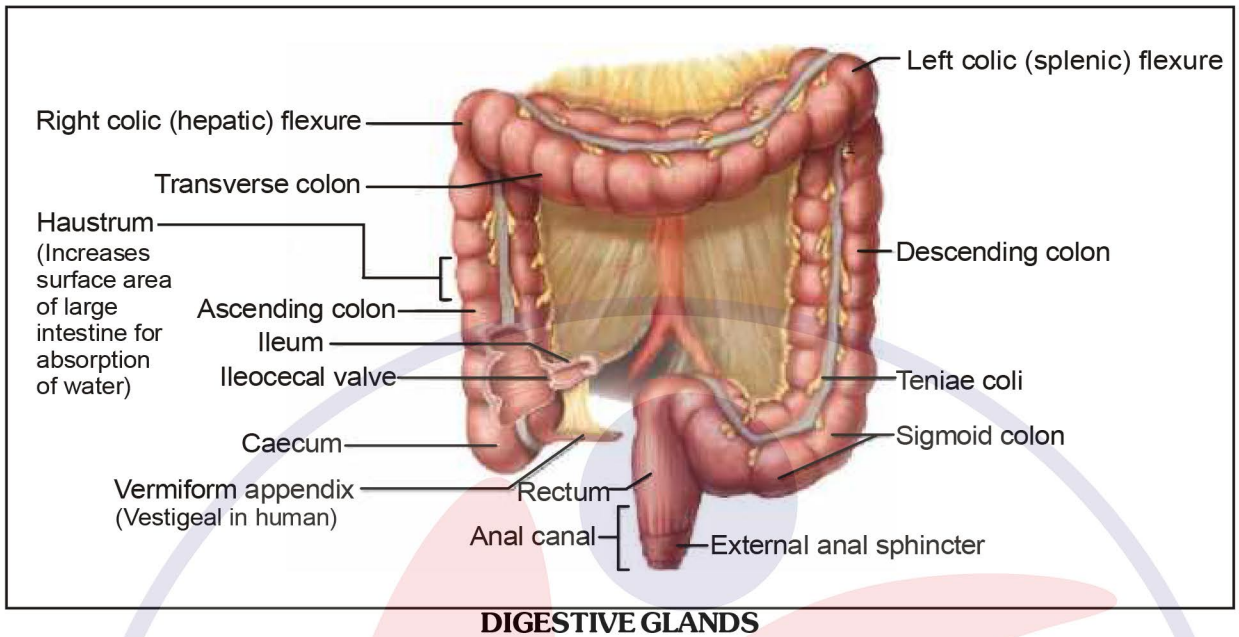
Small intestine is distinguishable into three regions, a 'C' shaped duodenum, a long coiled middle portion jejunum and a highly coiled ileum.



LARGE INTESTINE

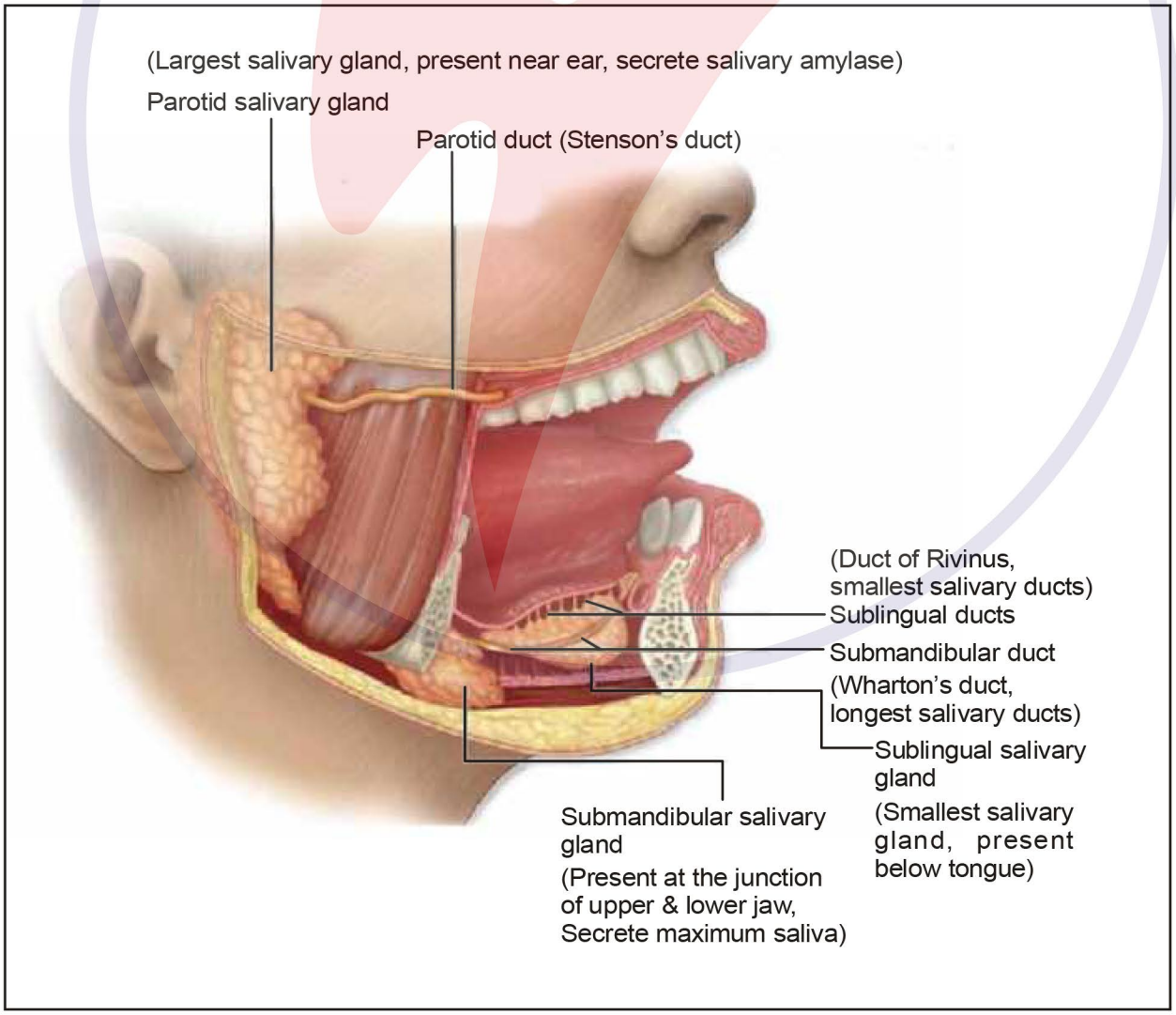
Ileum opens into the large intestine. It consists of caecum, colon and rectum. Caecum is a small blind sac which hosts some symbiotic micro-organisms. A narrow finger-like tubular projection, the vermiform appendix which is a vestigial organ, arises from the caecum. The caecum opens into the colon. The colon is divided into three parts – an ascending,

a transverse and a descending part. The descending part opens into the rectum which opens out through the anus.



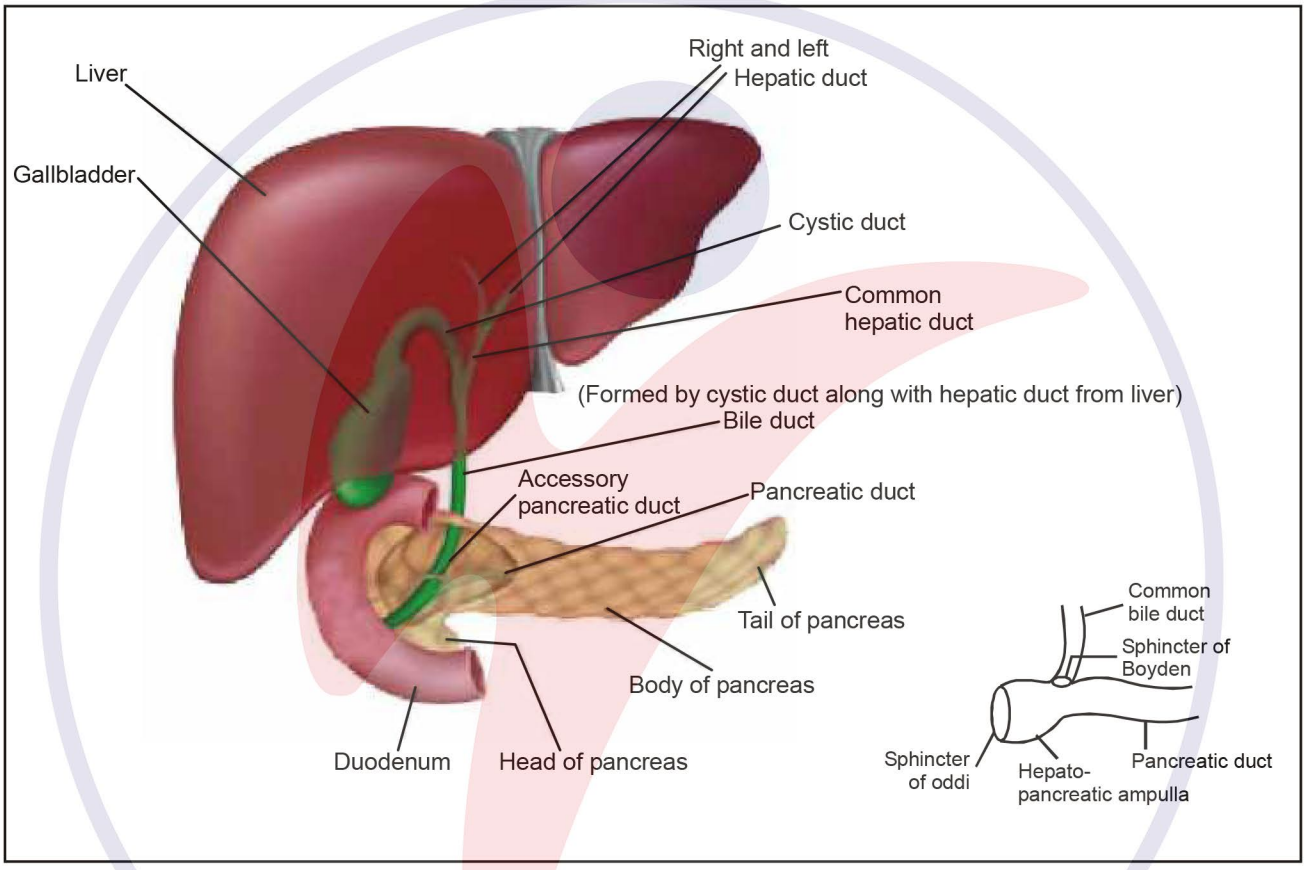
DIGESTIVE GLANDS

The digestive glands associated with the alimentary canal include the salivary glands, the liver and the pancreas. Saliva is mainly produced by three pairs of salivary glands, the parotids (cheek), the sub-maxillary/sub-mandibular (lower jaw) and the sublinguals (below the tongue). These glands situated just outside the buccal cavity secrete salivary juice into the buccal cavity.



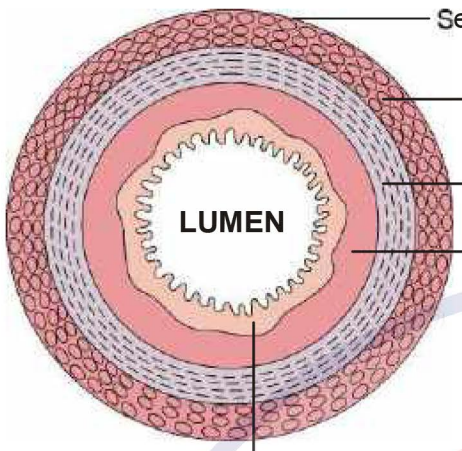
Liver is the largest gland of the body weighing about 1.2 to 1.5 kg in an adult human. It is situated in the abdominal cavity, just below the diaphragm and has two lobes. The bile secreted by the hepatic cells passes through the hepatic ducts and is stored and concentrated in a thin muscular sac called the gall bladder. The duct of gall bladder (cystic duct) along with the hepatic duct from the liver forms the common bile duct

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. 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.



HISTOLOGY OF ALIMENTARY CANAL

The wall of alimentary canal from oesophagus to rectum possesses four layers namely serosa, muscularis, sub-mucosa and mucosa. 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 foldings 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.



Serosa – Outermost layer, made up of a thin mesothelium with some connective tissue

Outer Longitudinal

Inner circular

Muscularis – an oblique muscle layer may be present in some regions as in stomach

Submucosa

Made up of loose connective tissue containing nerves, blood and lymph vessels. In duodenum, Brunners glands are also present which synthesise and secrete nonenzymatic part of intestinal juice (Succus entericus)

Mucosa (Innermost layer)
- forms irregular folds called rugae in stomach
- forms small finger like folding called villi in small intestine
- forms gastric glands in stomach whereas crypts of Lieberkuhn in small intestine
- Payer's patches and paneth cells in jejunum and ileum.

The cells lining the villi produce numerous microscopic projections called microvilli giving a brush border appearance. These modification increase the surface area enormously

Modifications in epithelium
- Oesophagus → Stratified squamous nonkeratinised epithelium
- Stomach → Simple columnar glandular epithelium
- Duodenum → Simple columnar brush border glandular epithelium with blunt villi
- Jejunum, Ileum → Simple columnar brush border glandular epithelium with sharp and pointed villi

DIGESTION OF FOOD

The process of digestion is accomplished by mechanical and chemical processes.

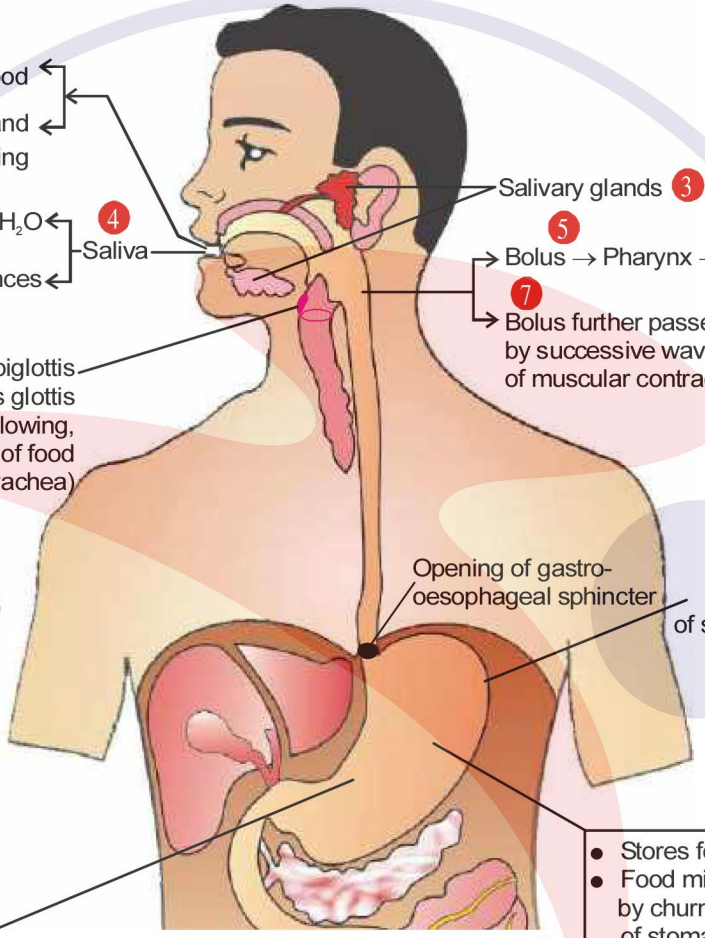
The buccal cavity performs two major functions, mastication of food and facilitation of swallowing. The teeth and the tongue with the help of saliva masticate and mix up the food thoroughly. Mucus in saliva helps in lubricating and adhering the masticated food particles into a bolus. The bolus is then 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 (Na^+, K^+, Cl^-, HCO^-) 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. About 30 per cent of starch is hydrolysed here by this enzyme (optimum pH 6.8) into a disaccharide – maltose. Lysozyme present in saliva acts as an antibacterial agent that prevents infections.

$$\text{Starch} \xrightarrow[\text{pH 6.8}]{\text{Salivary Amylase}} \text{Maltose}$$

The mucosa of stomach has gastric glands. Gastric glands have three major types of cells namely - (i) mucus neck cells which secrete mucus; (ii) peptic or chief cells which secrete the proenzyme pepsinogen; and (iii) parietal or oxyntic cells which secrete HCl and intrinsic factor (factor essential for absorption of vitamin B_{12}).

Vitamin B_{12} is also called cyanocobalamine. Deficiency of vitamin B_{12} causes pernicious anaemia.

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. 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).



1 (Teeth) Mastication of food

2 (Tongue) Blocks the mouth and Facilitation of swallowing

N_2 waste
(Lubrication of food), Mucin
(Bacteriocidal), Lysozyme
IgA antibody
Salivary amylase

Starch $\xrightarrow[pH = 6.8]{\text{Salivary Amylase}}$ Maltose

4 Saliva: 99.5% H_2O; 0.5% other substances

Salivary glands 3

5 Bolus → Pharynx → Oesophagus by swallowing or deglutition

7 Bolus further passes down through the oesophagus by successive waves of muscular contractions called peristalsis.

6 Epiglottis (Covers glottis during swallowing, prevent entry of food into larynx and trachea)

Opening of gastro-oesophageal sphincter

8 Mucosa of stomach

GASTRIC GLANDS

- **Mucus neck cells** → mucus
  This mucus & bicarbonates helps in the lubrication & protection of epithelium from excoriation
- **Peptic cells/Chief cells**
  Proenzyme pepsinogen
  Prorennin in infants
- **Parietal/Oxyntic cells** → HCl & Intrinsic factors

9

- Small amount of lipases are also secreted
- Gastric lipase convert 1% emulsified fats into fatty acids and glycerol.

Pepsinogen $\xrightarrow{HCl\ (pH = 1.8)}$ Pepsin (Proteolytic)

Proteins $\xrightarrow{Pepsin}$ Proteoses + Peptones

- Digestion of milk proteins in infants is done with help of **"Rennin"** i.e. proteolytic enzyme found in gastric juice of infants.

10

- Stores food for 4-5 hours
- Food mixes with acidic gastric juice by churning movements of stomach and is known as chyme

11 Three phases of release of Gastric Juice

- Cephalic Phase
- Gastric Phase
- Intestinal Phase

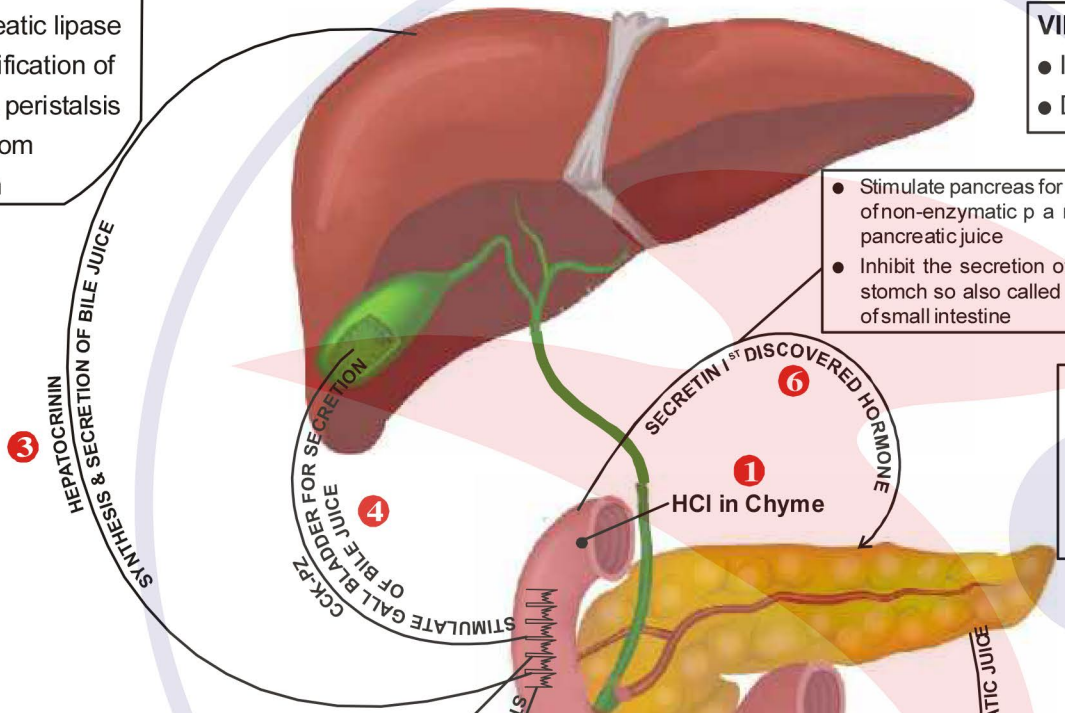
The mucus and bicarbonates present in the gastric juice play an important role in lubrication and protection of the mucosal epithelium from excoriation by the highly concentrated hydrochloric acid. HCl provides the acidic pH (pH 1.8) optimal for pepsins. Rennin is a proteolytic enzyme found in gastric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

DIGESTION IN SMALL INTESTINE

BILE JUICE - pH 8.0 ; alkaline in nature
- Also called pseudodigestive juice
- Inhibit the action of HCl
- Activate pancreatic lipase
- Helps in emulsification of fats. Stimulate peristalsis
- Prevent food from decomposition

GIP - Gastric Inhibitory Peptide (Glucose dependent insulinotrophic peptide)
- Decrease the secretion of gastric juice in stomach

VIP - Vasoactive Intestinal Peptide
- Increase peristalsis in intestine
- Decrease peristalsis in stomach



- Stimulate pancreas for syn/sec of non-enzymatic part of pancreatic juice
- Inhibit the secretion of HCl in stomch so also called fireman of small intestine

DIGESTION IN DUODENUM

Biomacromolecules are digested in presence of bile juice and pancreatic juice

Proteins, Peptones, Proteoses —(Trypsin/Chymotrypsin, Carboxypeptidase)→ Dipeptides

Polysaccharides (starch) —(Pancreatic amylase)→ Disaccharides

Fats —(Pancreatic Lipase)→ Diglycerides → Monoglycerides

Nucleic acids —(Nucleases)→ Nucleotides → Nucleosides

Enterokinase, and Ca^{+2} convert trypsinogen into trypsin

ENTEROENDOCRINE CELLS OF INTESTINE

- → **Villikinin -** Increase the activity of villi
- → **Duocrinin -** Stimulate Brunners glands for syn/sec of non-enzymatic part of intestinal juice

  Enterocrinin - Stimulate Paneth cells or syn/sec of enzymatic part of intestinal juice

DIGESTION IN JEJUNUM AND ILEUM

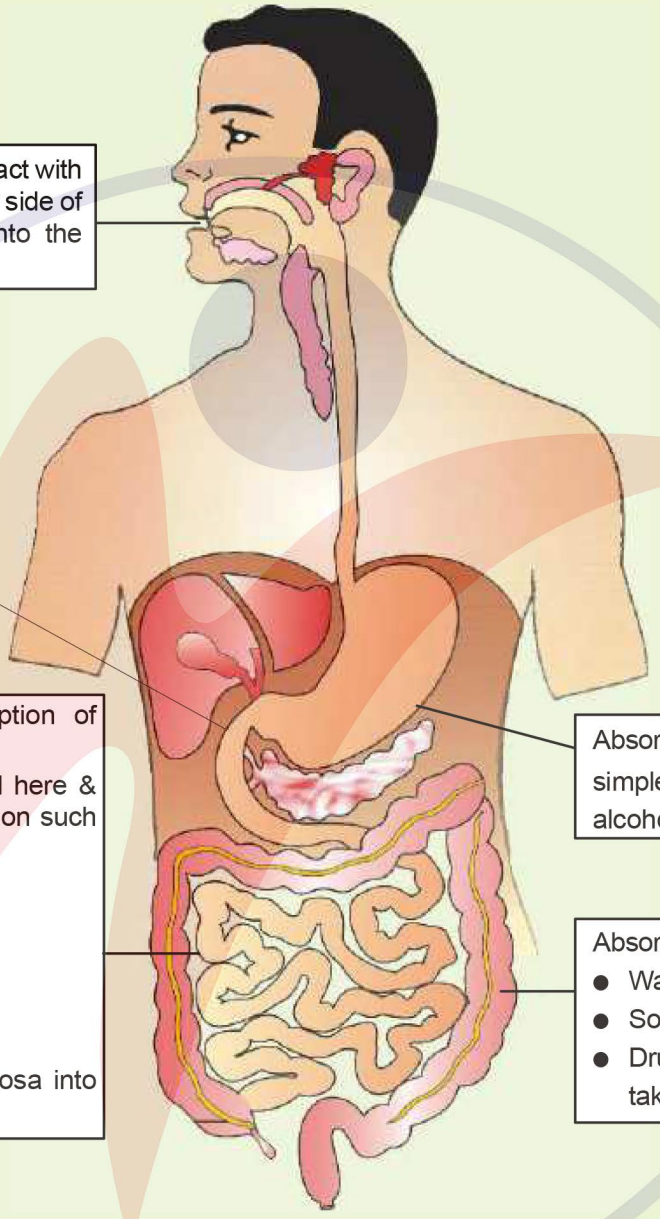
Biomicromolecules are digested in presence of intestinal juice

Dipeptides	Dipeptidases	Amino acids
Maltose	Maltase	Glucose + Glucose
Lactose (milk sugar)	Lactase	Glucose + Galactose
Sucrose	Sucrase	Glucose + Fructose
Nucleotides	Nucleotidases	Nucleosides + Phosphate Group
Nucleosides	Nucleosidases	Nitrogen bases + Pentose Sugar

* SYN/SEC : Synthesis and Secretion

ABSORPTION OF DIGESTED FOOD

End products of digestion pass through the intestinal mucosa into blood or lymph.



Certain drugs coming in contact with the mucosa of mouth & lower side of the tongue are absorbed into the blood capillaries lining them.

Iron and calcium ions are absorbed

Principal organ for absorption of nutrients.

The digestion is completed here & the final products of digestion such as -

- Glucose
- Fructose
- Fatty acids
- Glycerol
- Amino acids

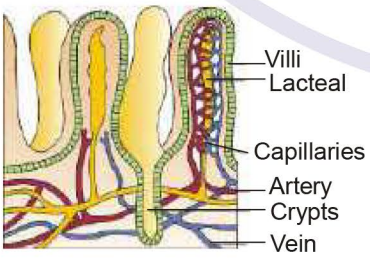
are absorbed through mucosa into blood vessels & lymph.

Absorption of H_2O, simple sugars and alcohol etc. takes place

Absorption of

- Water
- Some minerals and
- Drugs

takes place



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.

The absorbed substances finally reach the tissues which utilise them for their activities this process is called as Assimilation

DISORDERS OF DIGESTIVE SYSTEM

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 tape worm, round worm, thread worm, hook worm, pin worm, etc.

Jaundice : The liver is affected, skin and eyes turn yellow due to the deposit of bile pigments.

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.

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 constipation, the faeces are retained within the rectum as the bowel movements occur irregularly.

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.

Protein-energy malnutrition (PEM) : It is caused due to dietary deficiencies of proteins and total food calories. PEM affects infants and children to produce Marasmus and Kwashiorkar.

S.N.	KWASHIORKOR	MARASMUS
1.	It occurs due to protein deficiency unaccompanied by calorie deficiency	It occurs due to deficiency of proteins, carbohydrate & fats in the diet.
2.	It occurs in children of age 1-5 years (i.e. more than one year in age). It results from the replacement of mother's milk by a high calorie-low protein-diet.	It occurs in infants less than a year in age. If mother's milk is replaced too early by other foods which are poor in protein & calorie value. This often happens if the mother has second pregnancy or childbirth when the older infant is still too young.
3.	Symptoms : • Wasting of muscles. • Thinning of limbs. • Failure of growth & brain development • Oedema & swelling of body parts.	Symptoms : • Impaired growth & replacement of tissue proteins. • Extreme emaciation of the body • Thinning of limbs • Skin dry, thin, wrinkled • Declined growth rate & body weight. • Impaired growth & development of brain & mental faculties.

Caloric value :

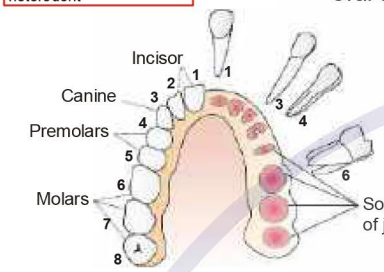
- The amount of heat liberated from complete combustion of 1 gm food in a bomb calorimeter (a closed metal chamber filled with O_2) is its gross calorific value or gross energy value (G.C.V.).
- The actual amount of energy liberated in the human body due to combustion of 1 gm of food is the physiologic value (P.V.) of food.

Food substance	G.C.V. (in K.cal/gm)	P.V. In K.cal/gm)
Carbohydrate	4.1	4.0
Protein	5.65	4.0
Fats	9.45	9.0

HUMAN DIGESTIVE SYSTEM

In human beings teeth are thecodont, diphyodont and heterodont

The oral cavity has a number of teeth and a muscular tongue.



Oral cavity

Parotid gland
Submaxillary and sublingual glands

Salivary glands

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

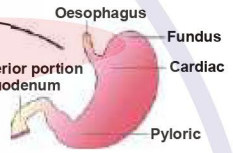
Pharynx — Common passage for food and air

Mouth

Oesophagus — 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.

Gastro-oesophageal sphincter

Stomach — The stomach, located in the upper left portion of the abdominal cavity, has three major parts – a cardiac portion into which the oesophagus opens, a fundic region and a pyloric portion which opens into the first part of small intestine



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.

Liver

Gall bladder help in concentration and storage of bile juice.

Gall bladder

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

Pancreas

C-shaped smallest part of small intestine

Duodenum

Transverse colon

Jejunum

Ascending colon

Descending colon

Ileum

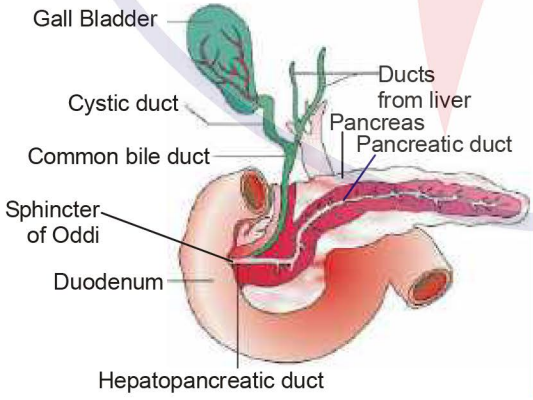
Caecum is a small blind sac which hosts some symbiotic micro-organisms. A narrow finger-like tubular projection, the vermiform appendix which is a vestigial organ, arises from the caecum. The caecum opens into the colon.

Caecum

Vermiform appendix

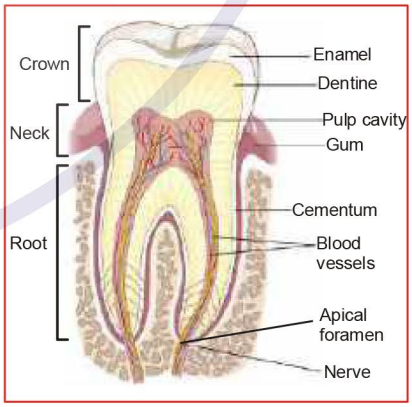
Rectum

Anus



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 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.

The Duct System of Liver, Gall-Bladder and Pancreas



Structure of Tooth