

Human Physiology-Digestion and Absorption

Introduction

- * Food is the basic requirement of all living organisms as it provides energy and organic materials for growth and repair of tissues.
- * Major components of food - carbohydrates, proteins and fats.
- * Minor components of food - vitamins and minerals.
- * Water plays an important role in metabolic processes and prevents dehydration of the body.

Important definitions and concepts

- * **Thecodont dentition:** Each tooth is embedded in a socket of the jawbone.
- * **Diphyodont dentition:** Teeth in humans are as two sets temporary teeth (Deciduous or lacteal teeth) and permanent teeth.
- * **Heterodont teeth:** Presence of different type teeth.
- * **Dental Formula:** Arrangement of teeth in each half of upper and lower jaws.
- * **Deglutition** means swallowing the food.
- * **Mesothelium:** Epithelium of visceral organs.
- * **Payer's patches:** Lymph nodules found in the wall of ileum.
- * **Epiploic appendages:** Small fat filled connective tissue pouches on the outer surface of colon along its length.
- * **Simple diffusion:** Passage of substances depending on concentration gradient.
- * **Active transport:** Transport of substances against the concentration gradient, hence requires energy.
- * **Facilitated diffusion:** Substances are absorbed using a carrier ion like Na⁺.

Digestive system

- * It consists of digestive tract or alimentary canal and associated glands.
- * **Gastro intestinal tract or GI tract** in man technically refers only to stomach and intestine.
- * Total length of alimentary canal in man is 30 feet.

Alimentary canal

- * Begins with mouth and opens out through anus
- * Mouth leads into the buccal cavity or oral cavity. It is followed by pharynx, oesophagus, stomach, small intestine and large intestine.

Oral Cavity or Mouth

- * It includes teeth, salivary glands and tonsils as accessory organs.
- * Oral cavity is bounded by lips anteriorly, fauces (openings) posteriorly, cheeks laterally, palate superiorly and tongue inferiorly.
- * It is lined by stratified squamous epithelium.
- * It has a number of teeth and a muscular tongue.

- * Vestibule of the oral cavity is bounded externally by cheeks and lip and internally by gum and teeth

Teeth

- * In human beings dentition is thecodont, heterodont and diphyodont.
- * Teeth are derived both from ectoderm and endoderm.
- * There are four types of teeth - incisors (I) canines (C), premolars (PM) and molars(M).
- * Canines and wisdom teeth are vestigial in man.
- * There are no premolar teeth in milk dentition.
- * Dental formula in human adult is $\frac{2123}{2123} \times 2 = 32$ while milk dentition is $\frac{2102}{2102} \times 2 = 20$.
- * Teeth are made mainly of dentine while the chewing surface of the teeth helps in mastication of food.
- * Enamel is the hardest substance of the body.
(Teeth of armadillos and sloths lack enamel)
- * Enamel is made of calcium carbonate and calcium phosphate.
- * It is secreted by **ameloblasts** of pulp cavity.
- * Dentine is harder than bone and is secreted by odontoblasts which line the pulp cavity.

Type of teeth:

- * **Acrodont dentition:** When the teeth are not embedded in sockets but they are part of some bone as maxillary teeth and vomerine teeth of frog
- * **Thecodont dentition:** When teeth are separate entities and are embedded in the teeth sockets as in mammals and crocodiles
- * **Diphyodont dentition:** When two sets of teeth are produced in the life time i.e. milk teeth and permanent teeth, as in Mammals
- * **Polyphyodont dentition:** When teeth can be replaced many times in life as in frog
- * **Homodont dentition (Isodont):** When teeth are alike as in frog
- * **Heterodont dentition:** When there are different types of teeth present, like incisors canines, premolars and molars as in Mammals
- * **Pleurodont dentition:** When the sides of teeth are fixed over the lateral surface of jaws as in reptiles
- * **Bunodont dentition:** When there are low cusps present made by ridges of the teeth as in man
- * **Solenodont:** When the cusps are crescentic as in sheep, etc
- * **Secodont:** In carnivores such as cat, dog, lion, etc. Cusps are pointed and are used in cutting

DENTAL FORMULAE

$$\text{Mouse } \frac{1003}{1003} = 16 \quad \text{Man Temporary } \frac{2102}{2102} = 20$$

$$\text{Squirrel } \frac{1003}{1013} = 18 \quad \text{Permanent } \frac{2123}{2123} = 32$$

$$\text{Rabbit } \frac{2033}{1023} = 28 \quad \text{Bear } \frac{3142}{3142} = 40$$

$$\text{Cat } \frac{3133}{3120} = 32 \quad \text{Horse } \frac{3143}{3143} = 44$$

$$\text{Opossum } \frac{5134}{4134} = 50$$

Dental diseases

- * **Pyorrhoea:** Inflammation of periodontal ligaments and gums.
- * **Dental caries:** Tooth decay due to acids produced by bacteria.
- * *Lactobacillus acidophilus* and *streptococcus mutans* are associated with tooth decay
- * **Periodontal disease:** Inflammation and degradation of periodontal ligaments, gingiva and alveolar tissue.
- * **Helitosis:** Bad breath due to pyorrhoeas or periodontal disease.
- * Diet should contain vitamin D, calcium and phosphorus for the healthy teeth

Tongue

- * Tongue is freely movable, muscular organ attached to the floor of the oral cavity by **frenulum**.
- * Tongue has striated extrinsic and intrinsic muscles.
- * Terminal sulcus is the groove that divides the tongue into two parts.
- * The anterior two thirds is covered by lingual papillae, those are with taste receptors
- * Four types of papillae are found on human tongue - circumvallate, fungiform (mushroom shaped), filiform (filament shaped) and foliate (leaf like)
- * Tongue possesses Nuhn's glands (glandular lingules anteriores)

Pharynx

- * It is about 12cm long
- * It is a short passage for food and air.
- * Structures that open into the pharynx are oesophagus and trachea (wind pipe).
- * It is divided into naso, oro and laryngopharynx
- * During the swallowing, entry of food into the wind pipe is prevented by epiglottis a cartilaginous flap.
- * Pharynx leads into oesophagus through aperture, gullet

Oesophagus

- * The part of alimentary canal which passes through neck, thorax and diaphragm is oesophagus.
- * It is 25cm, narrow muscular tube lined by stratified squamous epithelium contain mucus glands
- * Upper part of this is with striated muscle, middle part a mixture of striated and smooth and lower part purely smooth muscle
- * Opening of oesophagus into the stomach is regulated by gastro - oesophageal sphincter also known as cardiac sphincter.
- * Oesophagus opens into the stomach.

Stomach

- * Stomach is located in the upper left portion of the abdominal cavity.
- * It is J - shaped.
- * It is about 30cm long and 15cm wide
- * It has three parts cardiac, fundic and pyloric portions.
- * Stomach leads into small intestine.
- * Opening of stomach into duodenum is guarded by pyloric sphincter.

Compound stomach:

- * **Ruminant** animals such as cattle, buffalo, sheep, goat and camel have a **compound stomach**
- * Compound stomach consists of four chambers, viz, **rumen, reticulum, omasum and abomasum**
- * Some ruminants like camel and deer do not have omasum
- * Rumen is the largest and first of the four chambers
- * Rumen and reticulum are the sites of **cellulose** digestion these harbour numerous bacteria and protozoa which carry out extensive fermentation of cellulose
- * Omasum concentrates the food by absorbing water and bicarbonates
- * Fourth chamber, abomasum is the **true stomach** as it secretes gastric juice and HCl

Small intestine

- * It is about six meters in adults and it has three parts duodenum, jejunum and ileum.
- * Duodenum is 25cm inches long and is U-shaped.
- * Pancreas lies between the two limbs of duodenum.
- * It receives hepato-pancreatic duct formed by the union of bile duct and pancreatic duct
- * Jejunum is 2.4 meters long and is a coiled part.
- * Ileum is highly coiled and 3.6 meters long.
- * Wall of ileum has **Peyer's patches** which produce lymphocytes.
- * The distal end of ileum has a small dilated spherical sac called **sacculus rotundus** in rabbit

- * Lining of small intestine bears a series of transverse folds called **plicae circulares** or valves of Kerkring
- * Their internal lining is with villi
- Small intestine leads into large intestine.

Large intestine

- * Large intestine consists of caecum, colon and rectum.
- * It is about 1.5m long.
- * Caecum is a small blind sac, which has some symbiotic micro organisms.
- * A vestigial organ arises from the caecum called vermiform appendix - three inches in length.
- * Caecum opens into the colon.
- * Colon is 5 feet and is divided into three parts as **ascending, transverse and descending** part.
- * Constrictions on the wall of the colon form a series of pockets called **haustra**.
- * Three median longitudinal muscle cords on colon are called **Taeniae coli**.
- * Descending part of colon passes into the rectum.
- * Rectum is about 7-8 inches long, the terminal one inch is as anal canal.
- * Anal canal opens out through the anus

Histology of Alimentary canal

- * Wall of the alimentary canal has 4 layers.
1. Serosa 2. Muscularis 3. Submucosa 4. Mucosa.
- * **Serosa** - Outer most layer and is made up of mesothelium and some connective tissue.
- * **Muscularis** - Smooth muscles consisting of outer longitudinal and circular muscles. In some regions oblique muscles are also present.
- * **Submucosa** - Loose connective tissue and contains nerves, blood vessels and lymph vessels.
- * In duodenum submucosa has 'Brunner's' glands.
- * **Mucosa** - It is the inner lining layer of alimentary canal. Forms '**rugae**' which are irregular folds in stomach.
- * It also forms villi which are small finger like foldings in small intestine.
- * Cells lining villi bear microvilli which is seen as a '**brush border**'.
- * Microvilli increase surface area of absorption enormously.
- * Villi have capillaries and large lymph vessel called **lacteal**.
- * Goblet cells of mucosa secrete mucus for lubrication during food passage.
- * **Digestive glands of stomach and crypts of Lieberkuhn of intestine** are formed by mucosa.
- * **Plexus of Auerbach:** Network of nerve cells and parasympathetic nerve fibres between layers of longitudinal and circular muscles* **Plexus of Meissner:** Nerve cells and parasympathetic nerve fibres between circular muscles and submucosa

Digestive glands

- * The digestive glands associated with alimentary canal include salivary glands, liver, pancreas, and intestinal glands

Salivary glands

- * Human beings have three pairs of salivary glands. 1. **Parotids** (cheek), 2. **Submaxillary or submandibular** (lower jaw), 3. **Sub linguals** (below the tongue).
- * Infra orbital or zygomatic glands or absent in man
- * Saliva (pH 6.9) contains enzyme **ptyalin** (amylase).
- * Ptyalin acts on starch and converts it to maltose in the presence of **chloride ions**.
- * Smallest salivary glands are sublingual glands and the largest are parotid glands.
- * Parotid glands are **compound tubulo - alveolar** glands whereas submandibular and sublingual are **compound alveolar** glands.
- * 'Mumps' is a viral disease caused by *Paramyxo* virus causing inflammation of parotid glands.
- * Secretions of parotid glands is pored into buccal cavity through **stenson's** duct
- * Duct of submaxillary riches buccul cavity through **wharton's** duct
- * Ducts of sublingual gland is duct of Bartholin and **duct of Rivinus**

Liver

- * It is the largest reddish brown gland of the body.
- * It weighs 1.2 to 1.5 kg in an adult human.
- * It is located below the diaphragm in the abdomen.
- * It is attached to the posterior concavity of diaphragm by a fold called **coronary ligament**.
- * It is also attached to the anterior abdominal wall by **falciform ligament**.
- * It has two lobes.
- * Structural and functional units of liver are hepatic lobules.
- * Hepatic cells are arranged in the form of cords.
The connective tissue that covers each lobule is called **Glisson's capsule**.
- * Hepatic cells secrete bile (pH 7.6)
- * Bile is stored and concentrated in a thin muscular sac called the gall bladder.
- * The duct of gall bladder is called **cystic duct**.
- * Bile duct (ductus choledocus) of liver joined combine cystic duct and form, common bile duct
- * The common hepato-pancreatic duct opens into the duodenum and opening is guarded by a sphincter called **Sphincter of Oddi**.
- * Kupffer's cells are hepatic macrophages present between hepatic cords
- * Breaking down gall stones by use of ultra sonic vibration is called **lithotripsy**.
- * Surgical removal of the gall bladder is called **Cholecystectomy**.
- * Retarded function of liver can cause **jaundice**.

Functions of Liver:

- * Liver performs variety of functions
- * Glycogenesis: Extra glucose is converted to glycogen
- * Glycogenolysis: Glycogen is converted into glucose
- * Glucogenesis: Synthesis of glucose from other carbohydrates
- * Lipogenesis. Extra protein and carbohydrates are converted into lipid
- * Deamination of protein
- * Ornithine Cycle. NH_3 is converted into urea
- * Cori Cycle. Lactic acid formed in muscle is converted back to glycogen
- * Synthesis of substance like Vit_A From carotene Vit_D from cholesterol or ergocalciferol, Heparin Insulin-like growth factor
- * Detoxification of substances
- * Storage of glycogen, Vitamin like Vit_A, Vit_D, Vit_K, Vit_{B12} and folic acid etc.; Fe and Cu
- * It acts as thermoregulatory organ

Pancreas

- * Pancreas is a compound racemose organ situated between the two limbs of duodenum.
- * It is second largest gland
- * It has both exocrine and endocrine cells.
- * Exocrine portion secretes pancreatic juice (pH 8.8) containing enzymes.
- * Endocrine portion secretes hormones insulin and glucagon.

Intestinal glands

- * Submucosa of duodenum is with Brunner's glands produces alkaline mucus
- * In between the villi of ilem crypts of Lieberkühn are present
- * Succus entericus is secreted by crypts of Lieberkuhn

Digestion of food

- * Process of digestion involves mechanical digestion, chemical digestion and microbial digestion.
- * Break down of food by the action of teeth and muscles is called mechanical digestion.
- * Chemical digestion is by enzyme action.
- * All enzymes are proteins.
- * All digestive enzymes are hydrolytic.
- * The major functions of buccal cavity are mastication of food and mixing food with mucus to help in swallowing.
- * The food bolus formed is sent into oesophagus by deglutition.

- * Saliva contains electrolytes, enzymes and lysozyme.
- * pH of saliva is 6.8.
- * Daily secretion of saliva in man is about 1 to 1.5 litres.
- * Lysozyme is an anti bacterial agent.

Digestion in stomach

- * Gastric glands have three major types of cells.
 1. **Mucus neck cells** which secretes mucus
 2. **Peptic or chief cells** that secrete pro enzyme pepsinogen.
 3. **Parietal or Oxyntic cells** which secrete HCl and intrinsic factor.
- * pH of gastric juice is 1 to 3.5.
- * Protein digestion starts in stomach.
- * Food mixed with gastric juice in stomach is called **chyme**.
HCl provides the acidic pH. Optimal pH for pepsin is 1.8
Rennin helps in digestion of milk.
- * Another enzyme of the stomach is gastric lipase.
- * Gastric lipase acts best at pH of 5 to 6.

Digestion in small intestine

- * Three types of digestive juices are released into the small intestine.
- * 1. Bile, 2. Pancreatic and 3. Intestinal juice
- * Bile and pancreatic juice are released through hepato - pancreatic duct or ductus choledochus.
- * Daily secretion of bile in man is about 600ml.
- * Bile is alkaline, yellow to green in colour and has pH of 7.8 to 8.6.
- * Bile does not have any enzymes.
- * Bile salts like sodium taurocholates and sodium glycocholates help in emulsification of fats.
- * Bile salts also help absorption of fat soluble vitamins.
- * Bile pigments like bilirubin and biliverdin are produced during break down of old RBCs.
- * Bile also contains Cholesterol and phospho lipids.
- * Bile also activates lipases.

Pancreatic juices

- * Pancreatic juice is a complete digestive juice.
- * It takes part in the digestion of proteins, carbohydrates and fats.
- * Pancreatic juice contains trypsinogen, chymotrypsinogen, procarboxypeptidases, amylases, lipases and nucleases.
- * Enterokinase secreted by intestinal mucosa converts inactive trypsinogen to active trypsin.

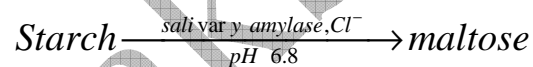
Intestinal juice

- * Intestinal juice or succus entericus is mainly secreted by crypts of Lieberkuhn.
- * It is a clear yellow fluid, slightly alkaline with a pH of 7.8.
- * The intestinal mucosal epithelium has goblet cells which secrete mucus.
- * The secretions of brush border cells of the mucosa along with the secretions of the goblet cells constitute the succus entericus.
- * Enzymes of intestinal juice are disaccharidases, dipeptidases, lipases, nucleosidases etc.
- * Mucus along with bicarbonates forms the layer that protects the intestinal mucosa from acids.
- * It also provides an alkaline medium for enzymatic functions.

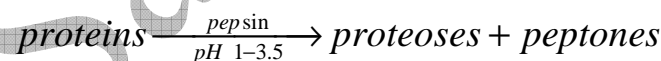
Process of digestion

- * Proteins, proteoses and peptones are partially hydrolysed proteins of chyme.
- * Trypsin, chymotrypsin and carboxy peptidase act on proteins, peptones and proteoses and convert them to dipeptides.
- * Pancreatic amylase hydrolyse carbohydrates in the chyme into disaccharides.
- * Lipases act on fats and convert them to di and monoglycerides.
- * Nucleic acids are converted to nucleotides and nucleosides by nucleases in the pancreatic juice.
- * Enzymes of succus entericus act on end products of the above reactions.
- * Biomolecule break down occurs in duodenum of the small intestine.
- * The regions of absorption of digested food are jejunum and ileum.
- * The undigested and unabsorbed substances pass into large intestine.
- * Functions of large intestine include
 1. absorption of water, minerals and drugs.
 2. secretion of mucus that adheres to the waste particle and helps in their easy passage.

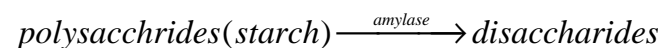
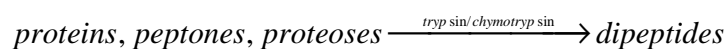
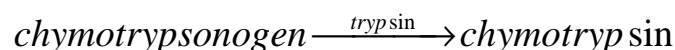
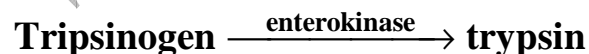
Chemical digestion in buccal cavity



In stomach



In small intestine pancreatic juice action



Fats $\xrightarrow{\text{lipases}}$ *diglycerides* \rightarrow *monoglycerides*

Nucleicacids $\xrightarrow{\text{In euclases}}$ *nucleotides* \rightarrow *nucleosides*

Action of enzymes of succus entericus

Dipeptides $\xrightarrow{\text{dipeptidases}}$ *a min oacids*

Maltose $\xrightarrow{\text{maltase}}$ *glu cos e + glu cos e*

sucrose $\xrightarrow{\text{sucrase}}$ *glu cos e + fructose*

Nucleotides $\xrightarrow{\text{nucleotidases}}$ *nucleosides*

Nucleosides $\xrightarrow{\text{nucleotidases}}$ *sugars + bases*

Di & monoglycerides $\xrightarrow{\text{lipases}}$ *fattyacids + glycerol*

- * Undigested, unabsorbed substances called faeces enter into the caecum of the large intestine through ileo-caecal valve.
- * Ileo-caecal valve prevents back flow of faecal matter.
- * Faecal matter is temporarily stored in the rectum till defaecation.

Neural control on GI tract

- * Secretion of saliva is stimulated by sight, smell or presence of food in the oral cavity.
- * Neural signals stimulate gastric and intestinal secretions.
- * Through CNS and local stimulation, muscular activities of different parts of alimentary canal can be moderated.

Hormonal control on GI tract

- * Control of secretion of digestive juice is carried out by the local hormones produced by gastric and intestinal mucosa.
- * Gastrin, enterogastrone, cholecystokinin (CCK), secretin, pancreaticozym and enterocinin are the hormones which act on the GI tract.

Absorption of digested products

- * End products of digestion pass through intestinal mucosa into blood or lymph.
- * Substances absorbed by simple diffusion are Monosaccharides like glucose, amino acids, some of the electrolytes like chloride ions.
- * Substances absorbed by facilitated diffusion are Fructose, some amino acids, with the help of carrier ions like Na⁺.
- * Transport of water depends on osmotic gradient.
- * Substances absorbed by active transport are Amino acids, Monosaccharide and elecrolytes like Na⁺.

Absorption of end products of fat digestion

- * Fatty acids and glycerol are insoluble and cannot be absorbed into the blood.
- * They are first converted to micelle which then moves into the intestinal mucosa.

- * In the intestinal cells they are converted into very small protein coated fat globules called chylomicrons which are transported into lacteals of the villi.
- * Lymph vessels carry chylomicrons into blood stream.

Summary of absorption in different parts of digestive system

- * **Mouth** - Certain drugs coming in contact with the mucosa of mouth on lower surface of tongue are absorbed into blood capillaries lining them.
- * **Stomach** - Water, simple sugars and alcohol.
- * **Small intestine** - Principal organ for absorption of nutrients. Glucose, fructose, fatty acids, glycerol and amino acids.
- * Large intestines - Water, minerals and drugs.

Assimilation

- * Utilization of the absorbed substances by the tissues is called assimilation.

Defecation

- * Digestive waste, seen as faeces in the rectum initiates a neural reflex causing an urge or desire for its removal.
- * Defecation is a voluntary process and is carried out by a mass peristaltic movement.
- * Faeces is egested to the outside through the anal opening.

Peristalsis

- * Peristalsis occurs usually in oesophagus, stomach and intestine.
- * Least peristalsis occurs in rectum.
Peristalsis is a part of mechanical digestion.
- * Stimulation of parasympathetic nervous system results in the increase of gut peristalsis.
- * Reverse peristalsis in the stomach produces vomiting.

PEM

- * **Protein - energy malnutrition (PEM)** may affect large sections of the population during drought, famine and political turmoil.
- * PEM affects infants and children to produce Marasmus and Kwashiorkor
- * **Marasmus** is produced by a simultaneous deficiency of proteins and calories.
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.
- * This often happens if the mother has second pregnancy of childbirth when the older infant is still too young.
- * **Symptoms:** Emaciation, thinning of limbs skin becomes dry, thin and wrinkled, growth rate and body weight decline.
- * **Kwashiorkor** is produced by protein deficiency unaccompanied by calorie deficiency.
- * 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.
- * **Symptoms:** Wasting of muscles, thinning of limbs, failure of growth and brain development, fat is still left under the skin: extensive oedema swelling of body

DISORDERS OF DIGESTIVE SYSTEM

- * Nausea – discomfort preceding vomiting
- * Anorexia – loss of appetite
- * **Haemorrhoids:** Enlargement of rectal vein which causes piles.
- * **Dyspepsis:** Indigestion due to defective diet.
- * **Pavlov pouch** was fabricated by Pavlov to study the effect of feeding on gastric secretion
- * Hiatal hernia or diaphragmatic is the opening in the diaphragm. The part of the stomach is pushed into the thoracic cavity.
- * Peptic ulcer is an erosion of the stomach or duodenal mucosa.
- * Cirrhosis of the liver – The liver appears orange.
- * Some people cannot digest milk and milk consumption in them causes diarrhea and gas generation because they do not produce lactase.
- * Removal of stomach produces **dumping syndrome**.
- * Abnormal metabolism of fats causes **Gaucher's disease**
- * The **vermiform** contain numerous **lymphatic nodules** and is subjected to inflammation – **appendicitis**.
- * Most common disorder is inflammation of the intestinal tract due to bacterial and viral infections.
- * Parasites like tapeworm, roundworm, thread worm, hook worm, pin worm etc cause infections of alimentary canal.
- * **Jaundice** - Liver is affected, skin and eyes become yellow due to deposition of bile pigments.
- * **Vomiting** - A reflex action controlled by vomit centre in medulla. A feeling of nausea precedes vomiting.
- * **Diarrhoea** - Abnormal frequency of bowel movement and increased liquidity of the fecal discharge is known as diarrhoea.
- * **Constipation** - Faeces are retained within the rectum, as bowel movements are irregular.
- * **Indigestion** - Food is not properly digested leading to a feeling of fullness.