DIGESTION AND ABSORPTION

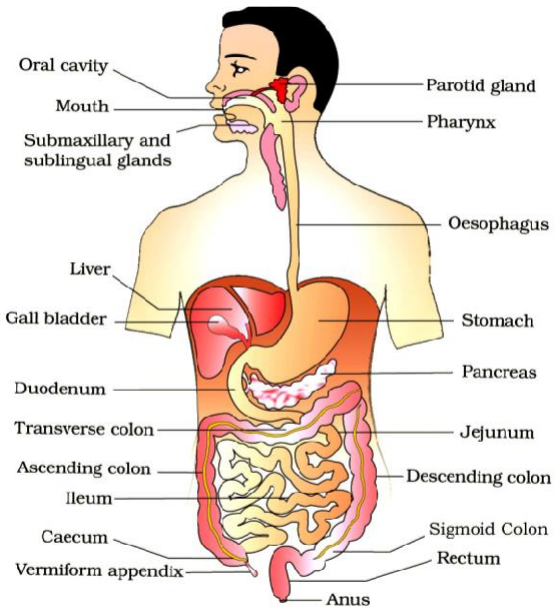
- **Nutrition** is the getting and utilization of energy rich nutrients (food) by an organism.
- Food consists of **carbohydrates, proteins, fats (lipids), vitamins, minerals** and **water.**
- Food provides ***energy for life activities, materials for growth, maintains body temperature*** and ***repairs tissues.***
- The water plays an important role in metabolic processes and prevents dehydration of the body.

HUMAN DIGESTIVE SYSTEM

ALIMENTARY CANAL
- Mouth
- Buccal cavity
- Pharynx
- Oesophagus
- Stomach
- Small intestine
- Large intestine
- Anus

DIGESTIVE GLANDS
- Salivary glands
- Gastric glands
- Liver
- Pancreas
- Intestinal glands

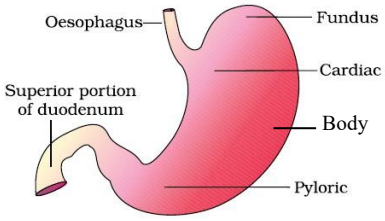
5 Processes of Digestive system
- Ingestion
- Digestion
- Absorption
- Assimilation
- Egestion



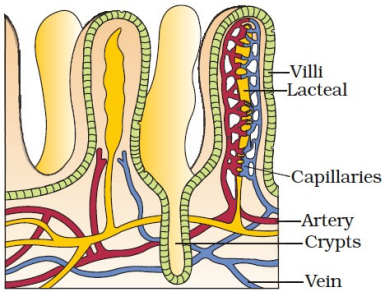
I. ALIMENTARY CANAL (GUT)

It includes the following parts:

- **Mouth:** To receive the food **(ingestion).**
- **Buccal cavity (oral or mouth cavity):**
  - Consists of ***palate (roof), teeth & muscular tongue.***
  - Palate has anterior ***hard palate*** and posterior ***soft palate***.
  - Tongue is a muscular organ attached to the floor of oral cavity by the **frenulum.** Tongue has small projections called **papillae.** Some papillae bear **taste buds.**
  - At the back, on either side of tongue ***tonsils*** present.
- **Pharynx:**
  - Common passage for digestive and respiratory systems.
  - When food materials pass through the pharynx, the cartilaginous ***epiglottis*** closes the ***glottis*** (opening of larynx) and prevents the entry of food into trachea.
- **Oesophagus:**
  - Muscular tube (30 cm) that conducts food into stomach.
  - Posterior part of the oesophagus has ***gastro-oesophageal sphincter*** (a circular muscle). It controls the opening of oesophagus into stomach.
- **Stomach:**
  - 'J' shaped structure for storage and digestion of food.
  - **4 parts:** a **cardiac** portion into which the oesophagus opens, a **fundic** region, **body** (main central region) and a **pyloric** portion (antrum).



  - Pyloric stomach leads to small intestine by an opening called **Pylorus**, guarded by ***pyloric sphincter muscle***.
  - Inner wall of stomach bears **rugae** (longitudinal folds).
- **Small intestine:**
  - Longest part of gut (7 m long and 2.5 cm diameter).
  - Consists 3 parts, namely **duodenum** (C shaped first part), **Jejunum** (middle part) and **Ileum** (terminal part).



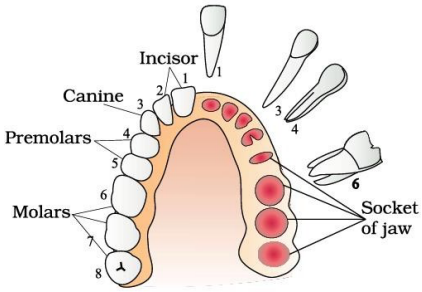
  - Finger-like **villi** are seen at the mucosa. Each villus has a brush-bordered columnar epithelial layer provided with ***microvilli***. Villus consists of a capillary network and a small lymph vessel **(lacteal).**
- **Large intestine:**
  - 1.5 m long. Consists of **caecum, colon** and **rectum.**
  - Caecum is well-developed in herbivores but very small in man. Arising from the caecum is a finger-like vestigial organ, the ***vermiform appendix.***
  - The colon consists of ***ascending colon, transverse colon, descending colon*** and ***Sigmoid colon***.
  - Pelvic colon leads to **rectum** that opens out by **anus**. Anus is guarded by ***anal sphincter*** (circular voluntary muscles).
  - In some herbivores, the large intestine consists of several cellulose digesting bacteria.

TEETH

Nature & mode of arrangement of teeth is called **dentition**. **Human dentition** is Thecodont, Heterodont & Diphyodont.

- **Thecodont:** It means teeth are placed in the jaw sockets.
- **Heterodont:** It means different kinds of teeth are present. They are ***incisors (I)*** for cutting, ***canines (C)*** for tearing, ***premolars (PM)*** & ***molars (M)*** for mastication.

Premolars & molars are collectively called as ***cheek teeth*** which have **cusps**.



- **Diphyodont:** It means teeth appear twice in the lifetime. They are ***milk (deciduous) teeth*** and ***permanent teeth***.
  Milk teeth (**20** in number) are erupted at **6-7 months** of birth. They are replaced by permanent teeth (**32** in number) at the age of **6-7.**
  Last 4 molars ***(wisdom teeth)*** appear only at the age of 18.

The hard chewing surface of teeth is made up of **enamel.**

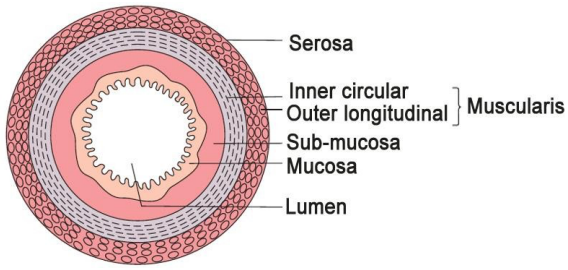
Dental formula: It explains the kinds and number of teeth.

Human dental formula (of permanent teeth):

$$I\ {}^{2}/_{2}\ C\ {}^{1}/_{1}\ PM\ {}^{2}/_{2}\ M\ {}^{3}/_{3} \times 2 = 32 \quad (\tfrac{2123}{2123})$$

Dental formula of milk dentition:

Histology of human gut (Transverse section)



Human gut is formed of 4 layers:

1. **Mucosa:** Innermost, moist epithelial layer. Contains secretory and absorptive cells.
2. **Submucosa:** Soft connective tissue layer just outside the mucosa. Nerves and blood vessels are present.
3. **Muscularis:** Outer to submucosa. Smooth muscle layer (inner circular & outer longitudinal muscles).
4. **Serosa:** Outermost fibrous layer.

II. DIGESTIVE (ASSOCIATED) GLANDS

- They secrete **digestive juices.**
- They include **salivary glands, gastric glands, intestinal glands, pancreas & liver.**

a. Salivary glands

- 3 pairs. They are
  - **Parotids (2):** Largest salivary gland. Seen in cheeks.
  - **Submaxillary/submandibular (2):** Seen in lower jaw.
  - **Sublingual (2):** Below the tongue.
- Salivary glands secrete ***saliva***. It contains 99.5% water, ***mucin (mucus)***, enzymes like ***salivary amylase (Ptyalin)*** and ***Lysozyme*** and electrolytes (Na^+, K^+, Cl^-, HCO_3^- etc).

b. Gastric glands

Tubular glands found on the inner wall. They consist of

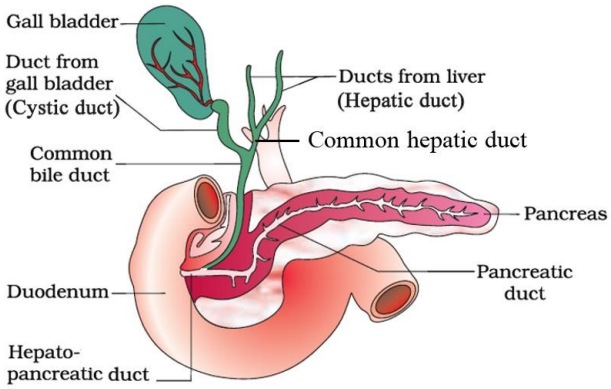
a. **Mucus neck cells:** Secrete **mucus.** Mucus and **bicarbonates** protect the stomach wall (mucosal epithelium) from HCl and prevents **autodigestion.**
b. **Chief (zymogen or peptic) cells:** Secrete proenzymes like ***pepsinogen & prorennin*** and some ***lipase***.
c. **Oxyntic (parietal) cells:** Secrete **HCl** & **Castle's intrinsic factor** (for absorption of vitamin B_{12}).

Gastric glands secrete acidic (pH 1.8-2.0) **gastric juice.**

c. Liver

- Largest gland (1.2 - 1.5 kg). Reddish brown.
- Situated in abdominal cavity, just below the diaphragm.
- Bilobed (large right lobe & small left lobe). Each lobe is formed of ***hepatic lobules*** (structural & functional units).
- A lobule has many ***hepatic cells*** arranged as cords around a ***central vein***. They secrete alkaline ***bile juice***.
- Liver lobule is covered by ***Glisson's capsule***.
- Bile is transported from liver to duodenum as follows:

  Bile → hepatic duct → gallbladder → cystic duct → common bile duct → common hepato-pancreatic duct → duodenum.
- ***Hepato-pancreatic duct*** is guarded by ***sphincter of Oddi***.



- Bile has **no enzymes** but contains ***bile pigments (bilirubin & biliverdin), bile salts, cholesterol*** and ***phospholipids***.

d. Pancreas

- Second largest gland. Seen near **duodenal loop**.
- It is a cream-coloured **heterocrine gland**, i.e. it has both **exocrine** and **endocrine** parts.
- The exocrine part has a **pancreatic duct** that opens into duodenum along with bile duct ***(hepato-pancreatic duct).***
- Exocrine part secretes alkaline ***pancreatic juice.*** It contains inactive protease enzymes ***(trypsinogen, chymotrypsinogen & procarboxypeptidases), amylases, lipases & nucleases.***

e. Intestinal glands

- Simple tubular glands. 2 types:
  1. **Crypts of Lieberkuhn:** Consists of mucus-secreting ***Goblet cells*** and enzyme-secreting ***Paneth cells.***
  2. **Brunner (duodenal) glands:** Confined to submucosa of duodenum. Secrete ***mucus*** only.
- Intestinal glands secrete alkaline ***intestinal juice (succus entericus).*** It contains enzymes ***(maltase, lactase, sucrase, dipeptidase, lipases, nucleotidases, nucleosidases etc).***
- The ***bicarbonate*** and ***mucus*** provide alkaline medium and protect intestinal mucosa.

DIGESTION AND ABSORPTION OF FOOD

Digestion is the conversion of complex insoluble food materials into simple and absorbable form. It includes mechanical processes such as ***mastication*** (chewing), ***deglutition*** (swallowing) & ***peristalsis*** (wave-like movement of food bolus through the gut by muscular contraction).

- **Digestion in buccal cavity:** Only starch digestion.
  Ptyalin converts starch (polysaccharide) into disaccharides. About 30% of starch is digested by ptyalin.

  Starch $\xrightarrow[pH\ 6.8]{Salivary\ amylase}$ Maltose + Isomaltose + limit dextrins

- **Digestion in stomach:** Stomach stores food for 4-5 hrs. It is mixed with gastric juice by the churning movements and is converted into acidic pasty form ***(chyme).***

  Pepsinogen (inactive) $\xrightarrow{HCl}$ Pepsin (active)

  Protein $\xrightarrow{Pepsin}$ Proteoses + Peptones (peptides)

  Prorennin (inactive) $\xrightarrow{HCl}$ Rennin (active)

  Casein (milk protein) $\xrightarrow{Rennin}$ Paracasein

  Paracasein $\xrightarrow{Ca2+}$ Ca paracaseinate (curd)

  Calcium paracaseinate $\xrightarrow{Pepsin}$ Peptones

  (Only in infants)

  The *gastric lipase* hydrolyses a small amount of lipids.

- **Digestion in small intestine (in Duodenum):** Chyme is mixed with ***succus entericus, pancreatic juice*** & ***bile juice***.

a) Action of bile: Bile helps in digestion by ***emulsification*** (conversion of ***fat*** into ***micelles*** or tiny droplets). It provides large surface area for the action of lipase on fat. Bile also activates lipase.

b) **Action of pancreatic juice:** ***Amylopsin (Pancreatic amylase)*** hydrolyses remaining starch into ***disaccharides***.

Starch $\xrightarrow{Amylopsin}$ Maltose + Isomaltose + limit dextrins

Enterokinase (Enterokinin) secreted by intestinal mucosa activates ***trypsinogen*** to active ***trypsin***. Trypsin activates *chymotrypsinogen & procarboxypeptidase.*

Trypsinogen $\xrightarrow{Enterokinin}$ Trypsin

Chymotrypsinogen $\xrightarrow{Trypsin}$ Chymotrypsin

Procarboxypeptidase $\xrightarrow{Trypsin}$ Carboxypeptidase

Proteins, Peptones, Proteoses $\xrightarrow[Carboxypeptidase]{Trypsin/Chymotrypsin}$ Dipeptides

Fats $\xrightarrow{Lipases}$ Diglycerides $\xrightarrow{Lipases}$ Monoglycerides

Nucleic acids $\xrightarrow{Nucleases}$ Nucleotides

c) Action of intestinal juice: At duodenum region, the intestinal enzymes act on the products of above reactions.

Dipeptides $\xrightarrow{Dipeptidase}$ Amino acids

Maltose $\xrightarrow{Maltase}$ 2 Glucose

Lactose $\xrightarrow{Lactase}$ Glucose + Galactose

Sucrose $\xrightarrow{Sucrase}$ Glucose + Fructose

Nucleotides $\xrightarrow{Nucleotidase}$ Nucleosides

Nucleosides $\xrightarrow{Nucleosidase}$ Sugars + Bases

Diglycerides, monoglycerides $\xrightarrow{Lipases}$ Fatty acid + Glycerol

In large intestine, there is no significant digestive activity. The functions of large intestine are:

a. Absorption of water, minerals and certain drugs.
b. Secretes mucus for adhering waste (undigested) particles together and lubricating it for an easy passage.

Fully digested semi fluid and alkaline food formed in small intestine is called ***chyle.***

The digestive activities like gastric & intestinal secretions are controlled by **neural** and **hormonal mechanisms**. The **sight, smell or presence of food** in buccal cavity stimulate salivary secretions. Gastric & intestinal mucosa secretes **digestive hormones.** They control secretion of digestive juices.

ABSORPTION OF DIGESTED PRODUCTS

Absorption is the transfer of end products of digestion through the intestinal mucosa into blood & lymph.

It is 2 types- passive and active.

a) Passive absorption (Passive transport): Absorption of nutrients from higher concentrated region to lower concentrated region without the expenditure of energy.

It includes **osmosis** (absorption of water) and **diffusion** (absorption of solute molecules).

Diffusion is 2 types:

i. **Simple diffusion:** In this, molecules alone can be diffused. E.g. Small amounts of monosaccharides like ***glucose, amino acids, vitamins,*** electrolytes like Cl^- etc.
ii. **Facilitated diffusion:** Diffusion with the help of carrier proteins. E.g. **glucose, amino acids** etc.

b) Active absorption (Active transport): Absorption of nutrients from lower concentrated region to higher concentrated region (i.e. against concentration gradient). It needs energy. E.g. absorption of ***amino acids, monosaccharides*** like ***glucose***, electrolytes like Na^+ etc.

Absorption of lipids

- ***Monoglycerides, diglycerides*** and ***fatty acids*** cannot be absorbed directly as they are insoluble in water.
- ***Bile salts*** and ***phospholipids*** convert them into small spherical water-soluble droplets called ***micelles***.
- They are reformed into small protein coated fat globules ***(chylomicrons).*** They are transported into ***lacteals*** in the villi. From the lymph, the chylomicrons enter the blood.

Absorption in different parts of alimentary canal

- **Mouth:** Certain drugs.
- **Stomach:** Water, simple sugars, some drugs & alcohol.
- **Small intestine** (mainly Jejunum & Ileum): All nutrients including minerals & vitamins.
  It is the ***chief area of absorption*** due to the presence of villi, its great length and coiled nature.
- **Large intestine:** Water, some minerals & drugs.

The absorbed materials are incorporated into tissues for their activities. It is called ***assimilation.***

The undigested substances like plant fibres, dead bacteria etc. form **faeces.** It enters caecum through the ***ileo-caecal valve,*** which prevents back flow of faeces.

Faeces are temporarily stored in ***rectum*** and are eliminated through anus. It is called ***egestion (defaecation).***

CALORIFIC VALUE OF PROTEIN, CARBOHYDRATE & FAT *(Not for evaluation)*

- Heat is the ultimate source of all energies. So energy content of food is expressed as measure of **heat energy.**
- Its unit is **calorie (cal) or joule (J).**
- **One calorie** is the amount of heat energy required to raise the temperature of **1g of water by 1°C.**
- This value is tiny amount of energy. So physiologists use **kilocalorie (kcal or Cal) or kilo joule (kjl or Joule).**
- **One kilo calorie** is the amount of energy required to raise the temperature of **1kg of water by 1°C.**
- Amount of heat liberated from complete combustion of 1g food in a **bomb calorimeter** (a closed metal chamber filled with O_2) is its **gross calorific (gross energy) value.**
- Actual amount of energy combustion of 1g of food is the **physiologic value of food.**

Food	Gross calorific value	Physiologic value
Carbohydrates	4.1 kcal/g	4.0 kcal/g
Proteins	5.65 kcal/g	4.0 kcal/g
Fats	9.45 kcal/g	9.0 kcal/g

DISORDERS OF DIGESTIVE SYSTEM

1. **Jaundice:** Here, the skin and eye turns yellow due to the deposition of bile pigments. It indicates liver damage.
2. **Vomiting:** Ejection of stomach content through mouth. It is controlled by medulla oblongata.
3. **Diarrhoea:** Frequent elimination of watery faeces. It reduces the absorption of food.
4. **Constipation:** Infrequent elimination of dry stool. It is due to decreased peristalsis in colon.
5. **Indigestion:** Condition leading to feeling of fullness due to improper digestion. It is due to anxiety, inadequate enzyme secretion, food poisoning, spicy food etc.
6. **Protein-Energy malnutrition (PEM):** It is the dietary deficiencies of proteins & food calories.
   PEM causes **Marasmus & Kwashiorkor** in children.

- **Marasmus:** It is due to deficiency of both **proteins and calories.** It is found in infants less than a year in age.

  Reason: Replacement of mother's milk by foods with poor proteins and caloric value. This often happens if mother has second pregnancy or child birth when the older infant is still too young.

  Symptoms: Impaired growth and replacement of tissue proteins; extreme emaciation of the body, thin limbs, dry, thin and wrinkled skin, declined growth rate and body weight, impaired growth and development of brain and mental faculties.

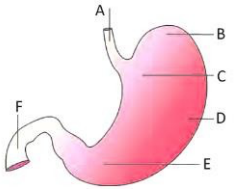
- **Kwashiorkor:** It is due to **protein deficiency** only.

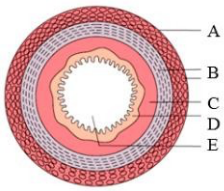
  Reason: Replacement of mother's milk by a high calorie-low protein diet in a child more than one year in age.

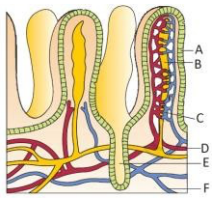
  Symptoms: Like marasmus, it shows wasting of muscles, thinning of limbs, failure of growth & brain development. Unlike marasmus, some fat is still under the skin; extensive oedema and swelling of body parts are seen.

MODEL QUESTIONS

1. Draw a flowchart indicating the parts of human alimentary canal starting from mouth to anus.
2. Analyze the given human dental formula. Make it correct: $I^2/_2\ C^2/_2\ PM\ ^1/_1\ M^3/_3$
3. Identify and label the following diagrams:







4. Find the odd one out from each group and justify your answer.
   a. Pancreatic juice, intestinal juice, bile juice, saliva
   b. HCl, Pepsin, Trypsin, Lactase
5. Name the digestive glands where these cells are found: Oxyntic cells, Paneth cells, Chief cells
6. What would happen if HCl were not secreted in the stomach?
7. a) Complete the equation by filling a_1, b_1 and c_1.

   Lactose $\xrightarrow{a1}$ Glucose + b_1 Maltose $\xrightarrow{Maltase}$ Glucose + c_1

   b) *Trypsinogen* is activated to trypsin by *enterokinase.* How *chymotrypsinogen* is activated to *chymotrypsin?*
8. A person eats some boiled rice. Draw a flowchart of its digestion in different regions of alimentary canal.
9. "Pancreatic juice is a complete digestive juice." Do you agree with this statement? Justify your opinion.
10. Sketch an outline (or a flowchart) of protein digestion taking place in your alimentary canal.
11. "Bile contains no digestive enzymes, so it is not needed for digestion". Do you agree with this statement? Justify.
12. Our small intestine is well developed for effective absorption. Give any two such adaptations.