

Digestion and Absorption

Digestion: The process of conversion of complex food substances to simple absorbable forms by mechanical and biochemical methods.

1 BASIC REQUIREMENTS OF LIVING ORGANISMS

1. **Food:** Provide **energy** and organic material for **growth** and **repair of tissues**.

Major components

- Carbohydrates, Proteins, Fats

Minor components

- Vitamins, Minerals

2. **Water:**

- Important for metabolic processes.
- Prevent **dehydration** of the body.

2 HUMAN DIGESTIVE SYSTEM

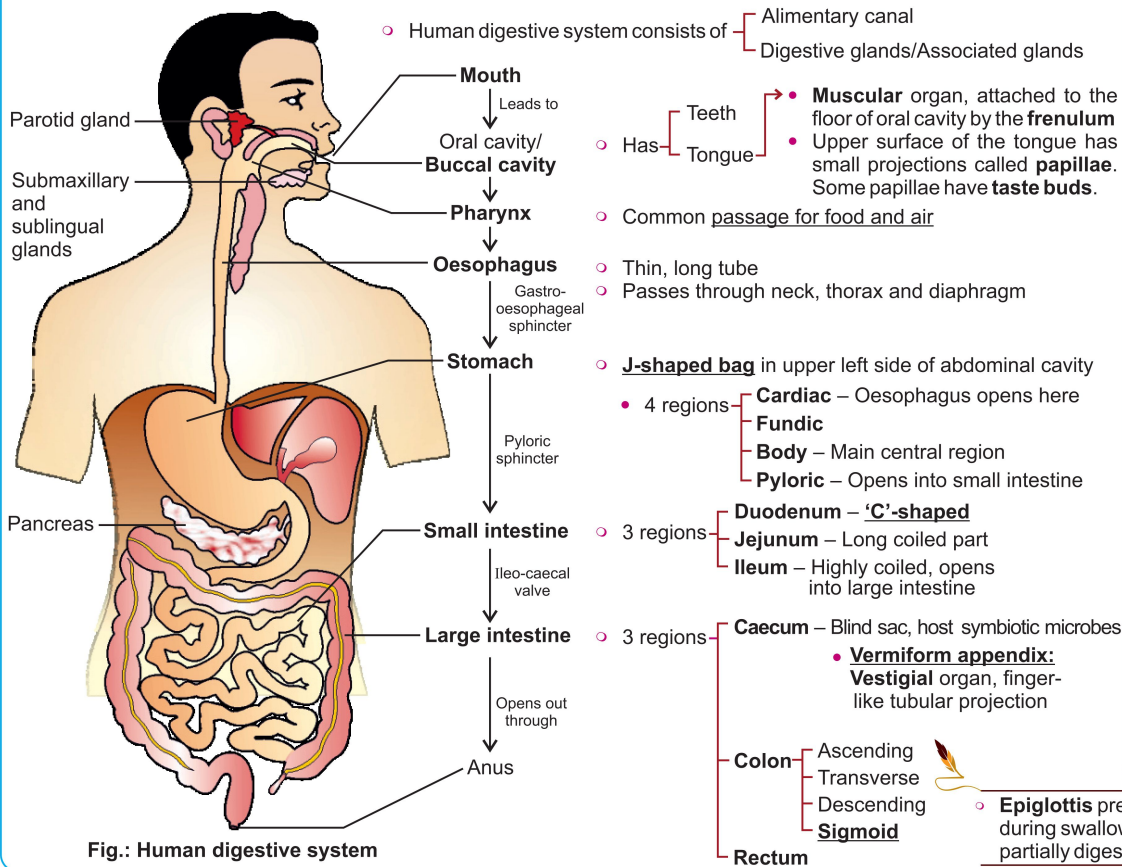
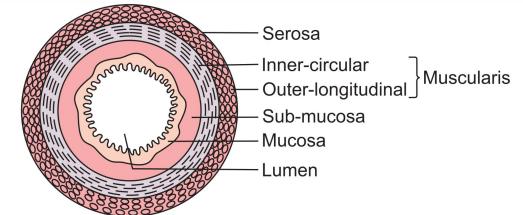


Fig.: Human digestive system

3 HISTOLOGY OF GUT

Layers	Typical
Serosa	Outermost layer, made up to thin mesothelium (epithelium of visceral organs) with some connective tissues.
Muscularis	<ul style="list-style-type: none"> Inner – Circular muscles Outer – Longitudinal muscles
Sub-mucosa	Loose connective tissue with nerve, blood and lymph vessels.
Mucosa	Innermost layer lining the lumen



Modifications

- Stomach:**
 - Oblique muscle** layer is present
 - Irregular folds of mucosa called **Rugae**
 - Finger like foldings of mucosa called **villi**
 - Cells lining villi produce microscopic projections called **microvilli** giving **brush border appearance**
- Small intestine:**
 - Villi, microvilli, rugae** – Increase surface area for absorption
 - Villi are supplied with blood capillaries and **lacteals (Lymph vessel)**
 - Gastric glands, goblet cells and crypts of Lieberkuhn – Present in mucosa
 - Brunner's gland** – Present in **sub-mucosa**
 - The muscular activities of different parts of alimentary canal can be moderated by neural mechanisms, both local and through CNS.

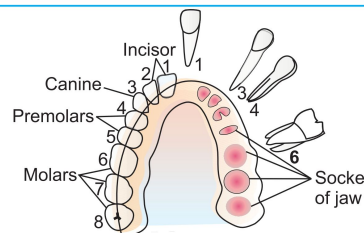
Epiglottis prevents the entry of food into the **glottis** (opening of trachea/wind pipe) during swallowing. **Sphincters** are **muscular structures** that regulate the flow of partially digested food in the alimentary canal.

4 TEETH

Dentition:

- **Thecodont** – Each tooth is embedded in socket of jaw bone
- **Heterodont** – Different types: Incisor (I), Canine (C), Premolar (PM), Molar (M)
- **Diphyodont** – 2 sets of teeth during life
 - A set of **temporary/milk/deciduous** teeth which are replaced by a set of **permanent/adult teeth**

Dental formula =
$$\frac{\text{Teeth in each half of upper jaw}}{\text{Teeth in each half of lower jaw}} = \frac{\begin{matrix} 1 & 2 & 1 & 2 & 3 \\ 2 & 1 & 2 & 3 \end{matrix}}{\begin{matrix} 2 & 1 & 2 & 3 \\ 2 & 1 & 2 & 3 \end{matrix}} \times 2 = 32$$

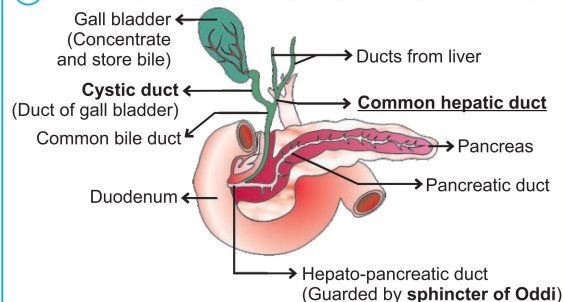


- **Enamel** – Hard chewing surface, helps in mastication of food.

5 DIGESTIVE GLANDS

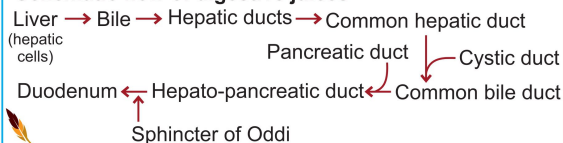
Glands	Location	pH	Secretion	Contents	Function
<ul style="list-style-type: none"> Salivary Glands 1 Pair – Parotids → Cheek 1 Pair – Submaxillary/→ Lower jaw 1 Pair – Sublinguals → Below tongue 	Outside buccal cavity	6.8	Saliva/salivary juice into oral cavity	<ul style="list-style-type: none"> Mucus → Lubrication and adhering of masticated food into bolus Electrolytes-Na^+, K^+, Cl^-, HCO_3^- Lysozymes → Antibacterial agent, prevent infections Salivary amylase → Carbohydrate splitting enzyme 	
<ul style="list-style-type: none"> Gastric glands Mucus neck cells Peptic/chief cells Parietal/oxynitic cells 	Mucosa of stomach	1.8	Gastric juice in stomach	<ul style="list-style-type: none"> Mucus → Lubrication and protection of mucosal epithelium from excoriation by HCl Pepsinogen → Active form → Protein digestion Prorennin (infants) → Active form → Digestion of milk proteins Lipase → Fat digestion HCl → Acidic pH, activation of gastric proenzymes Intrinsic factor → Absorption of vitamin B_{12} 	
<ul style="list-style-type: none"> Liver (Largest gland) 1.2-1.5 kg 	Right side of abdomen below diaphragm	>7	Bile released into duodenum	<ul style="list-style-type: none"> Bile salt → Emulsification of fats Bile pigments → Bilirubin and biliverdin Cholesterol Phospholipids Bile activates lipases 	
<ul style="list-style-type: none"> Pancreas (Heterocrine gland) 	Between limbs of duodenum	>7	Pancreatic juice released into duodenum	<ul style="list-style-type: none"> Trypsinogen → Active form → Protein digestion Chymotrypsinogen Procarboxypeptidase Amylase → Carbohydrate digestion Lipases → Fat digestion Nucleases → Nucleic acid digestion 	
<ul style="list-style-type: none"> Intestinal glands Brunner's gland → Sub mucosa of duodenum (no enzyme) Crypts of Lieberkuhn → Mucosa of small intestine between bases of villi 		7.8	Intestinal juice/ Succus entericus	<ul style="list-style-type: none"> Mucus → Lubricate and protect intestinal mucosa from acid and provide alkaline medium for enzymatic activities Brush border enzymes Disaccharidases → Carbohydrate digestion Dipeptidases → Protein digestion Lipases → Fat digestion Nucleosidases → Nucleosides digestion Enterokinase → Activates trypsinogen into trypsin which in turn activates other enzymes in the pancreatic juice 	

6 DUCTS ASSOCIATED WITH LIVER AND PANCREAS



- Pancreas
 - Exocrine part secrete **alkaline** pancreatic juice containing **enzymes**
 - Endocrine part secrete **hormones**, insulin and glucagon

Schematic flow of digestive juices



- **Hepatic lobules** are **structural and functional** unit of liver.
- Each lobule is covered by a thin connective tissue sheath called **Glisson's capsule**.
- Hepatic cells are arranged as cords in hepatic lobule.

Control of activities of gastro intestinal tract

- Saliva secretion – Stimulated by sight, smell and/or presence of food in oral cavity
- Gastric and intestinal secretion – **Local hormones** produced by gastric and intestinal mucosa
- Neural mechanisms – local and via CNS

7 DIGESTION OF FOOD

- Various types of movements in alimentary canal (e.g. peristalsis) are generated by muscularis layer that helps in a thorough mixing up of the food with various secretions and thereby facilitate digestion.
- Bolus** passes down into oesophagus by **swallowing/deglutition**.
- Complex food substances $\xrightarrow[\text{Biochemical process}]{\text{Mechanical process}}$ simple absorbable forms.

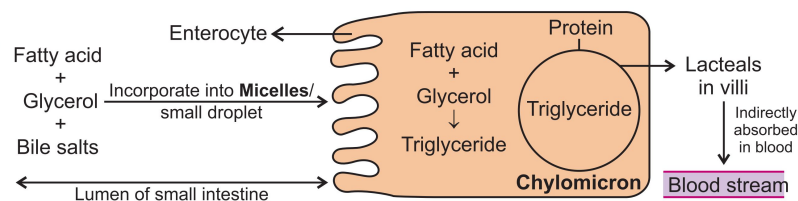
Juice	Site of Digestion	Carbohydrates	Proteins	Fats	Nucleic Acids
Saliva	Buccal cavity	(30%) Starch $\xrightarrow{\text{Salivary amylase}}$ Maltose	—	—	—
Gastric Juice	Stomach (stores food for 4-5 hrs.)	—	<ul style="list-style-type: none"> Pepsinogen $\xrightarrow{\text{HCl}}$ Pepsin Proteins \rightarrow Peptones (peptides) + proteoses Milk protein $\xrightarrow[\text{Infants}]{\text{Rennin}}$ Peptones + proteoses 	Lipase minor role	—
Bile	Intestine	—	—	<ul style="list-style-type: none"> Emulsification of fats i.e. Fats \rightarrow micelles Activates lipases 	—
Pancreatic juice	Intestine	Polysaccharides (Starch) $\xrightarrow{\text{Pancreatic amylase}}$ Disaccharides	<ul style="list-style-type: none"> Trypsinogen $\xrightarrow{\text{Enterokinase}}$ Trypsin Chymotrypsinogen \rightarrow Chymotrypsin Procarboxypeptidase \rightarrow Carboxypeptidase Proteins \rightarrow Peptones \rightarrow Proteoses \rightarrow Dipeptides	Fats $\xrightarrow{\text{Lipases}}$ Diglycerides + Monoglycerides	Nucleic acids $\xrightarrow{\text{Nucleases}}$ Nucleotides
Succus entericus	Intestine	Maltose $\xrightarrow{\text{Maltase}}$ 2 Glucose Lactose $\xrightarrow{\text{Lactase}}$ Glucose + Galactose Sucrose $\xrightarrow{\text{Sucrase}}$ Glucose + Fructose	Dipeptides $\xrightarrow{\text{Dipeptidases}}$ Amino acids	Monoglycerides + Diglycerides $\xrightarrow{\text{Lipases}}$ Fatty acids + Glycerol	Nucleotides $\xrightarrow{\text{Nucleotidases}}$ Nucleosides $\xrightarrow{\text{Nucleosidases}}$ Sugars + Nitrogen bases

- Food in stomach mixes with acidic gastric juice by churning movements and is called **chyme**.
- Breakdown of biomacromolecules into its simplest form occurs in the duodenum.

8 ABSORPTION OF DIGESTED PRODUCTS

Method	Mechanism	Examples
<ul style="list-style-type: none"> Passive: (Along concentration gradient) Active: (Against concentration gradient) by utilising energy 	Simple diffusion Facilitated transport Osmosis	<ul style="list-style-type: none"> Glucose, amino acids, Cl^- ions Glucose, amino acids Water Glucose, amino acids, Na^+ ions

- Absorption** is the process by which the end products of digestion (in the form of small units) pass through intestinal mucosa into the blood or lymph.
- The digested food is absorbed into the body through the epithelial lining of the intestinal villi of jejunum and ileum.

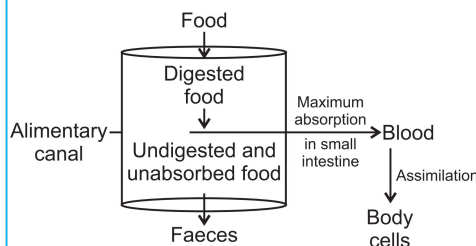


Summary of different substances absorbed in different parts of alimentary canal

Mouth and lower side of tongue		Certain drugs
Stomach		Simple sugars, alcohol, water
Small intestine	Lymph	Fatty acids, glycerol
	Blood	Glucose, fructose, amino acids
Large intestine		Water, drugs, some minerals

9 ASSIMILATION

- The digested end products formed in duodenum are absorbed and finally reach the tissues which utilise them for their activities. This process is called **Assimilation**.



10 ROLE OF LARGE INTESTINE

- No significant digestive activity occurs here.
- Site for **Absorption** of water, minerals, certain drugs
- Secretion** of mucus, to adhere waste and for lubrication
- Undigested, unabsorbed substances enter caecum through **ileo-caecal valve** and the wastes solidified into **coherent faeces** which is temporarily stored in rectum till defaecation.
- Egestion of faeces to outside through anal opening is **defaecation**. It's a **voluntary process** and is carried by a **mass peristaltic movement**.



In PEM — Growth rate and body weight decline
Growth and development of brain and mental faculties are impaired

11 PROTEIN ENERGY MALNUTRITION (PEM)

- Dietary deficiencies of proteins and total food calories are widespread in children of underdeveloped countries.
- It may affect large sections of the population during drought, famine and political turmoil.

Parameters	Kwashiorkor	Marasmus
Dietary deficiency	Proteins	Proteins and calories
Age	Child more than 1 year	Infants less than 1 year
Reason	Replacement of mother's milk by high calorie, low protein diet	Replacement of mother's milk too early by other foods or mother has second pregnancy when older infant is too young
Characteristics	<ul style="list-style-type: none"> Extensive oedema i.e. swelling of body parts Wasting of muscles, thinning of limbs 	<ul style="list-style-type: none"> Extensive emaciation of body, Skin is dry, thin and wrinkled, thinning of limbs

12 ENERGY VALUES

Gross Calorific Value	Physiological Value
<ul style="list-style-type: none"> Amount of heat liberated from complete combustion of 1 gm of food in bomb calorimeter (metal chamber filled with O₂) 	<ul style="list-style-type: none"> Actual amount of energy released on combustion of 1 g of food in body
<ul style="list-style-type: none"> Carbohydrates - 4.1 K cal/g Proteins - 5.65 K cal/g Fats - 9.45 K cal/g 	<ul style="list-style-type: none"> 4.0 K cal/g 4.0 K cal/g 9.0 K cal/g



- 1 kilo calorie is the amount of energy required to raise the temperature of 1 kg of water by 1°C
- Energy requirements of animals, and the energy content of food expressed in terms of heat energy, (calorie (cal) or joule (J)). Since this value is tiny amount of energy, physiologists commonly use kilocalorie (kcal) or kilo joule (kJ).

13 DISORDERS OF DIGESTIVE SYSTEM

Disease/Problem	Cause and Symptoms
Inflammation of intestinal tract	<ul style="list-style-type: none"> Most commonly due to bacterial and viral infections. Can be due to parasites like roundworm, tapeworm, threadworm, hookworm, pin worm etc.
Jaundice	<ul style="list-style-type: none"> Liver affected Skin and eyes turn yellow due to deposit of bile pigments.
Vomiting	<ul style="list-style-type: none"> Ejection of stomach content, feeling of nausea precedes vomiting. It's a reflex action controlled by vomit centre, medulla.
Diarrhoea	<ul style="list-style-type: none"> Abnormal frequency of bowel movement and Increased liquidity of faecal discharge, reduces food absorption.
Constipation	<ul style="list-style-type: none"> Faeces are retained within the colon as bowel movement occurs irregularly.
Indigestion	<ul style="list-style-type: none"> Food not digested properly, feeling of fullness. Can be due to inadequate enzyme secretion, anxiety, food poisoning, over eating and spicy food.