Digestion and Absorption

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Digestion and Absorption

- The primary struggle for any life form on Earth is first 'survival of self' and then 'survival of its species'.
- To survive, living bei ngs depend on necessary nutrients they get from the food they consume.
- **Nutrition** (L. *nutritio*- to nourish) has prime importance in providing energy to living beings.
- The components of food when digested, absorbed and assimilated by a living body help in their growth, development, maintenance of structure, repair and protection.
- Carbohydrates, proteins and fats are the major components of our food. Vitamins and minerals are also required in small quantities.
- An indigestible but essential component of food is roughage. It is composed of fibres of plant origin and connective tissues present in food from an animal source.
- Roughage does not provide any calorific value to the food but it maintains the efficiency of alimentary canal.
- Food eaten by human beings comes majorly from two sources i.e. plants and animals.
- Our digestive system carries out digestion of food by:
  - Mechanical method (physical breakdown of food into smaller pieces by chewing with the help of teeth)
  - Biochemical methods (chemical breakdown of complex organic food into simpler organic substances with the help of enzymes).

HUMAN DIGESTIVE SYSTEM

- Human beings exhibit a 'tube within a tube' body plan. The outer tube represents the body wall. The second inner tube is represented by digestive tract.
- Human Digestive System includes:
  - Alimentary canal (digestive tract) along with the digestive glands presents in its inner lining.

Rack your Brain

What is the principal requirement for the survival of any living individual?

Definition

Nutrition: The process by which living organisms obtain, digest, assimilate and utilise nutrients of food to produce enough energy for maintaining their structural and functional integrity.

Gray Matter Alert!!!

Roughage does not provide any calorific value to the food but it maintains the efficiency of alimentary canal.

- Accessory digestive glands like liver, gall bladder, pancreas, salivary glands that are located outside the alimentary canal.

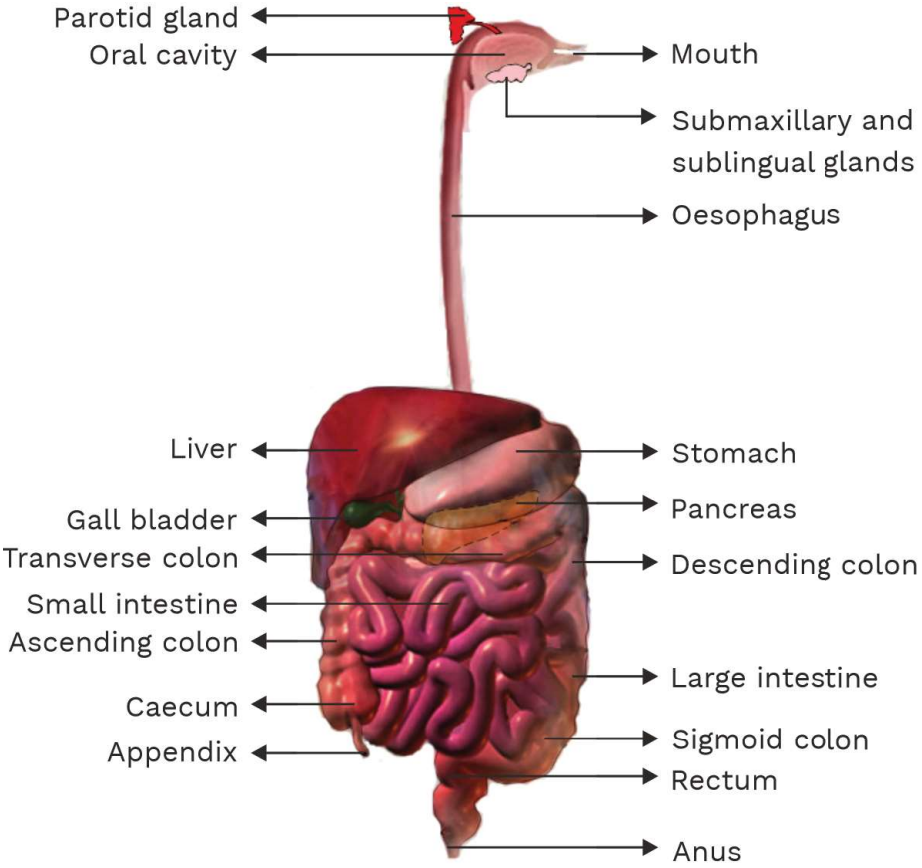

FIG. HUMAN DIGESTIVE SYSTEM

ALIMENTARY CANAL

The alimentary canal is a tubular structure (5-7 metres long) that extends from mouth to anus.

Mouth

- Anterior opening or slit of the alimentary canal.
- Covered by the upper and lower lip.

Buccal cavity

It is subdivided into two parts.

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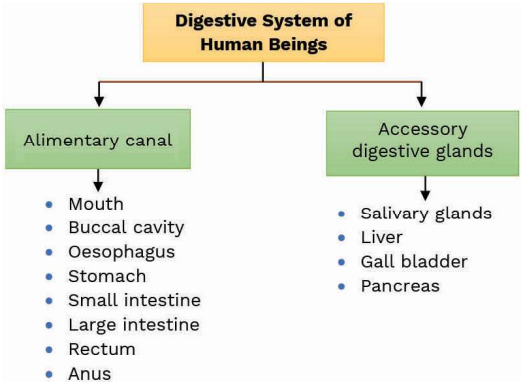
Alimentary canal develops from ectoderm and endoderm. Tissue supporting the alimentary canal from outside are mesodermal in origin.

- **Buccal vestibule**
  - The space between the gums and cheeks.
  - Peripheral in location.
  - Two folds of mucous membrane called **superior labial frenulum** and **inferior labial frenulum** are present in the vestibule between the upper lips and upper gums and the lower lips and lower gums respectively.
- **Main oral cavity**
  - It is the inner and central part.
  - Surrounded by the upper and lower jaw.
  - Contains openings of salivary glands.
  - Consists of palate, tongue, teeth.
- **Palate: The Roof of Buccal Cavity**
  - The anterior part of the palate is **hard palate.**
  - It is composed of maxilla and palatine bone in humans.
  - It consists of transverse ridges/folds **(palatine rugae)**. They help in holding the food during mastication and facilitates backward movement of food.
  - The posterior part of the palate is **soft palate** and it helps in swallowing.
  - It is composed of muscles, fibrous connective tissues and mucous epithelium.
  - The posterior outgrowth of the soft palate is **uvula** or velum palati.



Definition

Mastication: The action of chewing food in the oral cavity with the help of teeth and tongue to mix it with saliva for its initial mechanical and chemical breakdown.

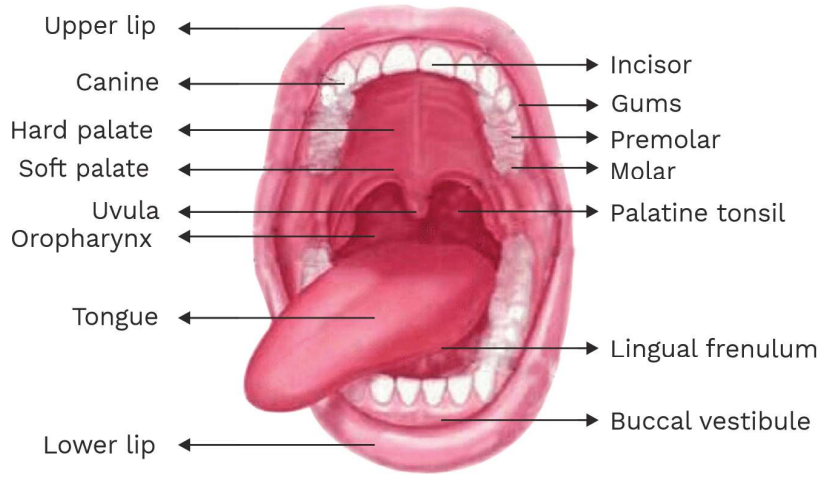


FIG. BUCCAL CAVITY

- **Tongue**
  - Tongue is joined to floor of the buccal cavity by frenulum linguae.
  - The posterior part of tongue is connected to the hyoid bone whereas the anterior part is free.
  - By sulcus terminalis, the upper surface of tongue is divided into two unequal parts.
  - Three types of functional papillae (raised projections) on the tongue give it a rough texture.
  - Gustatory (taste) receptors are present on the tongue surface in the form of taste buds.
  - Anterior tip of the tongue sense sweet taste. Taste buds present anterio-laterally sense salty taste. The posteriorly placed taste buds sense bitter taste while the laterally placed taste buds sense sour taste.

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Lingual frenulum is a fold of mucous membrane present below the tongue to provide support and to limit its movement in different directions.

DIFFERENT TYPES OF PAPILLAE PRESENT ON TONGUE		
Filiform	**Fungiform**	**Circumvallate/Vallate**
Most numerous	Less than filiform	8-12 in number
Smallest	Larger than filiform but smaller than circumvallate	Largest
Threadlike (cone shaped)	Mushroom like (spherical with a stalk like pedicle)	Dome shaped
White coloured	Pink coloured	Pinkish red

Filiform	Fungiform	Circumvallate/Vallate
Present on entire anterior 2/3 of tongue surface	Most numerous at the anterior most tip of tongue	Near sulcus terminalis
No taste buds present, tactile receptors	Approximately 5 taste buds present per papilla	Approximately 100 taste buds present per papilla

- The tongue helps in reception of taste, mixing of food with saliva, cleaning of the oral cavity, speech, and swallowing food.

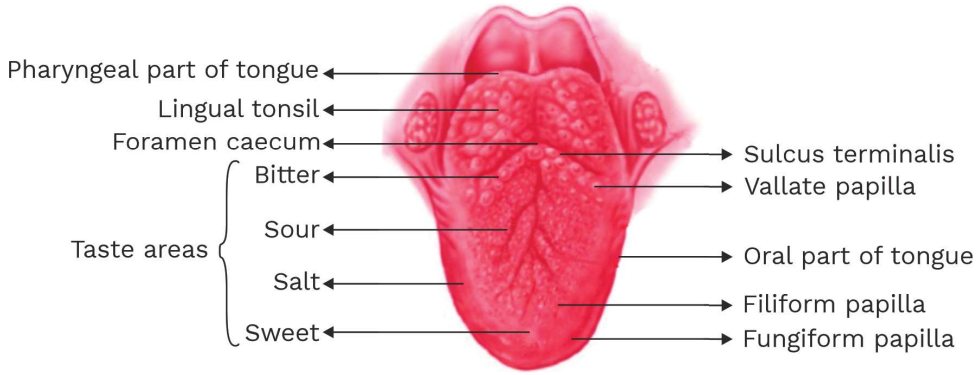

FIG. UPPER SURFACE OF HUMAN TONGUE

- **Teeth**

  In humans, teeth are anchored to the maxilla and mandible bone. The sockets presenting these bones are called alveoli. Thus, teeth are embedded in alveoli or **sockets**

- **Structure of Tooth**

  A tooth is differentiated into three parts— Crown, neck, and root.
  - **Crown:** It is the white part of the tooth that is exposed outside the gums (gingiva) and is covered by enamel. It is the hardest material in the body of human. Enamel is secreted by ameloblast cells.
  - The main part of tooth is dentine. It is formed by odontoblasts, lining the pulp cavity. It

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Teeth are ecto-mesodermal in origin. Enamel originates from the ectoderm of embryo. The remaining part of the teeth develops from the mesoderm of embryo.

contains fine canaliculi passing from pulp cavity to the enamel.

- **Neck:** It is the part of the tooth that is embedded inside the gums.
- **Root:** It is the basal part of tooth that is embedded inside the socket of jawbone (alveoli) and covered by cement and periodontal membrane.
- **Cement** is made up of cementocytes.
- Cement is further covered by a periodontal ligament which fixes the tooth in its socket.
- Dentine surrounds the pulp cavity. It consists of blood vessels, nerves, odontoblasts, and loose connective tissue.
- At the base of pulp cavity, an aperture called apical foramen is present.
- Through apical foramen, blood capillaries and nerve fibres enter into the root canal of tooth.

Previous Year's Question

The crown of the teeth is covered by:
(1) Keratin
(2) Enamel
(3) Dentine
(4) Chondrin

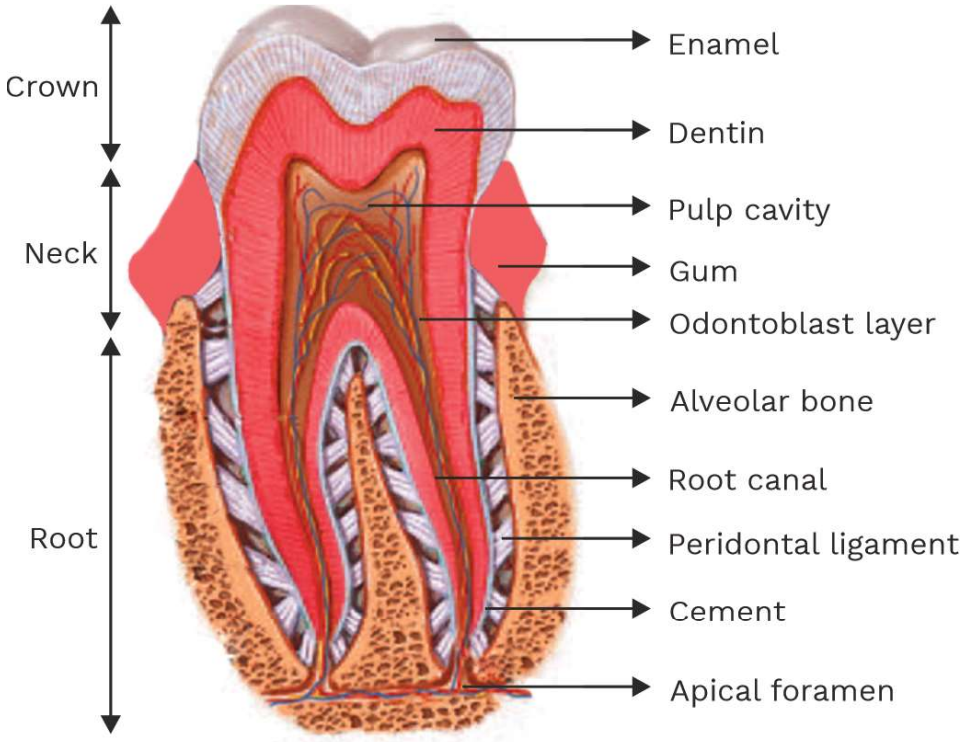

FIG. VERTICAL SECTION OF HUMAN TOOTH

- **Human Dentition**
  - **Milk teeth:** Teeth which appear during childhood are called milk teeth/temporary teeth/primary teeth.
  - **Permanent teeth:** Milk teeth are shed and replaced by permanent teeth which are not shed again in life.
- **Types of Teeth**
  - In mammals, four types of teeth are found:
  - **Incisors:** These are the long, chisel-like teeth with sharp edges for gnawing the food.
  - **Canines:** These are sharp-pointed, one cuspid teeth is meant for tearing and shearing the food.
  - **Premolars:** These bicuspid teeth are used for chewing and crushing the food.
  - **Molars (cheek teeth):** 4-5 cusps are present in the first and second molars while the third molars have 3 cusps. These are also meant for chewing and crushing the food.

Definitions

- **Dentition:** Arrangement of teeth on jaws.
- **Diastema:** The space between two teeth.

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Permanent human teeth do not form again because after certain time odontoblast activity gets over.

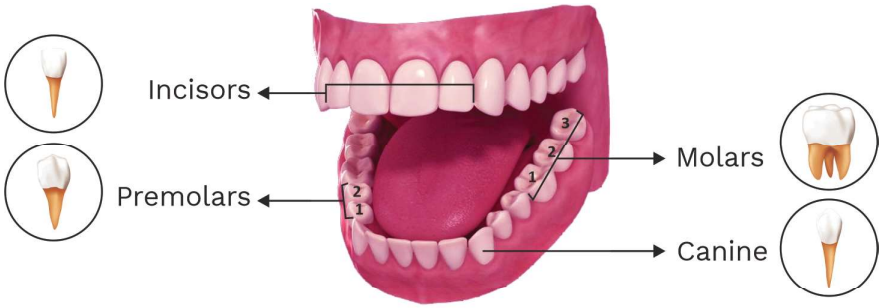

FIG. TYPES OF HUMAN TEETH

Human dentition shows the following features:

- **Monophyodont:** These teeth erupt only once in life e.g., premolars and last molars.
- **Diphyodont:** These teeth erupt twice in life e.g., incisors, canines, 1st and 2nd molars (20 teeth come twice in human life).
- **Thecodont:** These teeth are attached to the bony sockets of jaw.
- **Heterodont:** These are of different types based on their structure and function.

Dental formula

Child (2 – 4 years)

$$I\frac{2}{2}C\frac{1}{1}PM\frac{0}{0}M\frac{2}{2} = \frac{5}{5}\times 2 = \frac{10}{10} = 20$$

Adolescent (17 – 18 years)

$$I\frac{2}{2}C\frac{1}{1}PM\frac{2}{2}M\frac{2}{2} = \frac{7}{7}\times 2 = 28$$

Adult (23 – 25 years)

$$I\frac{2}{2}C\frac{1}{1}PM\frac{2}{2}M\frac{3}{3} = \frac{8}{8}\times 2 = \frac{16}{16} = 32$$

Pharynx

- It is a common passage for food, water and air.
- Pharynx has three parts– nasopharynx, oropharynx, and laryngopharynx.
- **Nasopharynx (behind the nasal cavity):** It is linked to middle ear by a pharyngotympanic tube (Eustachian tube). The mouth of this tube is enclosed by tubal tonsils. Posteriorly, nasopharyngeal tonsils are also present.
- **Oropharynx (behind the oral cavity):** In oropharynx, two palatine tonsils occur laterally.
- **Laryngopharynx (close to the mouth of the larynx):** It is found between hyoid bone, larynx and oesophagus and guides the movement of swallowed materials and air into oesophagus and larynx respectively.

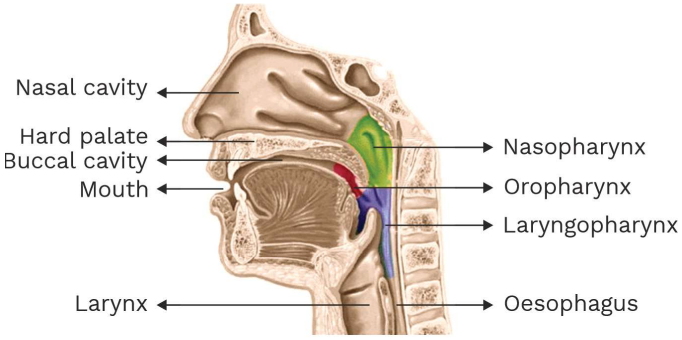

FIG. REGIONS OF PHARYNX

Definitions

- **Polyphyodont:** Teeth replaced many times during life e.g., fish, frog.
- **Monophyodont:** Teeth formed once in lifetime e.g., platypus, marsupials, moles, sirenians, toothed whales.

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- Canines are absent in herbivorous animals.
- Temporary teeth start shedding at around 6 years of age due to osteoclast cell activity

Rack your Brain

- Why food or water always goes into the food pipe even though windpipe is present immediately ventral to it?
- Why can we breathe during chewing of food and cannot breathe during swallowing?

Deglutition Reflex

- Ideally, the masticated food in the oral cavity (bolus) should move into the oesophagus via the oropharynx. To prevent the entry of bolus into the nasal cavities (through nasopharynx) and into the larynx (through the laryngopharynx) deglutition reflex occurs.
- Physiologically, larynx is placed ventrally, and oesophagus is placed dorsally in the neck. But the gullet is placed slightly at a higher level than the glottis.
- During the initial stage of swallowing, the tongue voluntarily exerts upward and backward pressure against the soft palate.
- As the bolus from oral cavity is pushed into the oropharynx, the stretch receptors (epithelial swallowing receptors) in the wall of oropharynx stretches and give this information to the brain.
- In the brain, a deglutition reflex is formed, because of which two responses occur:
  - The soft palate including uvula is pulled upwards to close the internal nares. This does not allow the bolus to enter into the nasal cavities.
  - The neck muscles contract and pull the trachea up so that glottis emerges at a higher position than that of gullet. When this happens, the epiglottis covers the glottis and closes it (breathing stops currently).
- The upper surface of epiglottis becomes like a slide or slippery surface over which the food slides and enters the gullet. As soon as, the food enters the gullet, the neck muscles relax and the trachea comes down and epiglottis moves away from glottis, thus breathing starts.
- From gullet food sinks down the oesophagus involuntarily and reaches the stomach due to peristalsis.

Definitions

- **Deglutition**: The act of swallowing food.
- **Bolus:** Soft mass of chewed partially digested food mixed with saliva which moves into the stomach from oral cavity via oesophagus.
- **Gullet:** Opening of oesophagus
- **Glottis:** Opening of Larynx

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- **Waldeyer's Lymphatic Ring**: Arrangement of tonsils of oral cavity and pharynx. It includes lingual, palatine, tubal and nasopharyngeal tonsils and provides lymphocytes and Immunoglobulin A.

Oesophagus

- Long (25 cm) and uniform fibromuscular tube.
- Originates from lower end of pharynx and runs downward through the thorax, pierces the diaphragm and finally opens into stomach through the gastro-oesophageal orifice.
- The outermost wall of oesophagus lacks serosa. Instead, a white fibrous peritoneum covering called tunica adventitia is present.
- It passes the food from the pharynx to the stomach through peristalsis.
- **No digestion** takes place in the oesophagus as enzyme secreting glands are absent in its inner epithelial lining (mucosa).

Stomach

- It is located to the left side of abdominal cavity.
- It is the **broadest part** of the alimentary canal.
- It is a bag-like, muscular structure, J-shaped in normal condition.
- Stomach is covered by peritoneum layer. Lymph tissues and fat tissues are deposited over the peritoneum. Such peritoneum is called **omentum**.
- Left curved surface of stomach is covered by the greater omentum. Right curved surface of stomach is covered by the lesser omentum.
- The stomach contains the following parts
  - **Cardia:** The food from the stomach enters in cardia through gastroesophageal sphincter (cardiac sphincter).
  - **Fundus:** It is filled with air.
  - **Body:** It is main part of the stomach.
  - **Pylorus:** It is the posterior end part of the stomach through which food enters the duodenum through pyloric sphincter.
- The bolus which enters the stomach remains there for about 4-5 hours.
- The longitudinal, circular and oblique muscular layers present in the gastric wall thoroughly mix the bolus with acidic gastric juice of the stomach.

Rack your Brain

Assertion: Digestion of carbohydrates starts in the oesophagus.
Reason: Mucosal lining of oesophagus consists of digestive glands.
Select the correct option.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If assertion is true but reason is false.
(4) If both assertion and reason are false.

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Heartburn: Sometimes the lower oesophageal sphincter fails to close adequately. This causes reflux of acidic stomach contents into the oesophagus. This is called gastroesophageal reflux disease (GERD) or heartburn.

- The inner lining of the stomach (mucosa) has many folds called gastric rugae for its timely expansion to accommodate more food.

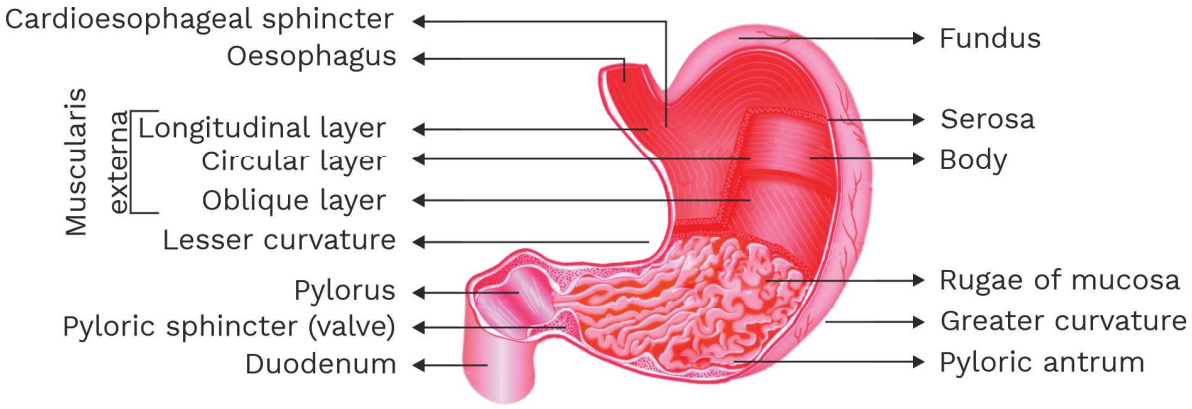

FIG. HUMAN STOMACH

- **Functions of Stomach**
  - HCl present in the gastric juice provides an acidic pH (pH – 1.8) which gives an optimum functioning condition for gastric enzymes and kills microorganisms coming along with the swallowed materials.
  - Gastric digestive enzymes are secreted on stimulation by Gastrin hormone which partially digests the food components.
  - Mucus and bicarbonates present in the gastric juice lubricate and protect the mucosal epithelium from highly concentrated HCl.

Small intestine

- It is about 6.25 m long. Proteins, carbohydrates, fats and nucleic acids are completely digested in the small intestine.
- Absorption of digested food also happens in the small intestine.
- Hormones like cholecystokinin, secretin, enterogastrone, duocrinin, enterocrinin and villikinin are produced here.
- It also secretes intestinal digestive enzymes.

Previous Year's Question

The mucosal layer in the stomach form irregular folds known as

(1) Villi
(2) Lumen
(3) Rugae
(4) Crypts of Lieberkuhn

- The small intestine is differentiated into three parts— duodnum, jejunum, and ileum,
  - **Duodenum (25cm long):** Duodenum is the shortest, widest, C-shaped part of small intestine. Maximum digestion takes place in duodenum.
  - **Jejunum (2.5m long):** It is a long, coiled, middle part of small intestine where maximum absorption takes place.
  - **Ileum (3.5m long):** It is the longest part of the small intestine. Small nodules of lymphatic tissue are particularly present along the ileum which are clustered in groups called **Peyer's patches** (produce lymphocytes).
  - Various modifications are present in the small intestine to increase the surface area for efficient absorption of digested food, e.g., greater length of the intestine, presence of permanent deep folds in mucosa called **plicae circulares** or Valves of Kerckring (prominent in jejunum), finger like projections called **villi** of the mucosa of small intestine (absent over Peyer's patches), finger-like extensions (**microvilli**) of the cell membrane of cells present in the villi (enterocytes).

Previous Year's Question

Peyer's patches are found on the ileum in
(1) Fish
(2) Reptiles
(3) Birds
(4) Mammals

DIFFERENCES BETWEEN DUODENUM, JEJUNUM AND ILEUM

Feature	Duodenum	Jejunum	Ileum
Location	Location-occurs in the upper abdomen close to the midline	Occupies upper and left part of the intestinal area	Occupies lower and right part of the intestinal area

Feature	Duodenum	Jejunum	Ileum
Wall	Wall less than 3 mm	Thicker and more vascular (redder)	Thinner and less vascular
Lumen	Widest	Wider and often empty	Narrower and often loaded
Villi	Villi broad leaf like, abundant	Large, thick (leaf-like) and more abundant	Shorter, thinner (finger-like) and less abundant
Peyer's patches	Absent	Absent	Present
Brunner's gland	Present	Absent	Absent
Plicae circulares	Less than jejunum	More prominent	Less prominent

Large intestine

- It is 1.5m in length. Absorption of water and elimination of solid wastes occur here.
- Large intestine is differentiated into three parts—Caecum, colon, and rectum.
- **Caecum (6 cm long):**
  - The lower end of the ileum opens in a pouch called caecum. This opening is guarded by an **ileocaecal valve**.
  - Its thick mucus membrane absorbs water and salts from the undigested and unabsorbed mass coming from ileum and also lubricates this mass with mucus.
  - About 2cm below the ileocaecal orifice, a worm-like blind structure arises from the

Previous Year's Question

Vermiform appendix is a part of
(1) Alimentary canal
(2) Nervous system
(3) Vascular system
(4) Reproductive system

caecum called a **vermiform appendix** (8 cm long). Its length ranges from 2 to 20cm. It serves as a safe storehouse of beneficial gut bacteria. It provides immune responses (B-cell mediated immune response and T-cells of extrathymic source).

- It is thought to give early protection against deadly diseases. Innate lymphoid cells are also present in the appendix which maintain digestive health.

- **Colon (140- 155 cm long)**
  - Colon of human has an **ascending** (shortest part of colon, 18 cm long), **transverse** (50 cm long), **descending** (25 cm long) and **sigmoid** (S – shaped, 40-45 cm long) part.
  - Its length is about 100 cm in living adults and about 150 cm at autopsy.
  - The bend between ascending colon and transverse colon is called the **right hepatic flexure** whereas the bend between the transverse colon and the descending colon is called the **left splenic flexure.**

Rack your Brain

What gives the colon its segmented appearance?

Previous Year's Question

Water is largely absorbed in the
(1) Stomach
(2) Oesophagus
(3) Small intestine
(4) Colon

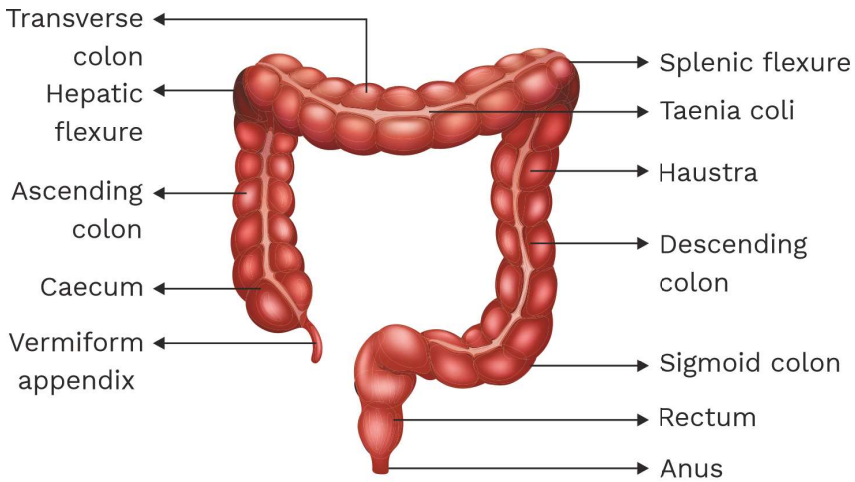

FIG. LARGE INTESTINE

- The fibres of its external muscular layer are collected into three longitudinal bands, the taeniae coli. As these bands are shorter than the rest of the colon, between the taeniae,

the wall of the colon forms outpouchings **(haustra)**. This sac-like haustra formation (sacculation) gives a segmented appearance to the colon.

- There are **no villi,** digestive glands and plicae circulares on its mucosa.
- Small, fat-filled epiploic appendages are present in the colon which are presumed to protect in the same way as greater omentum in the stomach and help in colonic absorption.
- Many symbiotic microorganisms reside in the colon and depend on undigested food. They produce Vitamin K and Vitamin B complex as their metabolic products.
- The type of contraction that occurs only in the colon is the progressive and continuous mass action contraction which pushes the waste material forward into the rectum.

- **Rectum (15-20 cm)**
  - The colon then continues in a uniform tube called rectum (storage area for faeces).
  - Taeniae coli and haustra are absent here.
  - Transverse and longitudinal folds are present internally to allow wavy motion of stool.
  - Terminal end of large intestine is anal canal (3-4 cm long).

Anus

- Anal canal leads to the outside by the anus. Anal opening is controlled by anal **sphincters**.
- There are two types of anal sphincters: Internal anal sphincter (involuntary) and external anal sphincter (voluntary).

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Haemorrhoids (Piles): Painful internal or external swollen (dilated) veins in the lower rectum, anal canal and anus.

Previous Year's Question

Which of the following is not a function of the large intestine?

(1) Absorption of water
(2) Elimination of waste
(3) Manufacture of vitamin K and vitamin B complex
(4) Absorption of fats

Gray Matter Alert!!!

We can survive without a colon. This is because the nutrients from the digested food are predominantly absorbed by the small intestine.
Therefore, to continue have a healthy life, a person can have his/her colon removed.

Previous Year's Question

Where do certain symbiotic microorganisms normally occur in human body

(1) Caecum
(2) Oral lining and tongue surface
(3) Vermiform appendix and rectum
(4) Duodenum

DIFFERENCES BETWEEN SMALL INTESTINE AND LARGE INTESTINE		
Feature	**Small Intestine**	**Large Intestine**
Length	6.25 m	1.5 m
Mobility	Greater part is freely mobile	Greater part is fixed
Sacculation (Haustra)	Absent	Present
Taenia coli	Absent	Present
Plicae circulares	Present	Absent
Epiploic appendages	Absent	Present
Villi	Present	Absent
Peyer's patches	Present in ileum	Absent
Digestion	Complete	No digestion
Effects of infection and irritation	Diarrhoea	Dysentery
Common site for	(a) Intestinal worms (b) Typhoid and (c) Tuberculosis	(a) *Entamoeba histolytica* (b) Organisms causing dysentery (c) Carcinoma

HISTOLOGY OF ALIMENTARY CANAL

The wall of alimentary canal is composed of four layers (outer to inner):

Serosa (visceral peritoneum)

- It is the most outer layer of alimentary canal.
- Serosa is composed of areolar connective tissue and simple squamous epithelium (mesothelium).
- Oesophagus is lined with external adventitia which is made up of dense elastic fibrous connective tissue.

Muscularis (muscle layer)

- The muscularis of the mouth, pharynx and superior and middle parts of the oesophagus consists of skeletal muscles that produce voluntary swallowing. The external anal sphincter is also formed by skeletal muscles, thus permitting voluntary control of defecation.
- The muscularis of the rest of the digestive tract consists of two layers of smooth muscles i.e. inner **circular** layer and outer **longitudinal** layer of smooth muscle.
- The thickest layer is found in stomach (maximum peristalsis) and the thinnest layer in rectum.
- Just inner to circular muscle layer, stomach contains an additional oblique muscle layer.
- **Auerbach's plexus (myenteric plexus)** is the network of nerve cells and parasympathetic nerve fibres which is present in between longitudinal and circular muscular fibres to **control** gastrointestinal movement **(peristalsis)**.

Submucosa

- It consists of areolar connective tissue layer with blood vessels, lymph vessels and nerves.
- **Meissner's plexus (submucosal plexus)** is the network of nerve cells and sympathetic nerve fibres which is present between muscularis and the mucosa. It controls gastrointestinal secretion and local blood flow. In stomach,

Previous Year's Question

In the gastrointestinal tract the Meissner's plexus and the Auerbach's plexus occur respectively in the

(1) Lamina propria and muscularis mucosa
(2) Submucosa and muscularis externa
(3) Submucosa and mucosa
(4) Mucosa and muscularis externa

Rack your Brain

How many layers of muscularis are present in the stomach?

Meissner's plexus lies between oblique muscle and submucosa.

Mucosa

- It is the innermost layer of alimentary canal that contains the secretory and absorptive cells. It forms plicae circulares in the intestine. Mucosa is differentiated into three layers— mucosa muscularis, lamina propria, and epithelial mucosa.
- **Mucosa muscularis**
  - It is the outer layer (towards submucosa).
  - It is made up of outer longitudinal and inner circular smooth muscle layers which open and close the folds of mucosa (villi) during digestion and absorption.
  - It plays an important role in exposing the surface area of intestinal wall for absorption.
  - It provides support to the mucosal folds.
- **Lamina propria**
  - It is the middle layer and contains blood vessels and lymphatic tissue called as **MALT (Mucosa Associated Lymphoid Tissue)** that provides immunity e.g., Peyer's patches (in small intestine, mainly ileum).

Previous Year's Question

The intestine is different from the stomach by the presence of
(1) Digestive gland
(2) Villi
(3) Sub mucosa
(4) Serosa

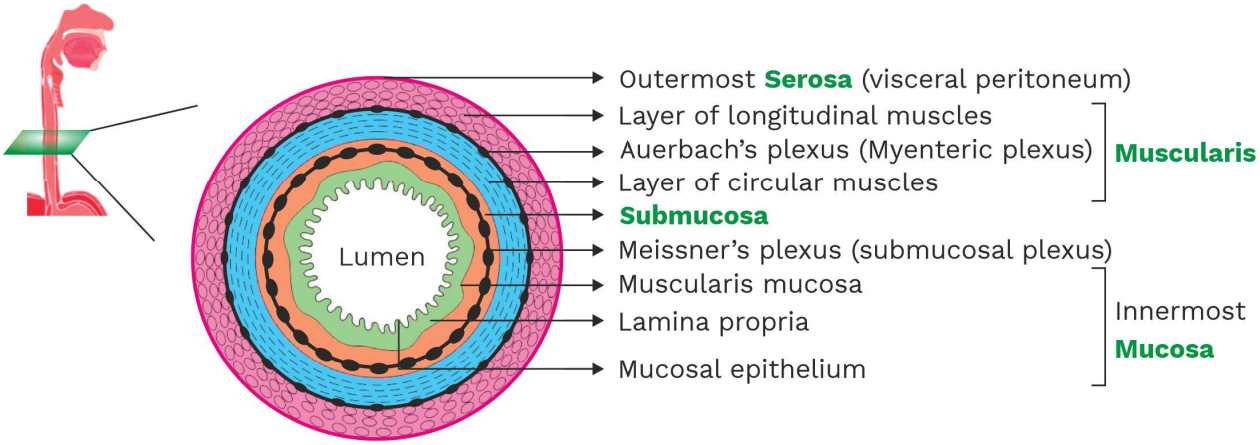


FIG. TRANSVERSE SECTION OF ALIMENTARY CANAL

- Made up of areolar connective tissue.

- **Epithelial mucosa**
  - It is the Innermost layer.
  - Folds of epithelial mucosa in oesophagus are less developed, whereas these folds in stomach are finger-shaped and well developed as glands known as gastric glands.
  - Folds of epithelial mucosa in oesophagus are less developed, whereas these folds in stomach are finger-shaped and well developed as glands called gastric glands.
  - Folds of mucosal epithelium in small intestine are conically shaped called villi (maximum villi are found in jejunum).
  - Intestinal villi contain blood and lymph (lacteals) capillaries.
  - Invaginations of epithelium called Crypts of Lieberkuhn are present in the small intestine.

DIGESTIVE GLANDS

Digestive glands bring about digestion of food by secreting digestive enzymes. Digestive glands present in the mucosa of alimentary canal are called gastric glands. Some digestive glands are present outside the alimentary canal and are called accessory glands.

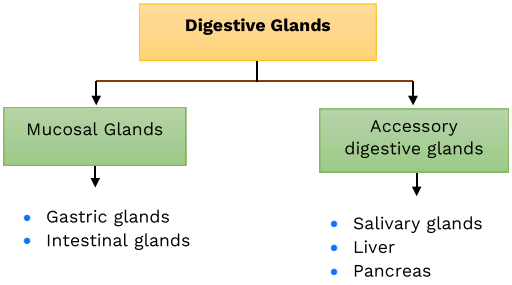
Salivary Glands

- There are three pairs of digestive glands present outside the oral cavity— parotid glands, submandibular glands, and sublingual glands.
- Secretion of salivary glands is known as saliva.
- Saliva composition:
  - Daily secretion - 1500 ml (appr.)
  - pH - 6.8
  - Composition of Water - 99.5% - moisten the food.
  - Salivary amylase (Ptyalin) – Mainly secreted by parotid glands- digests carbohydrates.
  - Antibacterial substances - Lysozymes, lactoferrin, thiocyanates
  - Few ions like Na^+, K^+, Cl^-, HCO_3^- Buffering

Gray Matter Alert!!!

Three types of ducts open in the lumen of intestine.

- Ducts from glands outside intestine: e.g. Salivary glands, liver, pancreas.
- Ducts from glands of submucosa: e.g. Brunner's glands.
- Ducts from glands of mucosa: e.g. Gastric glands, intestinal glands.



Gray Matter Alert!!!

Volume of saliva is more from submandibular glands but the amount of salivary amylase is more from parotid glands.

Definition

Mumps: Infection of Parotid glands by *Paramyxovirus*.

agents
- IgA antibody
- Mucin (mucus)
- Small amount of urea and uric acid (nitrogenous waste)

Gray Matter Alert!!!

Salivary amylase is not found in the saliva of most herbivores.

SALIVARY GLANDS			
	Parotid Glands	**Submandibular Glands**	**Sublingual Glands**
Location	Near ear (cheeks)	At the junction of upper and lower jaw	Below tongue
Size	Largest	Medium sized	Smallest
Duct	Stenson's duct	Wharton's duct (longest salivary duct)	Ducts of Rivinus (shortest salivary duct)
Openings of Duct	In vestibule of upper jaw near upper second molar	Behind lower incisors	Under the tongue
Saliva	25%	70% (max)	5% (min)
Nerve controlling the secretion	IXth (Glosso-pharyngeal nerve)	VIIth (Facial nerve)	VIIth (Facial nerve)

Liver

- Liver is endodermal in origin, weighs about 1.2- 1.5 Kg and is placed below the diaphragm towards the right side of abdominal cavity,.
- The largest gland of the body is liver.
- **Falciform ligament** (fibrous connective tissue) is made up of folds of peritoneum and divides the liver superficially into two lobes (left and right). Left lobe is smaller in comparison to the right lobe. 5/6th of the liver is formed by right lobe and 1/6th of liver is formed by left lobe
- Right and left hepatic duct drains bile from right and left hepatic lobe respectively. These ducts join to form a common hepatic duct.

Previous Year's Question

Which of the following guards the opening of hepatopancreatic duct into the duodenum?

(1) Semilunar valve
(2) Ileocaecal valve
(3) Pyloric sphincter
(4) Sphincter of Oddi

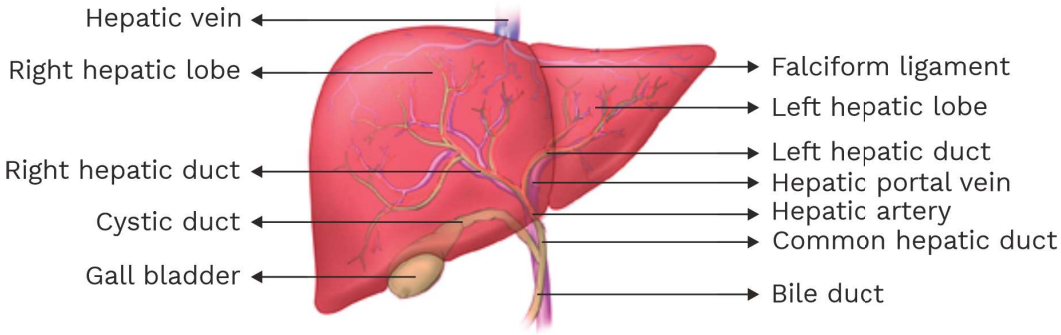


FIG. LIVER AND GALL BLADDER

- **Gall bladder** is situated below right lobe of liver and drained via cystic duct. Its function is to store and concentrate bile prepared by the liver.
- **Cystic duct** of gall bladder joins **common hepatic duct** to form a common bile duct (ductus choledochus).
- The common bile duct joins with the main pancreatic duct and forms an ampulla (Hepatopancreatic ampulla or the **ampulla of Vater).**
- **Sphincter of Oddi** guards the opening of hepatopancreatic ampulla into the duodenum.
- **Sphincter of Boyden** guards the mouth of common bile duct before it joins the main pancreatic duct.

Previous Year's Question

Fat digestion is facilitated by

(1) Bile juice
(2) Pancreatic juice
(3) Gastric juice
(4) None of the above

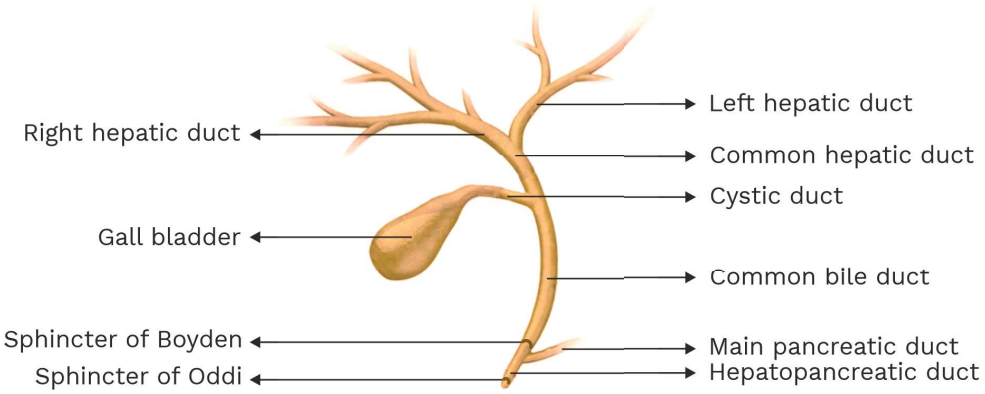


FIG. DUCTS OF LIVER AND GALL BLADDER

- **Hepatic Lobule**
  - Hepatic lobule is the functional and structural unit of liver.
  - Each hepatic lobule is enveloped with a thin fibrous connective tissue sheath called Glisson's capsule.
  - Each lobule comprises of radial rows of hepatic cells (hepatocytes) which are called hepatic cords.
  - The bile canaliculi run in between the two layers of cells in each cord. Hepatocytes pour bile into the canaliculi. Canaliculi open into the branch of hepatic duct which is situated at angular part of lobule in the Glisson's capsule
  - Hepatic portal vein and hepatic artery enter liver and divide to form many branches. These branches are also present at the angular part. Its fine branches open into hepatic sinusoids.
  - Branch of hepatic portal vein, hepatic artery and hepatic duct are collectively called portal triad.
  - All hepatic sinusoids open into central vein or intralobular vein through fine aperture. All the central veins unite to form a hepatic vein which emerges out from liver and opens into inferior vena cava
  - All branches of hepatic duct of right and left lobe unite to form right and left hepatic ducts

Previous Year's Question

Characteristic of mammalian liver is

(1) Kupffer cells and leucocytes
(2) Leucocytes and canaliculae
(3) Glisson's capsules and Kupffer cells
(4) Glisson's capsules and leucocytes

which emerge out from the liver and form a common hepatic duct

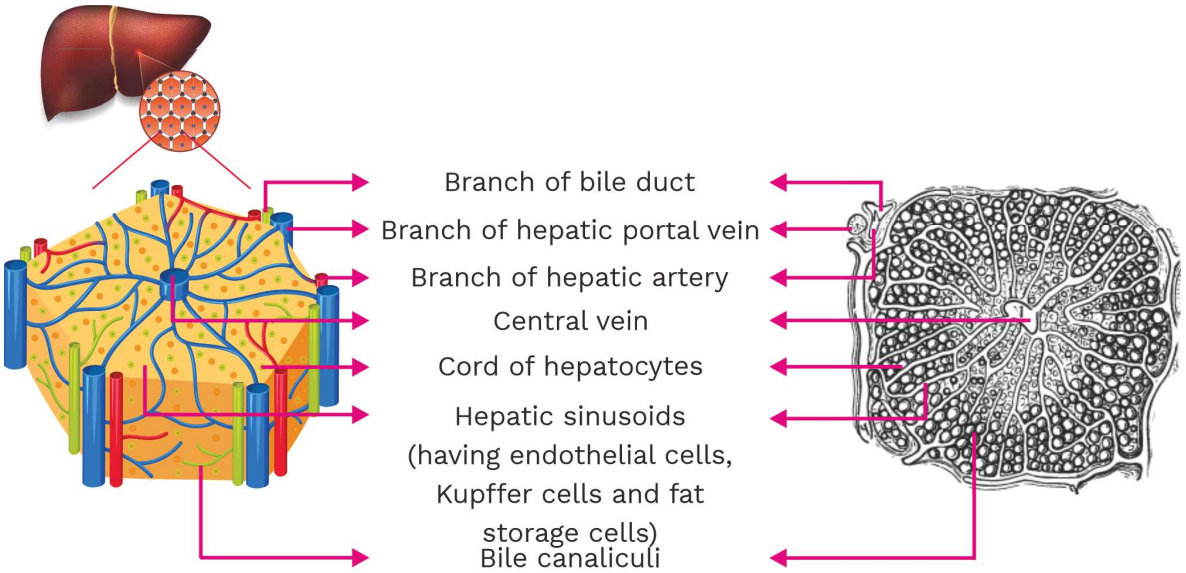


FIG. DIAGRAMMATIC REPRESENTATION **FIG. T. S. OF HEPATIC LOBUI**

- **Bile Juice**
  - Hepatic cells of the liver secrete bile juice and it is stored in the gall bladder.
  - Bile juice does not have any digestive enzyme. Hepatic bile pH is 8.6 whereas bile from gall bladder has a **pH of 7.6**.
  - Daily secretion is **500-1000ml.**
  - Bile contain water (**98%**), cholesterol, lecithin.
  - Bile pigments are the excretory materials of the liver. They are yellowish (**bilirubin**) and greenish (**biliverdin**).
  - Bile contains two types of salts– inorganic salts (NaCl, $Na2CO_3$, $NaHCO_3$, etc.), organic salts (Sodium bicarbonate, Sodium glycocholate and Sodium taurocholate).
  - Inorganic salt neutralizes the acidity of the food whereas organic salt help in **emulsification of fats**.
  - Bile salts also assist in the absorption of fats and fat-soluble vitamins (A, D, E, K). Bile salts mix with fats, cholesterol, phospholipid

Previous Year's Question

Bilirubin and biliverdin are found in
(1) Blood
(2) Bile
(3) Pancreatic juice
(4) Saliva

(lecithin) and fat-soluble vitamins to form compounds called micelles.

- **Functions of Liver**
  - Secretion and synthesis of bile.
  - **Carbohydrate Metabolism:** The site of carbohydrate metabolism is liver. Following processes are related to carbohydrate metabolism:

Glycogenesis: The conversion and storage of extra glucose into glycogen. The main stored food in the liver is glycogen.

Glycogenolysis: The conversion of glycogen into glucose, when glucose level in blood falls, is called glycogenolysis.

Gluconeogenesis: Liver converts non carbohydrate compounds (e.g. amino acids, fatty acids) into glucose.

Glyconeogenesis: Synthesis of glycogen from lactic acid.

  - **Storage of fats:** Liver stores fats in a small amount.
  - **Deamination and Urea formation:** Deamination of amino acids is mainly done by liver (Amino acid → NH_3).
  - Liver converts ammonia (more toxic) into urea (less toxic) through ornithine cycle.
  - **Purification of blood:** Kupffer cells of liver are the phagocytic cells, help in phagocytosis of dead blood cells and bacteria from the blood.
  - **Synthesis of plasma proteins:** All plasma proteins (except Gamma-globulins) are synthesised in the liver.
  - Prothrombin and fibrinogen proteins are also formed in hepatic cells. These help in clotting of blood. Factors II, VII, IX and X are formed in liver, which are responsible for blood clotting.
  - **Synthesis of heparin:** Heparin is a natural anticoagulant (mucopolysaccharide). Some heparin is also formed by basophils (granulated WBC) and mast cells.
  - **Synthesis of vitamin A:** The

Rack your Brain

Why is secretion of bile is proportional to the concentration of fats?

Previous Year's Question

One of the following is a specific function of liver. Mark it.

(1) Excretion
(2) Glycogenolysis
(3) Digestion
(4) Histolysis

Previous Year's Question

The toxic substances are detoxicated in the human body by

(1) Lungs
(2) Kidneys
(3) Liver
(4) Stomach

liver changes β-carotene into vitamin A.

- **Storage of vitamins:** Vitamins are stored in liver like vitamin A, D, E, K and B_{12}.
- **Storage of minerals:** Iron, copper, zinc, cobalt, molybdenum etc, are stored in liver.
- **Detoxification:** The liver converts toxic substances into non-toxic substances.
- **Haemopoiesis:** The formation of blood cells is called haemopoiesis. In embryonic stage, RBCs and WBCs are formed by liver.
- Formation of Lymph
- Formation of Angiotensinogen: Angiotensinogen formed in the liver is changed to angiotensin which helps in regulation of kidney.

- **Functions of Bile Juice**
  - Neutralization of HCl.
  - **Emulsification:** Sodium glycocholate and sodium taurocholate are bile salts which break large fat droplets into the smaller ones thereby increasing the surface area for lipase action.
  - **Absorption of fat and fat-soluble vitamins:** Salts of bile juice help in the absorption of fat (fatty acids and glycerol) and fat-soluble vitamins (Vitamin D, A, E and K).
  - **Excretion:** Bile pigments (bilirubin and biliverdin) are excretory products.
  - **Activation of lipase:** Bile activates the enzyme lipase but contains no enzyme.

Pancreas

- It is endodermal in origin.
- Pancreas is a mixed/**compound** (exocrine and endocrine) organ situated between the limbs of the C-shaped duodenum. Its **99%** part is exocrine while **1%** part is endocrine.
- **The exocrine part** of pancreas is composed of numerous acini. Acini is a group of secretory cells that surrounds a cavity. Each acinus is lined

Rack your Brain

How does liver help in formation of blood in human body?

Gray Matter Alert!!!

Gall stone: Sometimes the passage inside the bile duct gets blocked or becomes narrow, so the cholesterol gets deposited or precipitated in the gall bladder to form gall stone (cholelithiasis).

by pyramidal- shaped cells. These acinar cells secrete the enzymes of pancreatic juice

- Each acini joins pancreatic ductule. Many pancreatic ductules combine to form the **duct of Wirsung** (main pancreatic duct). The main pancreatic duct joins with the common bile duct to form the hepatopancreatic ampulla which opens into duodenum. The **duct of Santorini** (accessory pancreatic duct) opens into duodenum with a separate opening located above the opening of main pancreatic duct.

Previous Year's Question

In pancreas, pancreatic juice and hormones are secreted by

(1) Same cells
(2) Different cells
(3) Same cells at different times
(4) None of these

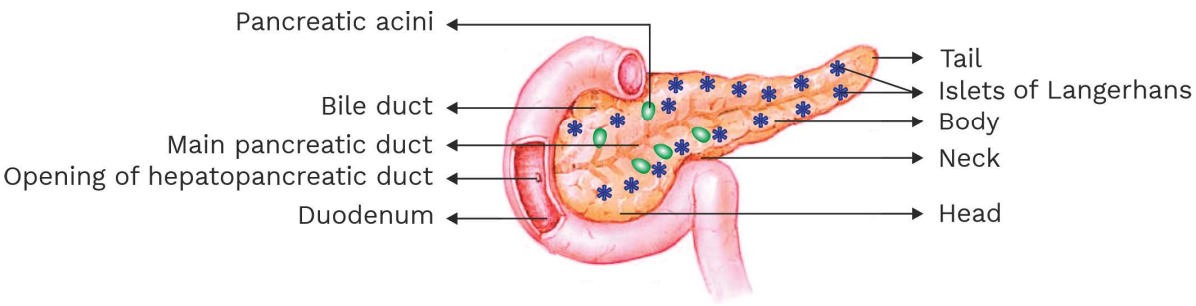


FIG. PANCREAS

- **The endocrine part** of pancreas consist of group of endocrine cells (a, b , d, and PP cells) found in-between group of acini are called **Islets of Langerhans**. These islets secrete somatostatin, glucagon, insulin, and pancreatic polypeptide hormone respectively.
- **Composition of pancreatic Juice:**
- Daily secretion of pancreatic juice in human is about **500-800 ml** (pH is 8.4).
- Pancreatic juice has water (98%), salt (sodium bicarbonate), inactive enzymes like , trypsinogen, chymotrypsinogen, procarboxypeptidase, and active enzymes like pancreatic lipase, pancreatic amylase, nucleases (DNase and RNase).

Rack your Brain

The zymogen cells release protein digesting enzymes in inactive form. Why?

Gastric Glands

- Digestive glands associated with the mucosa of stomach are called gastric glands.

- They are numerous, microscopic, simple, branched or unbranched tubular glands formed by the invagination of stomach epithelium.
- The cardiac region of the stomach has **cardiac gastric glands** which mainly consist of mucus-secreting goblet/mucous neck cells.
- **Principal gastric glands** are present in the fundus and body of the stomach.
- These glands have:
  - **Chief cells or peptic cells (Zymogen cells):** Secrete protein-digesting inactive enzymes called pepsinogen and prorennin, lipid digesting enzyme called gastric lipase and small quantity of carbohydrate digesting enzyme called gastric amylase.
  - **Oxyntic cells (Parietal cells):** These secrete hydrochloric acid and Castle's Intrinsic factor. The acidic medium in the stomach (due to HCl secretion) is necessary to convert inactive enzymes (zymogens) into active enzymes (Pepsinogen to Pepsin and Prorennin to Rennin). Microorganisms that enter the gut along with food are destroyed by HCl.
  - **Mucous neck cells or Goblet cells:** These secrete mucus.
  - **Argentaffin cell:** Secrete somatostatin (which suppresses the release of gastrin hormone), a precursor of serotonin (5-hydroxy tryptamine), and histamine.
  - **G-cells:** Secrete gastrin hormone which in turn stimulates the secretion of gastric juice.
  - **Stem cells:** Undifferentiated cells which differentiate periodically to replace damaged cells.
- **Pyloric Glands:** Present in the pyloric region of the stomach. These are of two types:
  - Mucus secreting mucous neck cells or goblet cells.
  - Gastrin secreting enteroendocrine cells or argentaffin cells.

Gray Matter Alert!!!

Prorennin is present in gastric juice of infants that helps in the digestion of casein(milk proteins).

Previous Year's Question

pH of pancreatic juice is about
(1) 6.4
(2) 8.4
(3) 12.0
(4) 7.0

Gray Matter Alert!!!

Serotonin acts as a vasoconstrictor and inhibits gastric juice secretion. Histamine acts as a vasodilator and promotes gastric acid secretion.

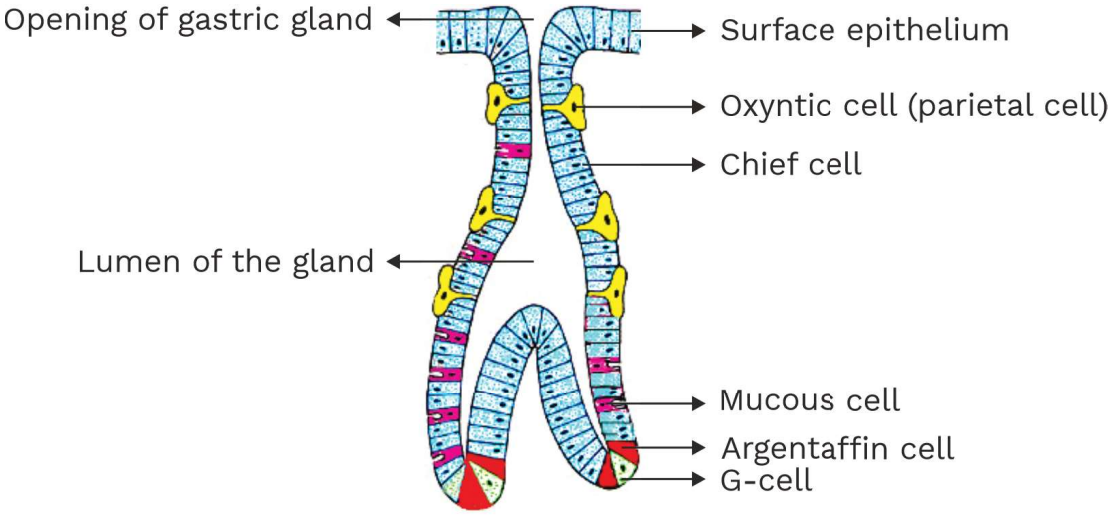


FIG. GASTRIC GLANDS

Composition of Gastric juice

- Daily secretion - 2-3 L
- Water = 99.5%
- HCl = 0.2 – 03%
- pH = 1.8 (in infants pH = 5)
- Rest is mucus, water and gastric enzyme (Pepsinogen, Prorennin, Gastric lipase, Gastric amylase)

Previous Year's Question

Argentaffin cells are found in
(1) Pancreas
(2) Internal ear
(3) Gastric glands
(4) Liver

GASTRIC GLAND CELLS	SUBSTANCE SECRETED
Mucous neck cell	• Mucus (protects lining of gastric mucosa by neutralising HCl) • Bicarbonate
Parietal cells	• Gastric acid (HCl) • Castle's Intrinsic Factor (vitamin B_{12} absorption)

Argentaffin cells	• Somatostatin (inhibits gastrin secretion) • Histamine (stimulates acid) • Serotonin (inhibits gastric juice secretion)
Chief cells	• Pepsinogen • Prorennin • Gastric lipase
G cells	• Gastrin (stimulates secretion of gastric juice)

Intestinal glands

The mucosal epithelium of small intestine makes two types of intestinal glands— crypts of Lieberkuhn and Brunner's gland.

- **Crypts of Lieberkuhn**
  - Occur between the villi of small intestine. They secrete mucus (goblet cells), water and electrolytes (enterocytes).
  - They contain paneth cells and argentaffin cells. Paneth cells (particularly in the duodenum) are phagocytic. They also release antibacterial lysozymes.
  - Argentaffin cells synthesise secretin hormone and 5-hydroxytryptamine.
- **Brunner's glands**
  - They are present in the submucosal layer of duodenum and opens into the crypts of Lieberkuhn.
  - They secrete mucus which protects the duodenal lining from getting digested by the HCl coming from the stomach.

Gray Matter Alert!!!

The secretion of intestinal glands is called intestinal juice or succus entericus with a pH 7.8. Around 2-3 litres of intestinal juice is secreted per day. It contains maltase, isomaltase, sucrase, lactase, enterokinase, aminopeptidase, dipeptidases, nucleotidases, nucleosidases and intestinal lipase.

DIGESTION OF FOOD

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

Digestion of Carbohydrates

- **Digestion of Carbohydrates in Oral Cavity**
  - Digestion of starch and glycogen begins in the oral cavity, where the food is mixed with the saliva while chewing.

Note: Major carbohydrates in diet:
Sucrose or cane sugar (disaccharide)
Lactose or milk sugar (disaccharide)
Starch and glycogen (polysaccharide)

- Saliva contains salivary amylase (α amylase) or ptyalin. It is functional at a nearly neutral pH **(pH 6.8)**. It causes hydrolysis of starch into three types of substances i.e. small or limit dextrins, maltose and isomaltose.
- The sweet taste of some foods after chewing is due to maltose.
- About **30%** of the food starch is hydrolysed in the oral cavity.

Gray Matter Alert!!!

Herbivores and predatory carnivores lack salivary amylase in the saliva.

$$\text{Starch/Glycogen} \xrightarrow[\text{pH 6.8}]{\text{Ptyalin}} \text{Maltose + Isomaltose + Limit Dextrins}$$

- **Digestion of Carbohydrates in the Stomach**
  - Starch digestion continues in the stomach because of the salivary amylase present in the bolus till it is mixed with the gastric secretion.
  - The activity of salivary amylase and the small amount of gastric amylase present in the gastric juice is blocked by the hydrochloric acid secreted by the oxyntic cells of the gastric mucosa.
- **Digestion of Carbohydrates in the Small Intestine**
  - In the duodenum, the food mixes with pancreatic juice. This juice contains amylase, also known as pancreatic amylase. Like salivary amylase, pancreatic amylase acts on starch and dextrins to produce limit dextrins, maltose and isomaltose.
  - The intestinal juice contains limit dextrinase, isomaltase and maltase enzymes for hydrolysing limit dextrins, isomaltose and maltose (respectively) into glucose. Glucose is absorbed in the small intestine.
  - There are two more carbohydrate digesting enzymes in the intestinal juice. They are sucrase and lactase. Sucrase hydrolyses sucrose into glucose and fructose and lactase converts lactose into glucose and galactose. The same are absorbed.

Rack your Brain

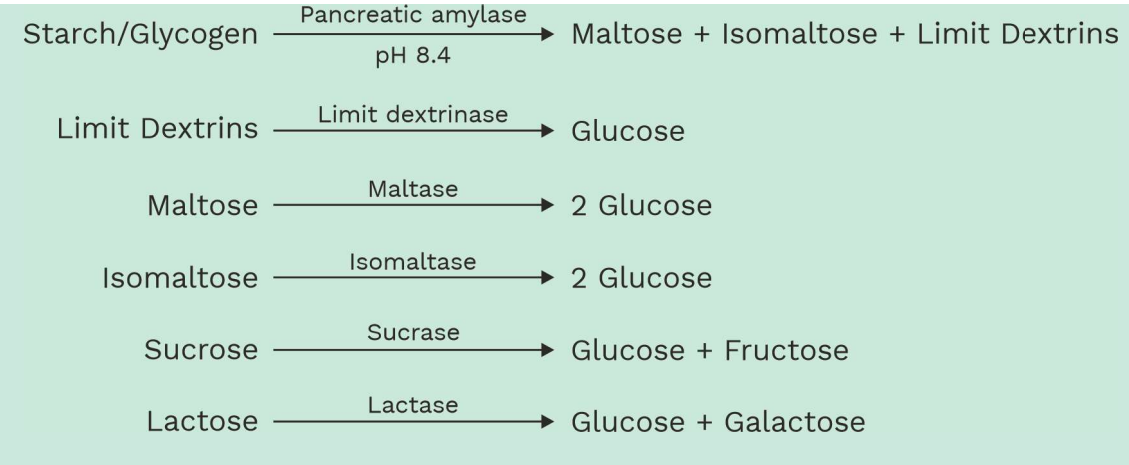
Why do bread taste sweet after chewing?

Gray Matter Alert!!!

Cellulosic cell wall of plant cells does not allow quick action of ptyalin. Cooking helps in breaching the cell wall of food from plant sources.

Rack your Brain

Why do old people often complain of intestinal cramps, flatulence and diarrhoea after consuming milk?



Digestion of Proteins

- The proteins consumed by human beings are chemically long chains of amino acids bound by peptide bonds. Each protein has a unique characteristic feature because of the type of amino acids present in it.
- **Digestion of Proteins in the Stomach**
  - Since saliva does not have any protein-digesting enzyme, the initial steps for hydrolysing proteins starts in the stomach.
  - Hydrochloric acid **(HCl)** secreted by the oxyntic cells of gastric glands create a highly favourable range of acidity **(pH 2-3)** for activation of pepsinogen enzyme.
  - Once inactive **pepsinogen** (secreted by the chief cells of gastric mucosa) gets converted into active proteolytic **pepsin**, it digests proteins into proteoses, peptones and a few polypeptides by breaking the peptide bonds between their amino acids.
  - Infant's gastric mucosa also secretes inactive prorennin which when activated by HCl (at pH 5), digests the milk protein casein into paracasein that combines with calcium to form insoluble calcium paracaseinate. Calcium paracaseinate is further broken down by pepsin to form peptones.

Definition

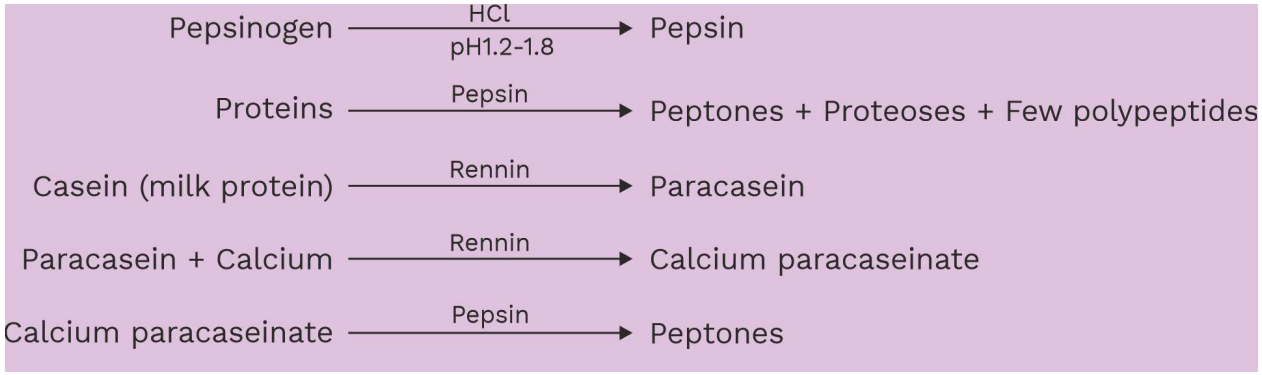
Digestion: The process of enzymatic conversion of complex organic substances to simpler organic substances which can be absorbed by the body.

Rack your Brain

Most important feature of pepsin is the ability to digest collagen. Why?

Previous Year's Question

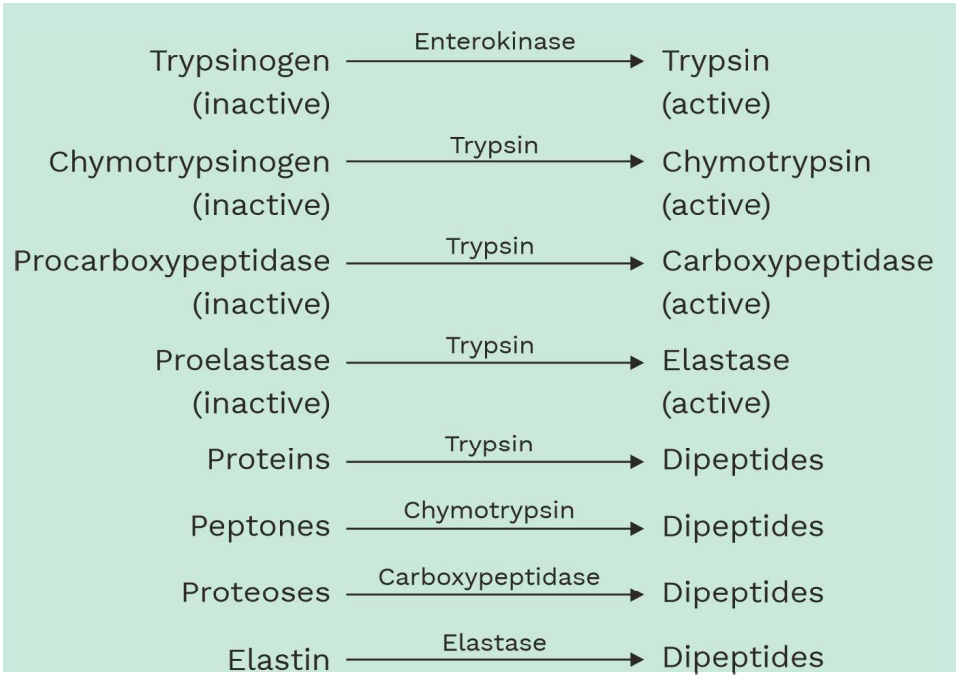
Gastric juice of infants contains
(1) Nuclease, pepsinogen, lipase
(2) Pepsinogen, lipase, rennin
(3) Amylase, rennin, pepsinogen
(4) Maltase, pepsinogen, rennin



- **Digestion of Proteins in the Small Intestine by pancreatic secretions**
  - The hepatopancreatic duct delivers bile from liver and gall bladder and pancreatic juice (pH 8.4) from the pancreas.
  - Pancreatic juice contains four inactive proteolytic enzymes namely trypsinogen, chymotrypsinogen, procarboxypeptidase and proelastase.

Rack your Brain

If pancreas is removed, which component of food will remain undigested?



- The enzyme enterokinase of intestinal juice converts trypsinogen into active trypsin.
- On activation, trypsin itself catalyses the activation of chymotrypsinogen to active chymotrypsin, proelastase to active elastase and procarboxypeptidase to active carboxypeptidase.
- Trypsin, chymotrypsin, carboxypeptidase and elastase hydrolyses proteins, peptones, proteoses and elastin present in the chyme into dipeptides and other small peptides.

Note:
Major fats in diet Neutral fats (triglycerides) are mainly present in the food from animal origin. Small quantities of phospholipids, cholesterol and cholesterol esters are also present in food.

- **Digestion of Proteins in the Small Intestine by intestinal secretions**
  - The enterocytes produce two types of peptidases, aminopeptidases and several dipeptidases. These enzymes finally break down remaining peptides and dipeptides into amino acids.

Gray Matter Alert!!!

Enterokinase enzyme is also called 'activator enzyme' as it converts trypsinogen into active trypsin.

Peptides $\xrightarrow{\text{Aminopeptidases}}$ Amino acids + Smaller peptides

Smaller peptides/dipeptides $\xrightarrow{\text{Dipeptidases}}$ Amino acids

Digestion of Fats

Most lipid digestion occurs in the small intestine by the action of pancreatic lipase although some fat digestion also occurs in the stomach by lingual lipase and gastric lipase.

- **Digestion of Fats (in Stomach)**

A very small amount of fats is digested in the stomach by gastric lipase and lingual lipase (swallowed with saliva) because of the absence of any emulsifying agent.

- **Digestion of Fats in the Small Intestine**

Emulsification of fats

  - **Lipases** can act only in the region of water-fat interface as they are soluble in water whereas fats are insoluble in water. To increase the interface, fats must be broken

Gray Matter Alert!!!

Triglycerides consist of three molecules of fatty acids chemically attached with a molecule of glycerol.

down to fine droplets through a process called emulsification by bile salts.

- Bile released in the duodenum consists of a large amount of bile salts and phospholipid lecithin.
- Bile salts and lecithin are **amphipathic** compounds (having both water-loving, hydrophilic or polar part and water-repelling, hydrophobic or non-polar part) and behave as biological detergents.
- The polar parts of bile salts and lecithin project out of the surface of fat lobules while the fat-soluble, non-polar part dissolves in the surface layer of fat lobules.
- On agitation in the lumen of duodenum, the big fat lobules with reduced interfacial tension (because of the water-soluble polar projections) are broken up into several minute particles very easily, and thus increase the total surface area of the fats manyfold.
- All this is important as the fat-digesting lipase enzymes are water-soluble and thus it can hydrolyse the fat globules only on their surfaces.

- **Action of Lipases:**
  - In the small intestine both pancreatic lipase (main fat-digesting enzyme) and intestinal lipase become active after bile salts produce a stable fine emulsion of fats (emulsified fat).
  - Lipases hydrolyse triglycerides to fatty acids and diglycerides. The diglycerides are further broken down into fatty acid molecules and monoglycerides and finally monoglycerides are hydrolysed to glycerol and fatty acids.
  - Both cholesterol esters and phospholipids contain fatty acids. These emulsified forms are hydrolysed by cholesterol ester hydrolase and phospholipase A_2 respectively.

Definition

Lipases: Fat digesting enzymes are known as lipases or steapsin. They are lingual lipase secreted by lingual glands in the mouth, gastric lipase which are present in the gastric juice, pancreatic lipase of pancreatic juice and enteric lipase secreted by the enterocytes.

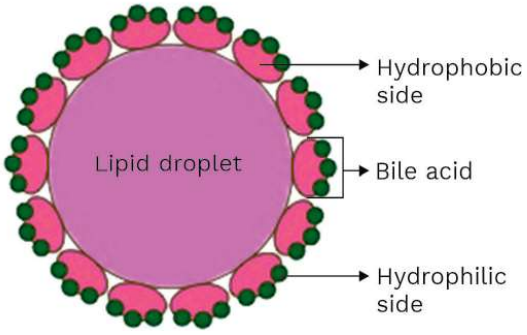
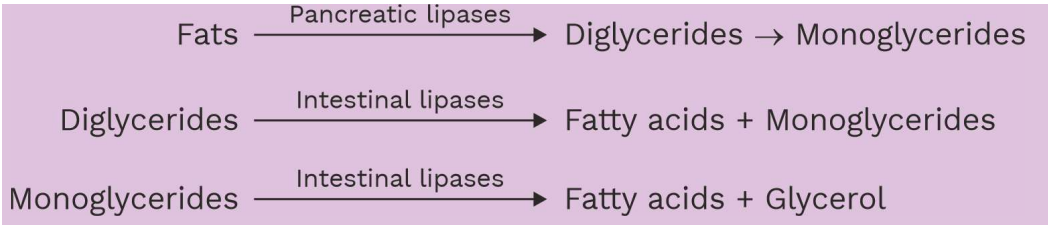


Fig: Emulsified Lipid Droplet



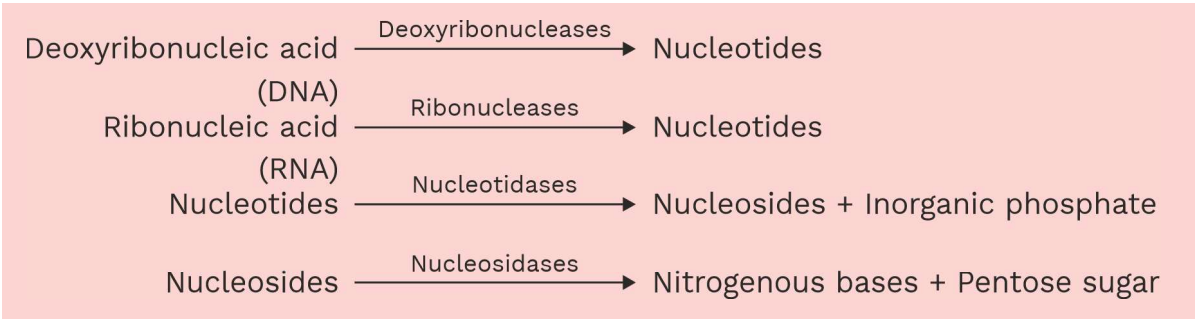
Digestion of Nucleic Acids

The major amount of food consumed by human beings come from either plant or animal source. Both plant and animal cells consist of large quantities of nucleic acids (DNA and RNA).

- **Digestion of Nucleic acids in the Small Intestine**
  - Hydrolysis of DNA and RNA begins only in the small intestine under the action of nucleases present in the pancreatic and intestinal juice.
  - Pancreatic deoxyribonuclease **(DNase)** and ribonuclease **(RNase)** convert DNA and RNA into deoxyribonucleotides and ribonucleotides respectively.
  - Further, the intestinal **nucleotidases** hydrolyses nucleotides into nucleosides and inorganic phosphate.
  - Intestinal **nucleosidases** then break down nucleosides into nitrogenous bases and pentose sugar.

Previous Year's Question

Fatty substances are emulsified by
(1) Lipase enzyme
(2) Bilirubin and biliverdin
(3) HCl
(4) Sodium salts of glycocholic acid and taurocholic acid



GASTROINTESTINAL HORMONES IN DIGESTION

- **Gastrin**
  - It is secreted by the **G-cells** of the antrum of the stomach (Pyloric stomach) on stimulation by distension of stomach, products of

Note: The energy released by the digestion of a food component is measured by the amount of heat generated during this process. On combustion of 1 g of food in a bomb calorimeter, the amount of heat energy produced is its gross calorific value. Inside a human body, when 1 g of food is completely oxidized with the help of enzymes, the amount of heat energy released is called its physiological value. Human body is an open system. So complete insulation is not possible. Thus, Physiological value of a food component is lower than its calorific value.

Components of food	**Calorific Value** (kcal/g)	**Physiological Value** (kcal/g)
Carbohydrates	4.1	4.0
Proteins	5.65	4.0
Fats	9.45	9.0

proteins and gastrin-releasing peptide, which is released by vagus nerve stimulation.
  - Its main function is to stimulate the secretion of gastric acid and to stimulate the growth of gastric mucosa.
- **Motilin**
  - It is secreted by upper duodenum during fasting. It increases gastrointestinal motility.
- **Cholecystokinin (CCK)**
  - It is secreted by **'I' cells** present in the inner lining of duodenum and jejunum as a result of response to digestive products of fatty acids, monoglycerides and fats in the contents of intestinal lumen.
  - Its main function is to contract the gall bladder strongly to release bile into the intestine.
- **Secretin**
  - It is secreted by the **'S' cells** of duodenal mucosa because of acidic gastric juice entering in the duodenum.
  - It mildly inhibits the gastrointestinal motility and promotes bicarbonate secretion from pancreas to neutralize the acid of the chyme. Also promotes secretion of Brunner's glands.
- **Vasoactive Intestinal Peptide**
  - Secreted by the small intestine and help in inhibition of gastric acid secretion and dilation of peripheral blood vessels of gut.

Gray Matter Alert!!!

Secretin is the first hormone discovered by scientists.

Previous Year's Question

Pancreatic secretion and gall bladder contraction are stimulated by
(1) Gastrin
(2) Enterocrinin
(3) Enterogasterone
(4) Cholecystokinin pancreozymine

- **Duocrinin**
  - It is also secreted by the duodenal mucosa because of chyme. Its function is to activate Brunner's glands.
- **Enterocrinin**
  - The mucosa of duodenum and jejunum secretes enterocrinin in response to the chyme. It activates crypts of Lieberkuhn.
- **Villikinin**
  - Secreted by the Small intestine, villikinin increases motility of villi.
- **Gastric inhibitory peptide (GIP) or Enterogastrone**
  - It is secreted by the mucosa of Duodenum in response to majorly fatty acid and amino acids and minorly carbohydrates.
  - It causes slow gastric emptying and stimulates insulin secretion.

ABSORPTION OF DIGESTED FOOD

- Absorption of digested food takes place via passive, active or facilitated transport mechanisms.
- Passive mechanisms include simple diffusion of amino acids, some monosaccharides like glucose and some electrolytes like chloride ions based on their concentration gradients.
- Some digestive products like fructose are absorbed with the help of the carrier proteins. This mechanism is called the **facilitated transport.**
- **Active transport** requires energy as it occurs against the concentration gradient. Molecules like glucose and galactose are absorbed into the blood by this mechanism with the help of sodium pumps present in the cell membrane (glucose and galactose are absorbed along with Na^+ ions by active symport (Co-transportation)
- **Absorption in buccal cavity**
  - Buccal cavity does not provide any major contribution in absorption.
  - Only some chemicals and alcohol are

Definition

Absorption: It is the process by which the products of digestion pass through the intestinal mucosal cells (enterocytes) into the blood or lymph.

Previous Year's Question

Which of the following hormone helps in the secretion of HCl from stomach?

(1) Secretin
(2) Gastron
(3) Cholecystokinin
(4) Gastrin

absorbed in buccal cavity.

- **Absorption in stomach**
  - Due to lack of villi containing absorptive surface and tight junctions between epithelial cells, stomach is poor in absorption.
  - However, some lipid-soluble materials like alcohol, water, some monosaccharides (glucose), some salts and few drugs like aspirin are absorbed in the stomach.
- **Absorption in small intestine**
  - **90%** absorption of digested food occurs in the small intestine.
  - From the chyme, water is absorbed by osmosis.
  - About **25-35** grams of sodium is actively absorbed by the intestine each day.
  - In the duodenum and jejunum, chloride ions are readily absorbed by diffusion and bicarbonates by active absorption.
  - Iron, calcium, potassium, magnesium, phosphate and other ions are actively absorbed through the intestinal mucosa.
  - **Maximum absorption** takes place in **jejunum**.
  - Most monosaccharides, amino acids, fatty acids, glycerol and vitamins are absorbed in the small intestine.
  - Vitamin B_{12} is absorbed with Castle's intrinsic factor by complex formation.
- **Absorption in large intestine**
  - In a day, about **5-8** litres of fluid and electrolytes can be absorbed by the large intestine.
  - Proximal one-half of the colon is mainly involved in most of the absorption. Hence, it called an **absorbing colon.** The distal colon principally stores faeces.
  - A large amount of sodium and chloride ions are absorbed actively in the large intestine whereas bicarbonate ions are secreted in exchange in the lumen of the colon. An osmotic

Gray Matter Alert!!!

Presence of folds of Kerckring, villi and microvilli increases the absorptive area of the mucosa of small intestine by about a thousand folds (more than 250 square meters i.e. about the surface area of a tennis court).

Definition

Chyle: Pale yellow fluid containing absorbed fats taken up by the lacteals.

Gray Matter Alert!!!

The formation of monoglycerides and free fatty acids is a highly reversible process. Therefore, they should be removed quickly from the duodenum.

gradient is created across the large intestinal mucosal by the absorption of sodium and chloride ions which in turn causes absorption of water.

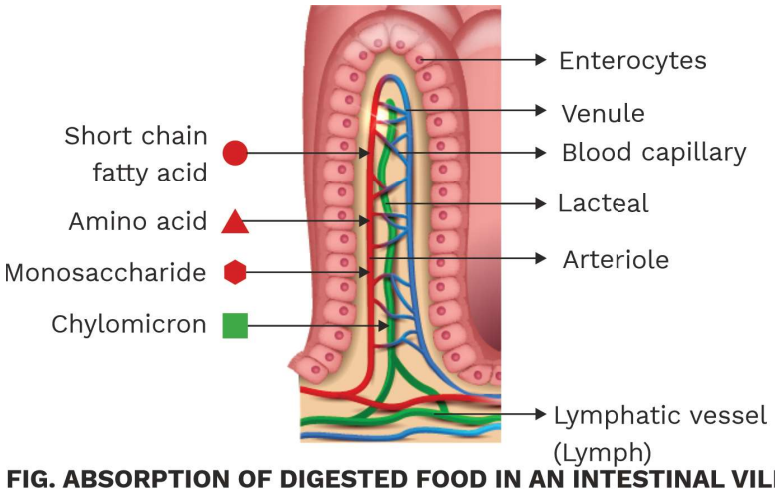


FIG. ABSORPTION OF DIGESTED FOOD IN AN INTESTINAL VILLI

- **Formation of Micelles**
  - About 20-40 molecules of bile salts combine to form micelles which are small, spherical, globules of 3-6 nanometre in diameter. Each bile salt molecule has a highly fat-soluble sterol nucleus carrying the fat-digestate (monoglycerides and free fatty acids) and a highly water-soluble polar groups projecting outwards.
  - The polar groups allow the micelles to be diffused into the enterocytes where the fatty acids and the monoglycerides are taken up by the endoplasmic reticulum to form new triglycerides. These triglycerides combine with proteins to form chylomicrons which move into the lacteals of the villi.

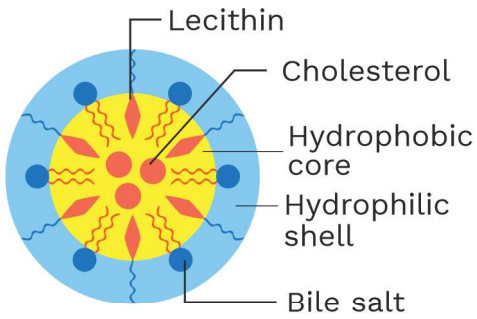


FIG. MICELLE

ABSORPTION OF DIGESTED PRODUCTS			
Products of Digestion	**Site of Absorption**	**Mode of Absorption**	**Capillaries of Villi**
Glucose	Stomach and jejunum	Active transport with Na^+ pump (cotransport)	Blood capillaries
Galactose	Stomach and jejunum	Active transport with Na^+ pump (cotransport)	Blood capillaries
Fructose	Stomach and jejunum	Facilitated transport	Blood capillaries
Amino acid (majorly)	Duodenum and jejunum	Active transport	Blood capillaries
Some amino acids	Duodenum and jejunum	Facilitated diffusion	Blood capillaries
Fatty acids, glycerol, glycerides (micelles)	Jejunum	Simple diffusion	Lymphatic capillaries (lacteals)
Some short chain fatty acids	Jejunum	Simple diffusion	Blood capillaries
Fat soluble vitamins	Jejunum	Simple diffusion	Lymphatic capillaries (lacteals)

Products of Digestion	Site of Absorption	Mode of Absorption	Capillaries of Villi
Water	Stomach, small intestine, large intestine	Osmosis	Blood capillaries
Water soluble vitamins	Jejunum	Simple diffusion	Blood capillaries
Sodium ions	Small intestine	Active transport	Blood capillaries
Calcium ions	Duodenum	Active transport	Blood capillaries
Chloride ions	Duodenum and jejunum	Simple diffusion or active transport	Blood capillaries
Bicarbonate ions	Duodenum, jejunum and large intestine	Active transport	Blood capillaries
Iron	Duodenum	Active transport	Blood capillaries
Bile salts	Ileum	Simple diffusion	Blood capillaries

ASSIMILATION

- Finally, the absorbed substances reach the tissues that utilise them for their activities. This process is assimilation.
- In the cells, amino acids are used for protein synthesis. Excess amino acids are deaminated in the liver. The detached amino groups from the amino acids form ammonia.
- Ammonia is then converted into urea and excreted by the kidneys.
- Glucose is utilised by cells to produce energy during cellular respiration. Excess glucose, fructose and galactose are stored in muscle cells and liver as glycogen.
- Fats are stored in the adipocytes as a future energy reserve.

EGESTION (DEFECATION)

- The discharge of faeces from the alimentary canal is known as egestion or defecation.
- Normally faeces consist of three-fourths water and one-fourth solid matter.
- The solid matter in the faeces is composed of about 30 percent undigested roughage, 30 percent dead bacteria, 10-20 percent inorganic matter, 10-20 percent fat and 2-3 percent protein, bile pigments and discarded epithelial cells.

DISORDERS OF DIGESTIVE SYSTEM

- **Jaundice (icterus)**
  - It is yellowing of the skin and the whites of the eye due to accumulation of bile pigment bilirubin in the blood.
  - Bilirubin from the blood reaches the liver where it gets mixed with the bile and leaves the body along with faeces.
  - During liver malfunctioning, excess bilirubin leaks into the tissues leading to hyperbilirubinemia which gives yellow colour to the skin and eyes.

Gray Matter Alert!!!

- **Flatus:** Gases in the gastrointestinal tract are collectively called flatus. Presence of flatus in the digestive tract is due to swallowed air, gases because of bacterial action in the large intestine and gases diffused into the gastrointestinal tract from the blood. Much of the swallowed air is released by belching or eructation (burping). The expulsion of excess gases of the large intestine from the anus is called flatulence or farting.

Gray Matter Alert!!!

The brown colour of the faeces is due to the presence of stercobilin and urobilin, derivatives of bilirubin.

- **Vomiting (emesis)**
  - It is the forceful ejection of gastrointestinal contents through the mouth. This reflex action is regulated by two centres of vomiting in the medulla oblongata.
  - Nausea and retching precede vomiting.
- **Diarrhoea**
  - The abnormally rapid frequency of bowel movement and increased liquidity of the faecal content is known as diarrhoea. It lowers down the absorption of food. It is caused due to increased motility of the intestinal wall due to:
    - Inflammation of the intestine (infectious diarrhoea).
    - Extensive inflammation and ulceration of colon walls (ulcerative colitis).
- **Constipation**
  - In constipation, the faeces are retained within the colon and rectum as the bowel movements takes place irregularly.
  - Causes of constipation include a practice of inhibition of normal defecation reflexes, spasms of sigmoid colon, inadequate fibre consumption, stress, lack of exercise, less water intake, tumours, etc.
- **Indigestion**
  - The food is not properly digested leading to a feeling of fullness during such condition.
  - The causes of indigestion are inadequate enzyme secretion, anxiety, food poisoning, overeating, and spicy food.
- **Protein Energy Malnutrition (PEM)**
  - Malnutrition is an inadequate amount of nutrients received by a body. Lack of protein and/or calories in diet is the main cause of PEM. Protein Energy Malnutrition can be classified into two types: Kwashiorkor and Marasmus.

Definition

- **Nausea:** An unpleasant feeling to vomit.
- **Retching:** Strong involuntary contractions of diaphragm, abdominal muscles and thoracic wall without any expulsion of gastrointestinal contents.

Rack your Brain

Why do most people experience nausea and vomiting during travelling in the mountains?

Definitions

- **Diarrhoea:** Bacterial infection of the small intestine. It is characterised by watery stool. The stool does not have much foul smell.
- **Dysentery:** Amoebic infection of the large intestine. It is characterised by semi-solid stool. The stool has too much foul smell.

PROTEIN ENERGY MALNUTRITION (PEM)	
Kwashiorkor	**Marasmus**
• Occur in children more than one year of age	Occur in children below one year of age
• Deficiency of proteins only	Deficiency of both protein and calories both
• Extensive peripheral oedema	No oedema
• Subcutaneous fat reduced but is still present	Subcutaneous fat disappears
• Wasting of muscles and thinning of limbs occur	Extreme emaciation of body and thinning of limbs occur
• Skin appears to be swollen	Skin is dry and wrinkled
• Underweight children	Severely emaciated
• Common occurrence of fatty liver	Occurrence of fatty liver uncommon
• Sparse hair	No change in hair

VITAMINS

- Vitamins are organic molecules and essential micronutrients that an organism needs in small quantities for the proper functioning of its metabolism and growth.
- Earliest extracted vitamin is Vitamin B_1 from unpolished rice (1912).
- The term 'Vitamin' was given by Funk.

Previous Year's Question

Continuous bleeding from an injured part of the body is due to the deficiency of
(1) Vitamin A
(2) Vitamin B
(3) Vitamin K
(4) Vitamin E

MAJOR DIETARY VITAMINS					
Vitamin	**Common name**	**Source**	**Deficiency disease**	**Symptoms**	**Functions**
K	Menadione/ Phylloquinone	Leafy vegetables, soyabean oil and intestinal bacteria	Abnormally high bleeding	Slow or delayed coagulation	Synthesis of prothrombin which is required for normal coagulation. Present in intestinal bacteria
E	Tocopherol/ Antisterility/ Beauty Vitamin	Leafy vegetables, cereals and vegetable oils	Macrocytic anaemia, muscular dystrophy	Destruction of RBC (haemolytic anaemia)	Antioxidant and plays an important role in ETS, metabolism of selenium, formation of RNA, DNA and RBC
D	Calciferol	Fish oil, liver, egg yolk, milk	Rickets in children and osteomalacia in adults	Fragile bones contorted skeleton and poor muscular development	Promotes absorption of calcium and phosphorous in intestine
A	Retinol	Yellow and green vegetables, fruits, milk and butter	Nightblindness (nyctalopia) xerophthalmia, dermatitis	Keratinisation of mucous in membranes e.g. respiratory tract, urinogenital tract and skin	Growth, prevent keratinisation of epithelia
H	Biotin/ Vitamin B	Vegetables and fresh fruits, liver, milk, eggs	Dermatitis	Scaly skin, Muscle pain and weakness	Coenzyme in synthesis of fatty acid convention of pyruvate into OAA
C	Ascorbic Acid	Amla, citrus fruits, tomatoes	Scurvy, anaemia, joint pain	Bleeding in gums, loose teeth, anaemia and swollen and painful joints	Helps in formation of collagen, in adrenal gland's working as an antioxidant, in erythropoiesis, absorption of Ca^{+2} and Fe^{+2}

Vitamin	Common name	Source	Deficiency disease	Symptoms	Functions
B_1	Thiamine	Wheat, gram, peanuts, yeast, beans	Beri-Beri/ Polyneuritis/ Cardio vascular atrophy	Loss of appetite, fatigue, muscular atrophy, paralysis, cardiomegaly	Form coenzymes in carbohydrate metabolism and help in pentose metabolism
B_2	Riboflavin vitamin-G or yellow enzyme	Yeast, liver, milk, cheese, leafy vegetables and intestinal bacteria	Cheilosis, glossitis, keratitis	Inflammation of eyes and lip sores	Part of coenzymes (FMN and FAD) in ETS
B_3	Niacin/Vitamin 4-D/PP-Factor	Yeast, gram, peanuts and meat	Pellagra, diarrhoea, dermatitis, dementia, death (4-D syndrome)	Scaly skin, dehydration, loss memory	Part of coenzymes NAD and NADP that acts as H_2 acceptors and acts as donors for functioning of nervous system and gastro - intestinal tract
B_5	Pantothenic acid, yeast factor	Yeast, peas, liver, max. in wheat, honey	Burning feet syndrome	Abnormal functioning of adrenal degeneration	Part of coenzyme A in cell respiration, needed for neural tissue, formation of acetylcholine, required for normal functioning of adrenal gland
B_6	Pyridoxine	Meat, milk, wheat, liver, banana	Nausea and vomiting	Lesions over skin, disorders of central neural system, convulsions	Part of coenzymes pyridoxal phosphate needed in the formation of amino acids and glycogen
B_9	Folic acid or folacin or vitamin M	Liver, green vegetables, banana and oranges	Macrocytic anaemia	Malfunctioning of antibody synthesis and stunted growth, ulceration in mouth	Part of coenzymes in nucleic acid (Purine and pyrimidine) synthesis and protein synthesis, erythropoiesis, cell division in bone marrow

Vitamin	Common name	Source	Deficiency disease	Symptoms	Functions
B_{12}	Cyanocobala-mine	Liver and eggs	Pernicious anaemia/ megaloblastic anaemia	Abnormally large and immature RBCs with Hb but lacks nucleus	Coenzymes for nucleic acid synthesis

MINERALS

- Minerals are classified as macrominerals and microminerals based on thier requirement in the body.
- Macrominerals are importanat in diet, whereas micronutrients are needed only in minute quantities.

Gray Matter Alert!!!

Nature's most potent antioxidant is vitamin E, which is maximum in liver. Vitamin B_{12} is absent in plants. It is considered that *Spirulina* (an alga) contains B_{12}.

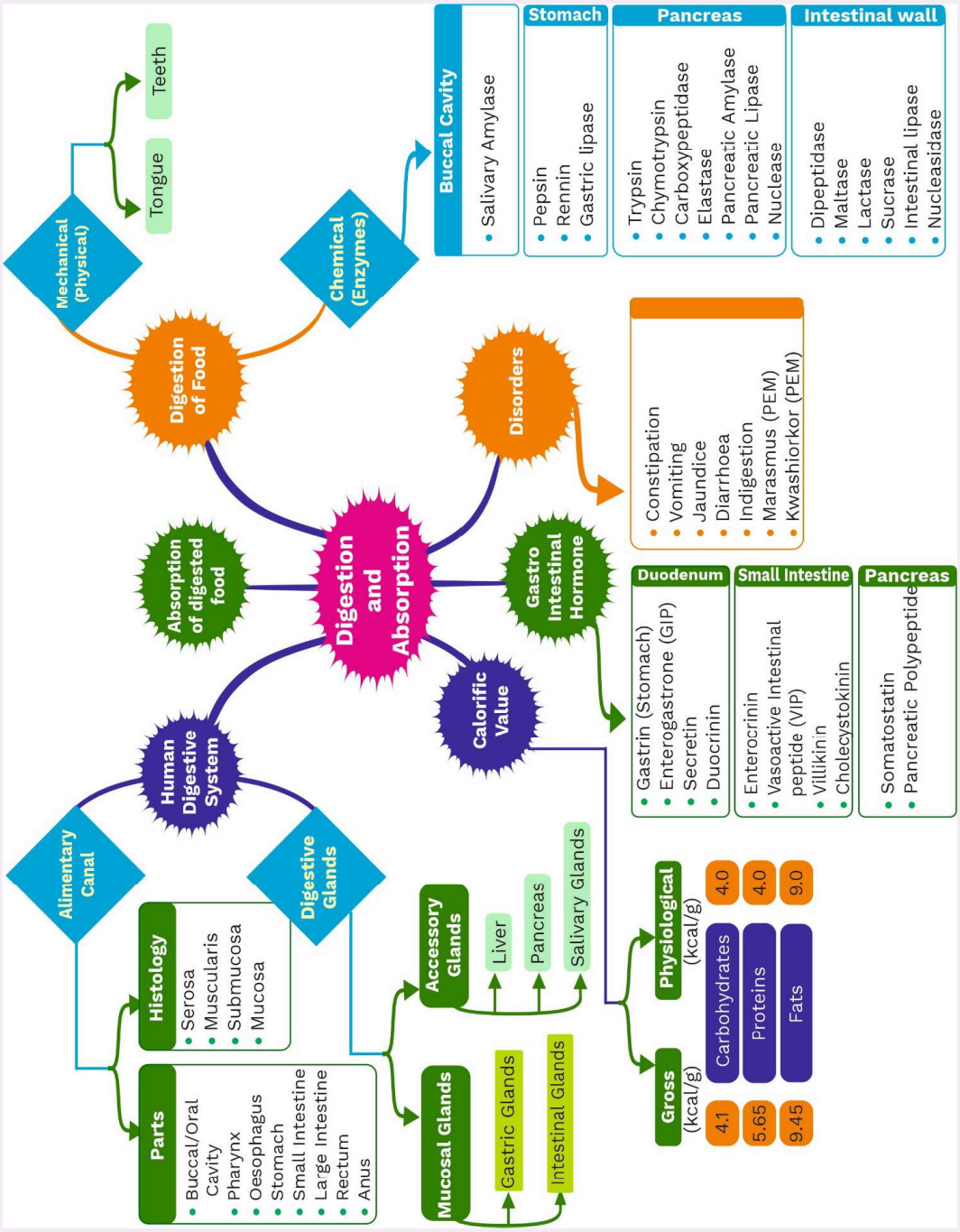
SOME IMPORTANT MINERALS, THEIR DEFICIENCY DISORDERS AND FUNCTIONS

Mineral	Effect of Deficiency	Functions
Calcium	Rickets, muscular spasm (Vitamin D is also required)	Element of bone and teeth; important for coagulation; needed for normal functioning of muscle, nerve and heart (vitamin D is also required).
Chlorine	Anorexia, muscular cramp	Main anion of interstitial fluid; Important in the formation of HCl and maintaining acid-base balance.
Magnesium	Muscular convulsion in intestine	Enzyme activator, required in muscle relaxation, ribosome binding and nerve function
Potassium	Rickets, risk of paralysis	Main cation in the cytoplasm; controls nerve excitability and muscle contraction, Dietary deficiency causes rickets among children.

Mineral	Effect of Deficiency	Functions
Sodium	Muscular cramps, hypotension and anorexia	Main cation in interstitial fluid; maintains fluid balance; important for conduction of nerve impulse. Element of bile salt, promotes absorption of glucose, fructose and few amino acids.
Phosphorus	Malformation of bone and teeth, ceased body growth and physiological function	Important structural component of bones, DNA and RNA; essential in energy transfer, storage of energy (ATP) and other metabolic activities; maintains normal blood pH (buffer action)
Sulphur	Skin patches, disturb metabolism	Components of hormones (e.g. insulin): needed for normal metabolism and present in amino acid like methionine, cysteine.
Trace Elements		
Zinc	Weak immunity and fertility, Retarded growth and Anorexia	Part of at least 70 enzymes e.g. carbonic anhydrase, and some peptidases.
Copper	Anaemia and damage of CNS	Part of enzymes for melanin synthesis; Essential for haemoglobin synthesis. Component of cyt-a_3 in ETS (Cytochrome oxidase).
Cobalt	Pernicious anaemia	Component of Vitamin B_{12} and erythropoiesis.

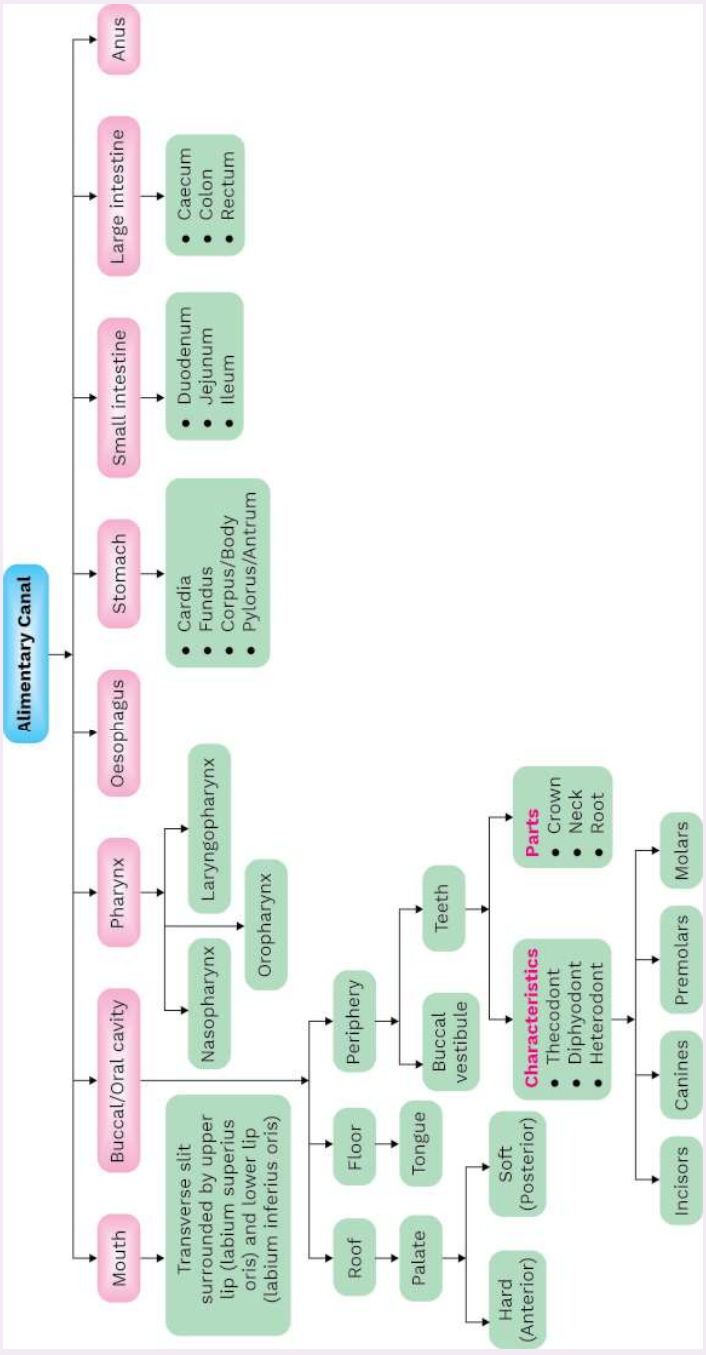
Mineral	Effect of Deficiency	Functions
Chromium	Diabetes mellitus and irregular production of ATP	Normal activity of insulin, carbohydrate and lipid metabolism
Selenium	Infertility in male, prostate gland cancer, necrosis in liver and muscular dystrophy	Antioxidant, promotes sperm motility, therefore, it is required for male fertility, synthesis of thyroid hormone
Fluorine	Dental fluorosis and deformity in bones (Hunchback)	Maintains enamel and prevents dental decay formation of flourapeptite, Antibacterial
Manganese	Irregular growth of bone, cartilage, connective tissue, anaemia	Working of lipase enzyme, formation of urea, required for haemoglobin synthesis, releases insulin, lactation, bone formation.
Molybdenum	Irregular excretion of nitrogenous waste	Co-factor in some enzyme, formation of ascorbic acid.
Iodine	Goitre, abortion, infant death, cretinism	Component of thyroid hormone
Iron	Anaemia, weak immunity	Components of respiratory pigments (like haemoglobin and myoglobin), respiratory enzymes (like cytochromes) and oxygen transport enzymes.

Summary



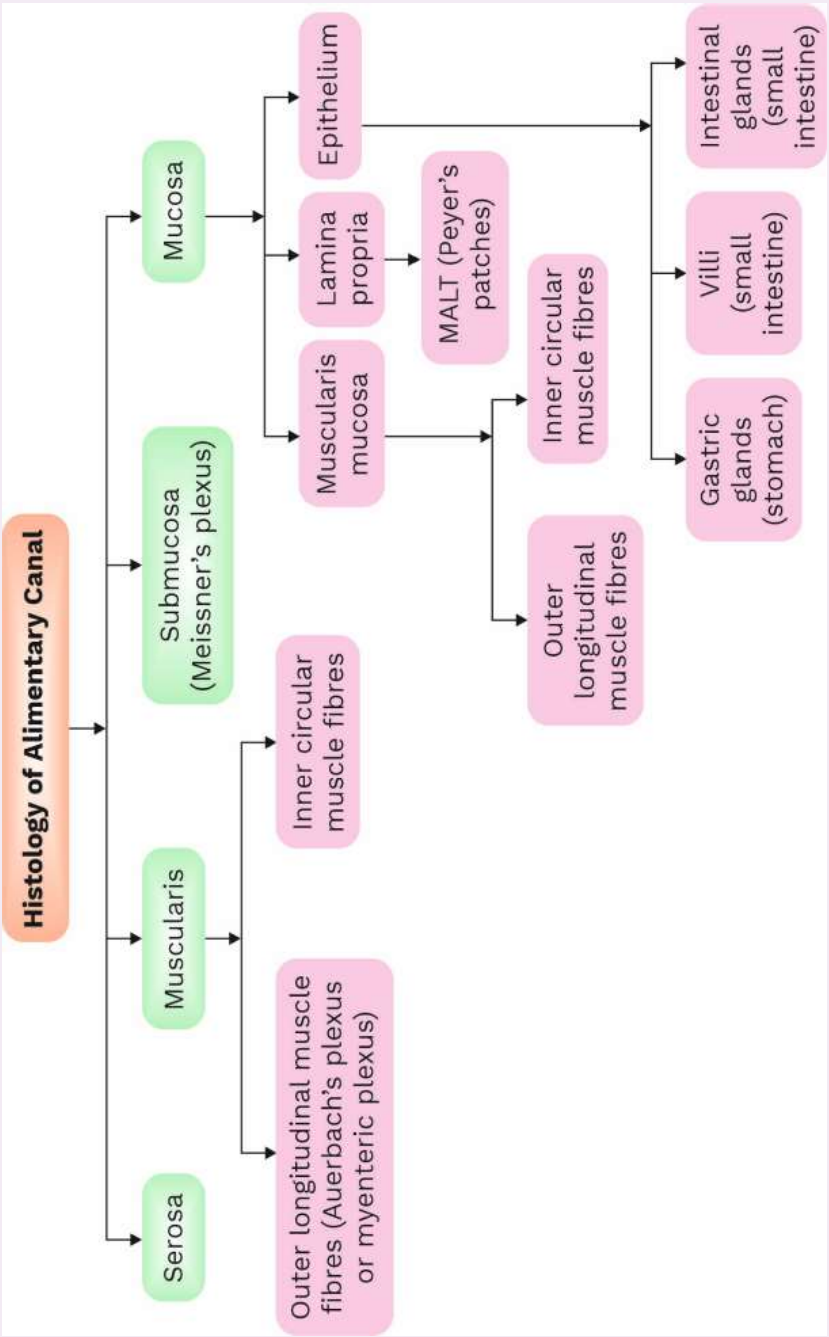
Digestion and Absorption

Summary



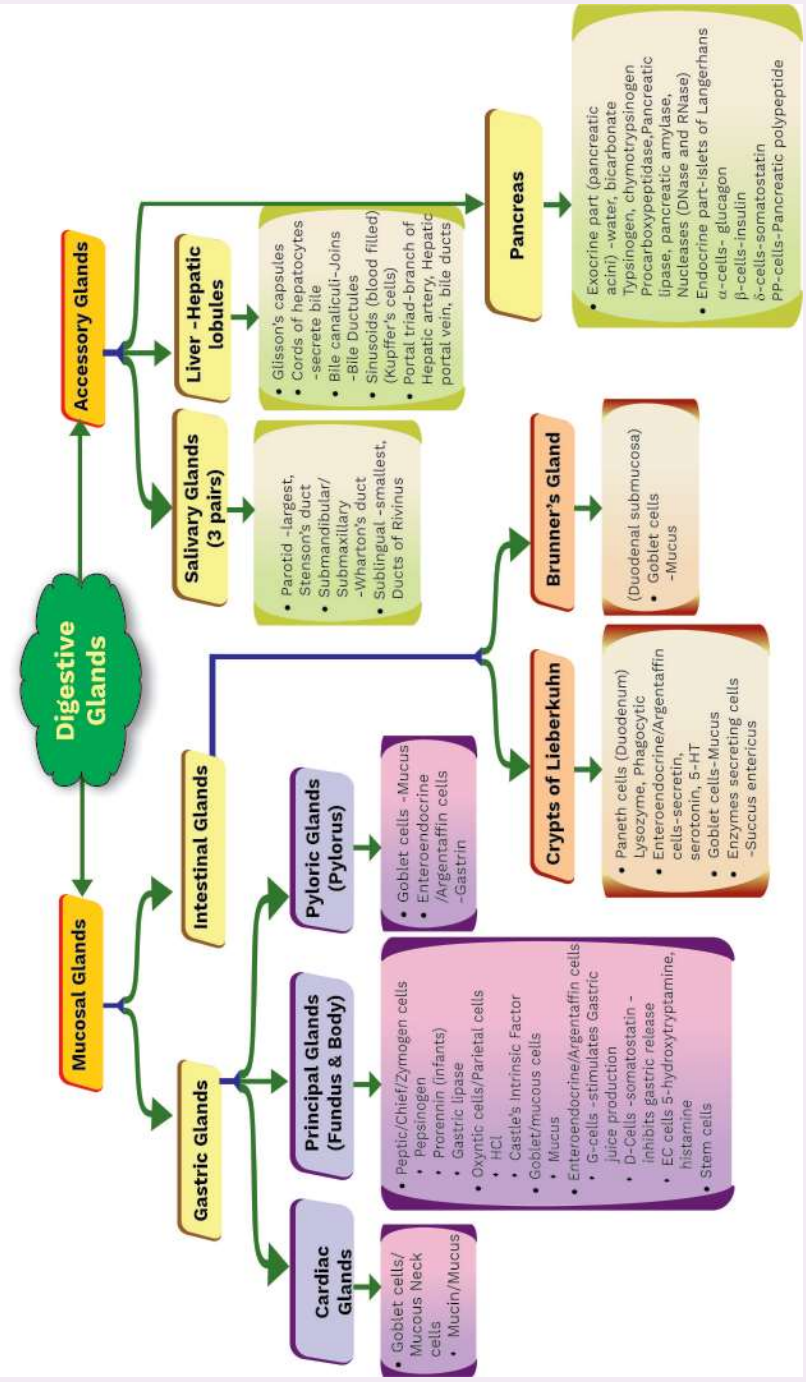
Alimentary Canal

Summary



Histology of Alimentary Canal

Summary



Digestive Glands

Role of Enzymes in Alimentary Canal

Digestive Enzyme	Source	Site of Action	Food Component	Products of Digestion
Salivary amylase or ptyalin	Salivary juice (salivary glands)	Oral Cavity	Starch	Limit dextrins, maltose and isomaltose
Pepsinogen (inactive) Pepsin (active)	Gastric juice (stomach)	Stomach	Proteins	Peptones, proteoses and large peptides
Pancreatic α-amylase	Pancreatic juice (pancreas)	Small intestine (duodenum)	Starch	Limit dextrins, maltose and isomaltose
Trypsinogen (inactive) Trypsin (active)		Small intestine (duodenum)	Proteins	Dipeptides
Chymotrypsinogen (inactive) Chymotrypsin (active)		Small intestine (duodenum)	Peptones	Dipeptides
Proelastase (inactive) Elastase (active)		Small intestine (duodenum)	Elastin	Dipeptides
Procarboxypeptidase (inactive) Carboxypeptidase (active)		Small intestine (duodenum)	Proteoses	Dipeptides
Pancreatic Lipase		Small intestine (duodenum)	Triglycerides	Fatty acids and glycerol
Nucleases		Small intestine (duodenum)	Nucleic acids	Nucleotides

Digestive Enzyme	Source	Site of Action	Food Component	Products of Digestion
Erepsin (exopeptidases)	Intestinal juice (small intestine)	Jejunum	Oligopeptides and dipeptidases	Amino acids
Intestinal lipase		Jejunum	Fats, glycerides	Fatty acids and glycerol
Intestinal amylase		Jejunum	Polysaccha-rides	Limit dextrins, disaccharides
Limit dextrinase		Jejunum	Limit dextrins	Glucose
Disaccharidases		Jejunum	Disaccharides	Monosaccha-rides
Nucleotidase		Jejunum	Nucleotides	Nucleosides and phos-phoric acid
Nucleosidase		Jejunum	Nucleosides	Pentose sug-ars, Nitrog-enous bases (purines and pyrimidines)

SOLVED EXERCISE

Q1 **Which of the following substances is not absorbed in jejunum?**
(1) Amino acids (2) Vitamin B_{12} (3) Fat soluble vitamins (4) Glucose

A1 **(2)**
Monosaccharides, amino acids, fatty acids, glycerol, vitamins, water etc., are absorbed in jejunum. Vitamin B_{12}, bile salts, water are absorbed in ileum.

Q2 **Which of the following does not produce any digestive enzyme?**
(1) Acini of pancreas (2) Liver (3) Stomach (4) Duodenum

A2 **(2)**
Liver produces bile. There is no digestive enzyme secreted along with bile.

Q3 **Select the correct statement regarding digestion of boiled potatoes by humans.**
(1) Cellulose will be digested by cellulase
(2) Starch will not be digested
(3) Lactase will digest carbohydrates
(4) DNA will be digested by pancreatic enzymes

A3 **(4)**
- Cellulose in boiled potatoes is not digested by humans as their body is devoid of enzyme cellulase.
- Salivary amylase and pancreatic amylase will digest starch present in boiled potatoes into maltose (in mouth) and glucose (in duodenum).
- Lactose is milk sugar. Boiled potatoes do not contain lactose.
- Pancreatic enzymes contain nucleases (RNase and DNase). They digest the DNA present in the potato cells (plant cells).

Q4 **In human beings, which of the following pairs of teeth appear twice in life?**
(1) Canines and First Molars (2) Third Molars and First Premolars
(3) First Premolars and Second Molars
(4) Second Incisors and Second Premolars

A4 **(1)**
In human beings, except the premolars and last molars all types of teeth appear twice in life.

Q5 **A person is passing whitish-gray faecal matter, what is not functioning properly in the body?**
(1) Kidney (2) Liver (3) Spleen (4) Pancreas

A5 **(2)**
Liver secretes bile in the duodenum. Bile contains bile salts (sodium bicarbonate, sodium glycocholate, sodium taurocholate) and bile pigments (bilirubin and biliverdin) due to which faeces has its usual colour. Whitish-gray faecal matter usually means that these bile salts and pigments are absent in the faeces. This could be caused by improper functioning of liver.

Q6 **During prolonged fasting**
(1) First, fats are used up followed by carbohydrates from liver and muscles, and protein in the end.
(2) First, carbohydrates are used up followed by fats and proteins towards the end.
(3) First, lipids are used up followed by proteins and carbohydrates towards the end.
(4) None of the above.

A6 **(4)**
After prolonged fasting, firstly glucose and glycogen which are stored in the body are used up. The body then derives energy by burning stored fats in the adipocytes. When maximum fat storage is used up, then the body digests vital proteins.

Q7 **The cells of pancreas are not autodigested by their enzymes as**
(1) Cells are covered by mucous
(2) Enzymes are produced only when required
(3) Enzymes do not have coenzymes
(4) Enzymes are secreted in inactive form

A7 **(4)**
The enzymes secreted by pancreatic cells are inactive. They become active in the duodenum.

Q8 **Select the incorrect statement about gastrointestinal hormones?**
(1) The growth of gastric mucosa is stimulated by gastrin hormone.
(2) Secretin hormone promotes the secretion of bicarbonates from the pancreatic cells.
(3) Brunner's glands are activated by duocrinin hormone.
(4) Enterogastrone hormone increases the gastric emptying.

A8 **(4)**
Enterogastrone or Gastric Inhibitory Peptide (GIP) hormone inhibits the gastric secretion and motility.

Q9 **Which statement about nutrient absorption by the enterocytes is true?**
(1) Carbohydrates are absorbed as disaccharides.
(2) Fats are absorbed passively as fatty acids and monoglycerides.
(3) Amino acids move across the plasma membrane only by diffusion.
(4) Fructose is absorbed by facilitated transport.

A9 **(4)**
- All carbohydrates are absorbed in the form of monosaccharides in stomach and jejunum.
- Fatty acid and glycerol are absorbed via simple diffusion.
- Amino acids are absorbed by active transport and some amino acids are absorbed by facilitated transport. It occurs mainly in the duodenum and jejunum.
- Fructose is absorbed by facilitated transport.

Q10 **The following are absent in the case of upper one-third part of oesophagus, except**

(1) Visceral peritoneum (Serosa) **(2) Digestive gland**

(3) Myenteric plexus **(4) Skeletal muscles**

A10 **(4)**

Since oesophagus lies outside the coelom, its outer wall is not covered by peritoneum.

In upper one-third of the oesophagus both Auerbach and Meissner's plexuses are absent.

No digestion takes place in the oesophagus, as digestive glands are absent in oesophagus.