# ANIMAL NUTRITION

## INTRODUCTION

Animals are not able to synthesise their own food, therefore they depend on ready-made food for their nutritional requirements. The term nutrition refers to the sum total of all the processes related with the conversion of the raw foodstuff into the stuff of the body to supply energy for different metabolic activities and also for the repair and growth. In other word we can define nutrition as the process by which an organism derives energy to work and other materials, required for growth and maintenance of the various activities of life.

**Food intake :** Different organisms obtain food in different ways but carry out similar chemical reactions to utilize it. To take food, protozoans use pseudopodia, flagella or cilia; sponges and mussels, a current of water; Hydra, tentacles beset with stinging cells; planarians and earthworms, a muscular pharynx; flukes and leeches, oral sucker; insects and other arthropods, mouth parts of various kinds; and seastars and sea urchins, tubefeet. Sharks capture prey with the jaws; frog and lizard with the tongue; birds with beaks of sorts; rabbit and hare use forepaws, lips and teeth; cattle, lips and teeth; carnivores, claws and teeth; giraffes, tongue; elephants, proboscis (trunk); humans, monkeys and apes use hands.

## 3.1 DIGESTION

The process by which complex food is converted into simplest food with the help of digestive enzymes (Hydrolytic enzymes), hence process of digestion is a hydrolytic process.

**Types of digestion**

(i) **Intracellular :** When the process of digestion occurs within the cell in the food vacuole. Examples : Protozoa, Porifera, Coelenterata and free living platyhelminthes. With the help of lysosomal enzymes. Food particle is taken in through endocytosis (phagocytosis). It forms a phagosome which fuses with a lysosome. Digestion occurs and the digested materials are passed on to cytoplasm. The undigested materials is thrown out by exocytosis.

(ii) **Extracellular :** When the process of digestion occurs outside the cell. Examples : Coelenterates and phylum platyhelminthes to phylum chordata. Therefore, coelenterata and free living platyhelminthes (flat worms) perform both intracellular and extracellular digestion.

## 3.2 DIGESTIVE SYSTEM OF HUMAN

Digestion in vertebrates occurs in the digestive tract or alimentary canal. The various parts involved in digestion can be broadly grouped in two groups –

(i) **Digestive tract or alimentary canal**

(ii) **Digestive glands**

(i) **Digestive tract or alimentary canal**

**On the basis of the embryonic origin, the alimentary canal of vertebrates can be divided into three parts** –

(a) **Fore gut / Stomodaeum :** Ectodermal. It includes buccal cavity / oral cavity.

(b) **Mid gut / Mesodaeum :** Endodermal. It includes pharynx, oesophagus, stomach, small intestine, and large intestine.

(c) **Hind gut / Proctodaeum :** Ectodermal. It includes anal canal and anus.

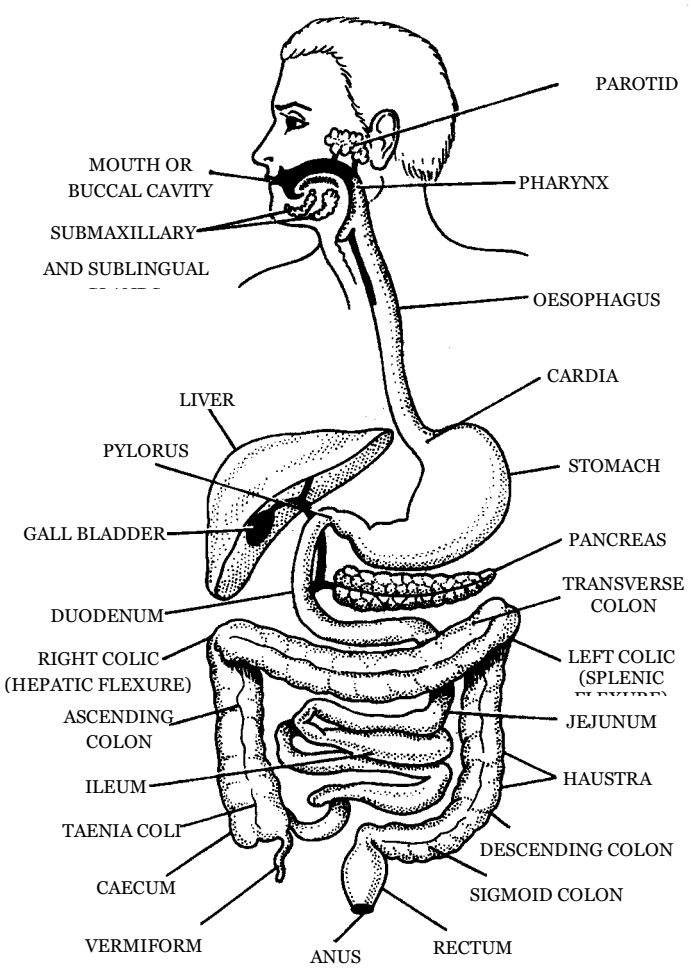



***Fig. – Alimentary canal of man***

**Parts of alimentary canal and its histology**

(a) Mouth

(b) Vestibule

(c) Bucco-pharyngeal cavity

(d) Oesophagus

(e) Stomach

(f) Small intestine consist of duodenum, jejunum, lleum

(g) Large intestine consist of caecum, colon, rectum

(h) Anal canal and anus

(i) Generalized histology of alimentary canal

(a) **Mouth :** The mouth is a transverse slit bounded by two movable lips or labia, upper lip and lower lip. Upper lip has small ridges on the sides, a tubercle in the middle and a vertical groove (philtrum) above.

(b) **Vestibule :** It is a narrow space between lips and gums in front and gums and cheeks on the sides. Its lining contains mucous glands. In the vestibule, a small median fold of mucous membrane, the superior labial frenulum, connects the middle of the upper lip to the gum and usually a similar but smaller inferior labial frenulum connects the middle of the lower lip to the gum.

(c) **Buccopharyngeal cavity :** It includes anterior buccal cavity lined by stratified squamous epithelial cell and posterior pharyngeal cavity lined by columnar epithelial cell. It is distinguished into three region. Pharynx is a vertical canal beyond the soft palate. The food and air passages cross here. Pharynx may be divided into three parts.

| Nasopharynx | Oropharynx | Laryngopharynx |
|---|---|---|
| Upper part of pharynx. | Middle part of pharynx. | Lower part of pharynx. |
| Lined by pseudostratified columnar epithelium | Lined by stratified squamous epithelium. | Lined by columnar epithelium. |
| It has internal nares in the roof, a pair of openings of the eustachian tube on the sides leading to middle ear. | Oral cavity open to it. | It lead to oesophagus behind and larynx in front. |
| Lymphoid Pharyngeal tonsil (Adenoid) in the back wall of Nasopharynx. | Lymphoid palatine tonsil lies on either side of the oropharynx between two vertical folds. | Opening of oesophagus is called gullet and opening of larynx is called glottis. A cartilagenous flap epiglottis present in the front of glottis. |

The various structure present in buccopharyngeal cavity are as follows –

(a) **Fauces :** A triangular area present between buccal cavity and pharynx in human.

(2) **Palate :** The roof of buccal cavity is called Palate. In crocodiles and mammals horizontal shelf like processes of premaxilla and maxilla and the palatine bones of upper jaw fused and form a secondary palate. Which separates the buccal cavity from nasal cavity. Palate is distinguished into three regions –

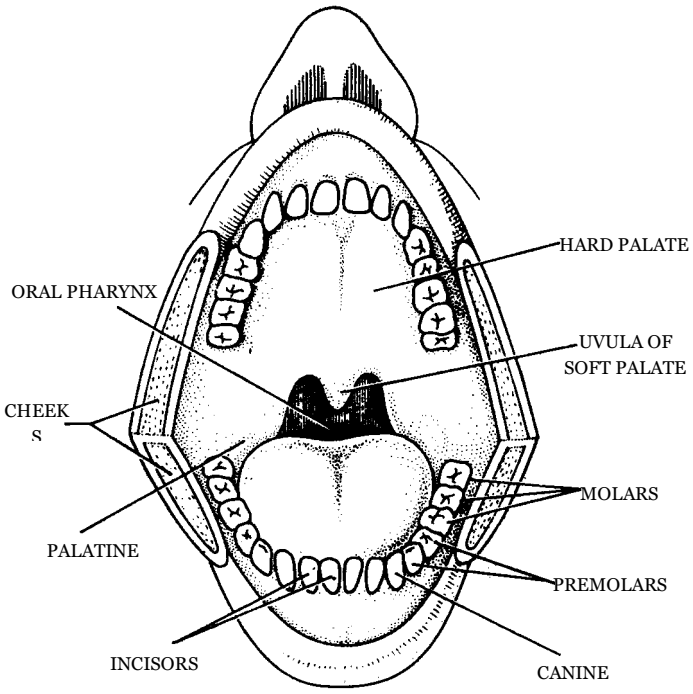



***Fig. – The mouth and permanent dentition of a man***

(i) **Hard palate :** Anterior, bony portion formed of maxilla and palatine bones in human and premaxilla, maxilla and palatine bones in rabbit. Hard palate have transverse ridges called palatine rugae Such rugae or ridges are more develop in carnivorous mammals because their function is to firmly grip the food and prevent it from slipping out the cavity.

(ii) **Soft palate :** Posterior soft part, made up of connective tissue and muscles.

(iii) **Vellum palate/uvula :** Part of soft palate, which hangs in the region of pharynx. It closes the internal nostrils during degglutition.

(3) **Palatine glands :** Numerous mucous glands. Chiefly present in soft palate, secretes mucous for lubrication.

(4) **Naso-palatine duct :** One pair, present in rabbit, extends from nasal passage to the buccal passage, contains Jacobson's organ concerned with olfaction.

(5) **Vibrissae :** A tuft of hairs on upper lip of rabbit.

(6) **Hare-cleft :** A cleft on the upper lip of rabbit, which makes it bilobed.

(7) **Tongue (lingua) :** Ectodermal, single, pinkish, oval, elongated highly muscular (mesodermal) and protrusible present on the floor of buccopharyngeal cavity the cells present are stratified squamous epithelial cells. A furrow termed the sulcus terminalis divides the oral part and pharyngeal part of the tongue. The limbs of the sulcus terminalis run laterally and forward from a median pit, named the foramen caecum.

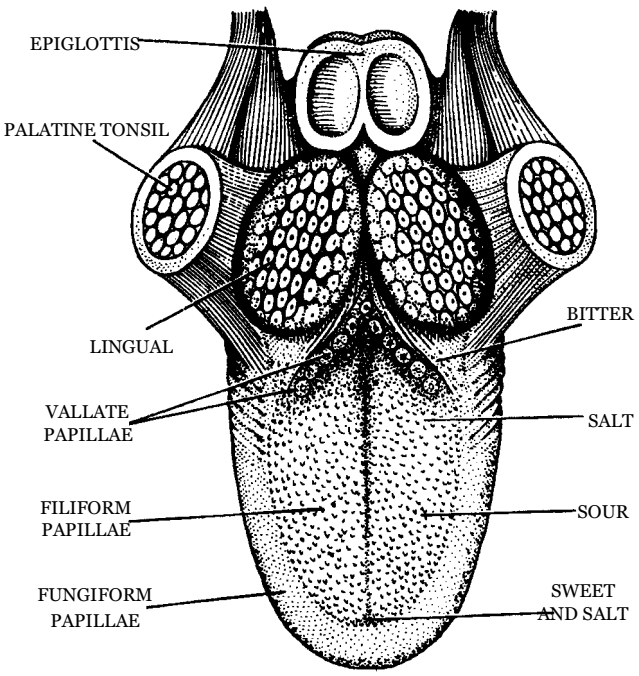



***Fig. – Locations of papillae and areas of taste on the tongue***

Posterior part of tongue (endodermal) is attached with hyoid, middle one with the floor of buccopharyngeal cavity with the help of frenulum lingum and anterior part is free. The tongue is provided with two specialized structure viz. lingual papillae and lingual glands or weber's gland. Lingual glands are the mucous glands, which secretes mucous. Lingual papillae are numerous, minute projections chiefly present on the dorsum of the tongue. All these lingual papillae can be grouped as simple lingual papillae and taste papillae. Taste papillae are of following types –

(i) **Circumvallate :** Circular largest 8-12 in number, present in the posterior part of the tongue extending from one side to another. They possess taste buds. These are the largest of all the papillae.

(ii) **Fungiform :** Mushroom shaped (Fungi – shaped), numerous, present at the anterior margins and tip of the tongue. They have taste buds.

(iii) **Foliate :** Leaf like flat, less in number, present at the posterior margin of the tongue. They are absent/vestigeal in human.

(iv) **Filliform :** Conical shaped, smallest and most numerous distributed throughout tongue. They are without taste buds.

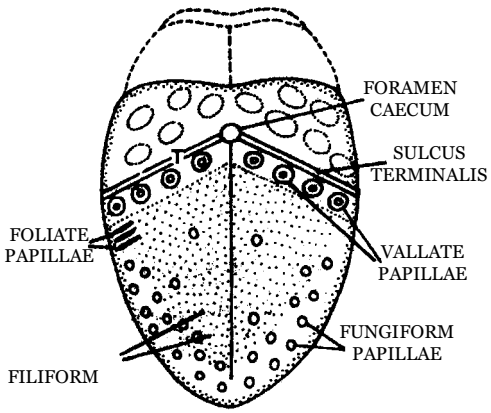



***Fig. – Dorsal surface of human tongue, showing four kinds of papillae and some other associated structures***

Hence, in human taste is recognized with the help of circumvallate and fungiform taste papillae. In man the anterior end of tongue feels sweet taste, posterior part feel bitter taste, sides feel sour taste and a small part behind the anterior end feel salty taste.

**Functions of tongue :** Important function of tongue are as follows –

(i) Acts as universal toothbrush, as it helps in tooth cleaning.

(ii) Helps in speaking.

(iii) Helps in degglutition.

(iv) Helps in mixing saliva with food.

(v) Acts as a curry comb in many animals, hence help in body cleaning.

(vi) Helps in taste detection.

(vii) In dog helps in regulation of body temperature. The phenomenon is called as "Panting".

(viii) In frog and other animals, it helps in prey capturing

(8) **Teeth :** Teeth is a living structure.

(i) **On the basis of embryonic origin, teeth in vertebrates are of following two types –**

(a) **Horny/ectodermal/epidermal/false teeth :** The teeth which develops only from ectoderm. Examples – Cyclostomes, tadpole larva of frog, prototherian mammals etc.

(b) **True teeth :** The teeth which develops from both ectoderm and mesoderm. Examples – Fishes, amphibians, reptiles, eutherian mammals etc.

(ii) **Differentiation of teeth :** Morphologically, teeth can be distinguished as homodont or heterodont.

(a) **Homodont :** When all the teeth are structurally and functionally similar. Examples – Vertebrates except metatherian and eutherian mammals.

(b) **Heterodont :** When the teeth are different in structure and functions. They are distinguished into four types incisors, canines, premolars and molars. Examples – metatherian and eutherian mammals.

(1) **Incisors :** These are the front teeth borne by the premaxillae in upper jaw and tips of dentaries in lower jaw. They are single-rooted monocuspid and long, curved and sharp-edged. They are adapted for cutting or cropping and biting.

(2) **Canines :** There is one pointed canine in each maxillary of upper jaw and each dentary of lower jaw next to the incisors. They are meant for piercing, tearing and offence and defence. They are single rooted and monocuspid.

(3) **Premolars :** They have two roots and two cusps (bicuspid). They are meant for crushing, grinding and chewing.

(4) **Molars :** They have more than two roots and 4-5 cuspid.

(iii) **Attachment of teeth :** On the basis of attachment of teeth at their bases with the jaw bones, teeth can be differentiated into –

(a) **Acrodont :** Teeth are attached to the free surface or summit of the jaw bone, as in a shark or frog. Such teeth are apt to break off easily but are replaced.

(b) **Pleurodont :** In this condition, common in urodeles and lizards, teeth are attached to the inner side of jaw bone by their base as well as one side.

(c) **Thecodont :** Such teeth are characteristic of mammals. Teeth have well developed roots implanted in deep individual pits or socketes called alveoli or theca, in the jaw bone. These type of teeth also present in crocodilians, fossil toothed bird (Archeaeopteryx).

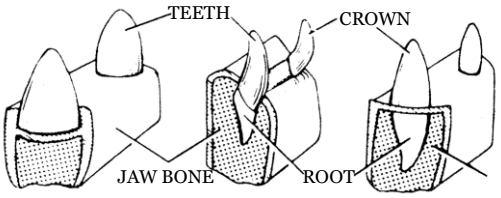


***Fig. – Methods of attachment of teeth on***

(iv) **Succession of teeth :** According to their replacement (succession), teeth can be divided into 3 categories: polyphyodont, diphyodont and monophyodont.

(a) **Polyphyodont :** In lower vertebrates, teeth can be replaced an indefinite number of times during life. e.g. – amphibia, reptilia.

(b) **Diphyodont :** In most mammals teeth develop during life in two successive sets, a condition known as diphyodont. Teeth of the first set are known as deciduous teeth or milk teeth or lacteal teeth whereas the second set is called permanent teeth.

(c) **Monophyodont :** In some mammals such as platypus, marsupials, moles, sirenians, toothless whale etc. only one set of teeth develops known as monophyodont condition.

## Important Tips

- Canines are absent in some herbivores such as rodents (rats), lagomorphs (rabbits) and some ungulates (ox), leaving a wide toothless space called diastema.
- Upper canine form tusk in walrus for digging mollusc and for locomotion.
- Premolars and molars are called cheek teeth.
- In carnivores, last premolars in upper jaw and first molars in lower jaw may have very sharp cusps for cracking bones and shearing tendons. These are called carnassial teeth.
- Birds are edentulous i.e. teeth are absent.
- In lemurs, first premolars are like canines.
- In crabeater seal, molars bear denticulate processes to strain plankton.
- In higher primates (man), last molar is called wisdom teeth.
- Incisors may be totally absent in sloths and absent in the upper jaw in ox.
- Tartar is a hard deposit of calcium phosphate from saliva on the teeth.
- Tonsillectomy – Surgical removal of tonsil.
- Toothless mammals – In spiny anteaters (tachyglossus) no teeth are found at any stage of life but platypus (ornithorhynchus) embryonic teeth replaced in the adult by horny epidermal plates.

(v) **Types of cheek teeth**

(a) **Bunodont :** Crown with small, blunt and round cusps as in man, monkey, pig etc. found in mixed diet mammals.

(b) **Secodont :** With sharp cutting edges for tearing flesh as in carnivores.

(c) **Lophodont :** With transverse ridges called lophos, *e.g.*, Elephant.

(d) **Selenodont :** With vertical crescentic cusps as in grazing mammals like cow, sheep and goat. Selenodont teeth are two type –

(1) **Brachyodont :** Normal low crowned selenodont teeth with short roots are termed brachyodont. e.g. Ground squirrel.

(2) **Hypsodont :** In large grazing mammals teeth are elongated, prism shaped with high crown and low roots. e.g. Horse, cattle.

(vi) **Structure of teeth :** Teeth divided into three parts –

(a) **Root :** Inner most attached to the bone with help of cement (hyaluronic acid).

(b) **Neck :** Middle, small, covered with gum. Gum provides strength to the teeth.

(c) **Apex or crown :** External exposed part of teeth. Longest part, white in colour.

Teeth are made up of a hollow cavity, called as pulp cavity or dentine pulp cavity**.** It contains blood vessels lymphatic vessels nerve fibres, connective tissue etc. and provides nutrition to odontoblast cells or osteoblast cells. The odontoblast cells are mesodermal in embryonic origin forming immediate covering of the pulp cavity. The cells secrete dentine/ivory. Bulk of tooth in a mammal is formed of dentine. Dentine is a layer of inorganic substances (62-69%), which surrounds the odonto-blast cells. It is mesodermal in origin. Enamel**,** secreted by Ameloblast/Enameloblast cells, forms the outermost covering. It is ectodermal and made up of 92% of inorganic substances, hence considered as hardest part of the body. The inorganic substances present are [$Ca_3(PO_4)_2$,$Ca(OH)_2$.$H_2O$] Calcium phosphate (85%), Calcium hydroxide and Calcium Carbonate.

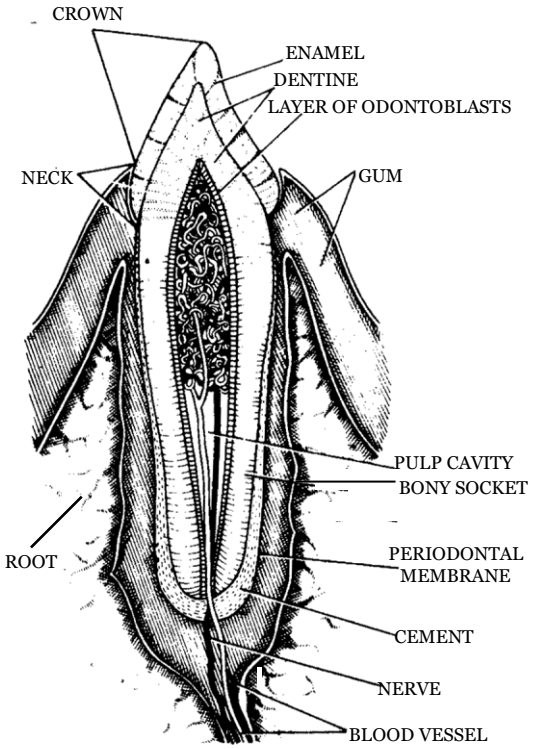



***Fig. – Structure of tooth***

Cement/Cementum attaches the tooth root to the bone. A thin peritoneal membrane is present between the two called as peridontal membrane or Sharpey's fiber running from cement to bone. Gum is chiefly made up of connective tissue. In the incisors of rodents, lagomorphs and elephants, pulp cavity remains open basally so that these teeth continue to grow throughout life and are termed open-rooted. In the majority of mammals, including man, the basal aperture of pulp cavity becomes closed at a certain age so that nourishment stops and further growth ceases. Such teeth are termed close-rooted.

(vii) **Odontogenesis :** In mammals, teeth develop in the gum or the soft tissue covering the borders of premaxillae, maxillae and dentaries. Enamel of tooth is derived from epidermis, while the rest of tooth from dermis or mesenchyme. In the beginning there is a thickening of ectoderm along the margin of Jaw bone. The basal layer of ectoderm, the Malpighian layer, forms a continuous solid ridge-like vertical invagination into the underlying dermis. This forms the dental lamina, which retains its connection with the outer epidermis.

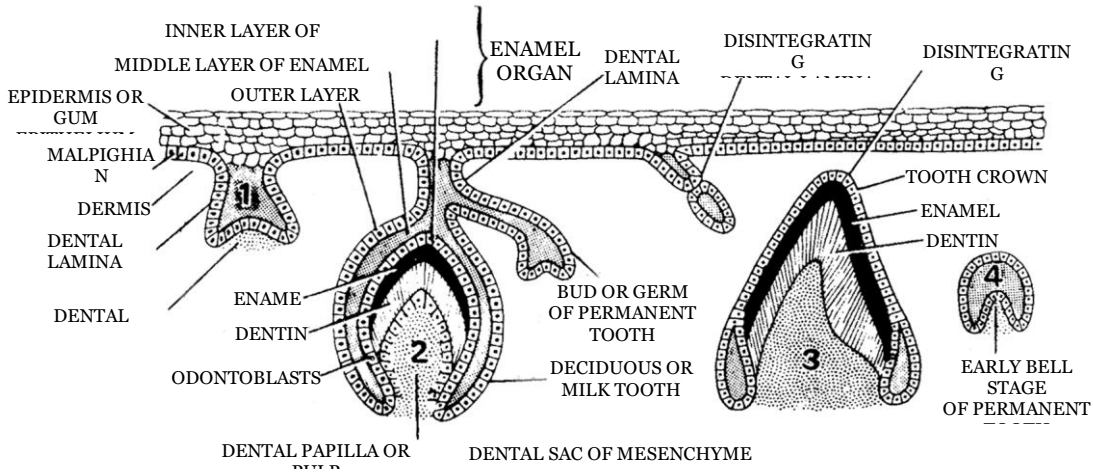
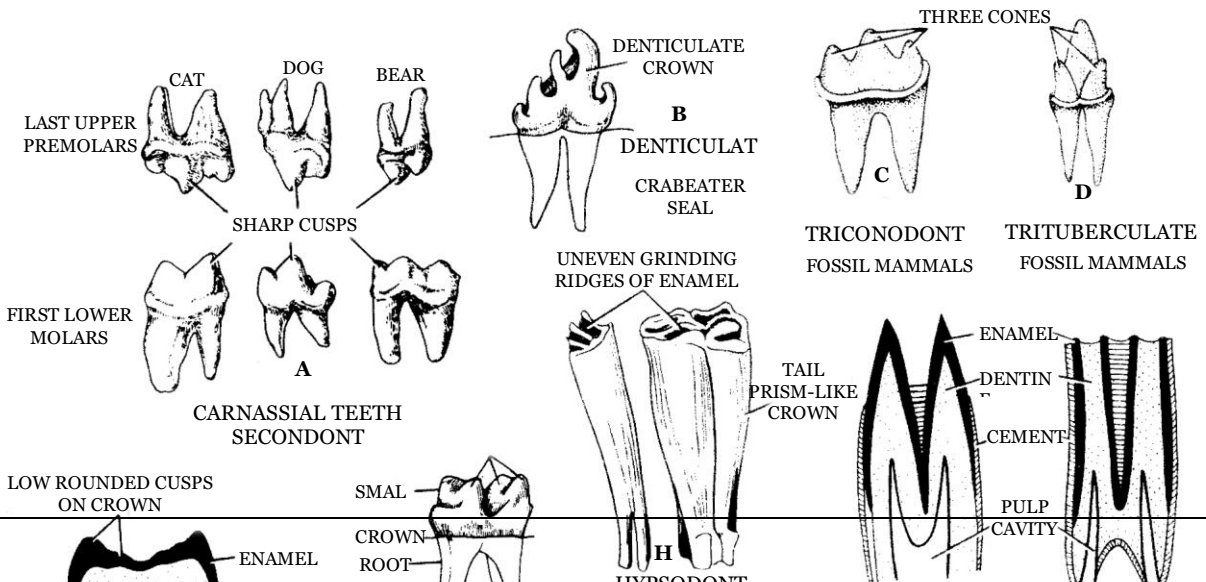



***Fig. – Development of a mammalian tooth***

Mesodermal cells multiply rapidly beneath the ectodermal ingrowth or dental lamina forming a series of solid bud-like outgrowths at intervals, called tooth germs. Their number is as many as the number of milk teeth. In each tooth germ, the inverted cup-like epithelial cap will secrete the enamel, hence termed the enamel organ. The mesodermal aggregation beneath enamel organ is termed dermal or dental papilla. Its outer columnar cells become differentiated into odontoblasts, which secrete a layer of dentine on their outer surface. The cells of inner epithelial layer of enamel organ similarly become ameloblasts, which form a cap of hard enamel around the top and sides of dentine. No enamel is deposited on the root. Dental papilla is retained as pulp. Its central cavity goes on increasing to become the pulp cavity. Nerves and blood vessels enter the pulp cavity through the basal opening. Upto this stage the tooth remains inside the tissue (gum). Later, its eruption through the overlying epidermis is known as cutting of tooth. Around the root of tooth appears cement or cementum, which is a modified bone. Odontoblasts become inactive when tooth is fully formed. However in rodents, lagomorphs, etc. the odontoblasts remain active throughout life and teeth continue to grow.



(viii) **Dental formula :** Each mammalian species is characterized by its own specific dentition with a definite number and arrangement of teeth. Hence, dentition is of taxonomic importance. It is expressed by a dental formula as below –

Rabbit : $i\frac{2}{1}, c\frac{0}{0}, pm\frac{3}{2}, m\frac{3}{3} = \frac{8}{6} \times 2 = 28$ or briefly, $\frac{2300}{1023} = \frac{2+0+3+3}{1+0+2+3} \times \frac{2}{2} = \frac{16}{12} = 28$

(*i* = incisors; *c* = canines; *pm* = premolars; *m* = molars)

**Dental formulae of some common mammals**

| | | | |
|---|---|---|---|
| Horse and pig | $\frac{3.1.4.3}{3.1.4.3} = 44$ | Cat | $\frac{3.1.3.1}{3.1.2.1} = 30$ |
| Dog | $\frac{3.1.4.2}{3.1.4.3} = 42$ | Squirrel | $\frac{1.0.2.3}{1.0.1.3} = 22$ |
| Lemur | $\frac{2.1.3.3}{2.1.3.3} = 36$ | Rat | $\frac{1.0.0.3}{1.0.0.3} = 16$ |
| Man | $\frac{2.1.2.3}{2.1.2.3} = 32$ | Elephant | $\frac{1.0.0.3}{0.0.0.3} = 14$ |
| Cow | $\frac{0.0.3.3}{3.1.3.3} = 32$ | Permanent set milk set | $\frac{2.1.2.0}{2.1.2.0} = 20$ |

## Important Tips

- ☞ Baleen – Whale bone whale have in the buccal cavity a special structure called baleen or whale bone. It consists of several parallel horny plates hanging from the palate.
- ☞ Cheek pouches – In some rodents (squirrel, rat) certain old world monkey, the vestibule extends to form cheek pouches for temporary storage of masticated food.
- ☞ Taste buds contain group of sensory epithelial cells. These cells are anteriorly provided with kinocilium and posteriorly with nerve fibres. The taste centres are present in brain.
- ☞ Gustatoreceptor – The organ concerned with taste detection. They are a type of chemoreceptor

found in the parietal lobe of cerebrum.

- In frog, tongue is anteriorly attached with the floor of buccopharyngeal cavity at lower jaw, whereas posterior end is free and bifid.
- The tongue of snake is bifid and sensitive to odour and vibration.
- Toothpaste protects the gum, whereas fluorides present in toothpaste clean the apex. The excess of fluorides causes the disease fluorisis which leads to decaying of teeth and bones.
- Elephant tusk is the upper incisors.
- $3^{rd}$ molar in human is called as wisdom teeth as arises after the age of 16-17 years. Wisdom teeth 4 in number.
- Teeth of fishes are modified placoid scales.
- Teeth in frog are present only on upper jaw.
- Caries  Decay of teeth due to degeneration of enamel and formation of cavities.
- Pyorrhoea infected gums and tooth sockets.
- Maximum number of teeth present in opossum is $50\frac{5134}{4134}=50$.
- The number of teeth that grows once and twice in humans life is 12 and 20 respectively.
- Lophodont teeth in elephant are premolar and molar.
- Incisors of rats are polyphyodont.
- Teeth of sloths and armadillos have no enamel.
- Enamel is lacking in the teeth of whales.
- Jacobson organ (Vomeronasal organs) – They are independent chambers below nasal cavities found in most tetrapods, although they are sometimes vestigial (like human). Absent in fish but occurs embryonic rudiments in most vertebrates. In reptiles, they are best developed in lizards, snakes and sphenodon but are absent in adult crocodiles. Jacobsons organ well developed in such animals that hold food in their mouth. This organ serve to smell food and recognize its chemical nature. They also help enemy recognition, locating members to opposite sex, courtship etc.
- Teeth absent in Bufo and Pipa (Toads).
- Taste of chilli is not real taste but it is burning sensation of nerves.
- Fangs of poisonous snake attached to maxillary bones, they are replaceable. Solenoglyphous, Proteroglyphus and Opisthoglyphus types of fang occurs in poisonous snake.

(d) **Oesophagus (food tube)**

(1) **Morphology :** Single, endodermal, dorsal to trachea, approximately 25-40 *cm* long. passes through thoracic cavity and opens into stomach present in abdominal cavity. Oesophagus anteriorly opens into pharynx through gullet and posteriorly into stomach through cardiac orifice.

(2) **Histology :** Serosa is absent but outermost layer of connective tissue is called *as* tunica adventitia. Muscular layer are stratified voluntary in anterior region and unstriated involuntary in

posterior part. The epithelial lining is made up of non-keratinized stratified squamous epithelial cells. Goblet cells are present.

(3) **Function :** Conduction of food.

(e) **Stomach**

(1) **Structure :** Single oval, elongated, unilobed present within abdominal cavity below diaphragm. It consists of three parts as **c**ardiac/fundic (anterior), corpus/body (middle, chief part) and pyloric (posterior part) in human, whereas in rabbit stomach is bilobed and consists of three parts as cardiac (Anterior) fundic (middle), chief part and pylorus (posterior)**.** Two types of valves are present in the stomach *viz***.** Cardiac sphincter valve between oesophagus and stomach and pyloric sphincter valve between stomach and duodenum.

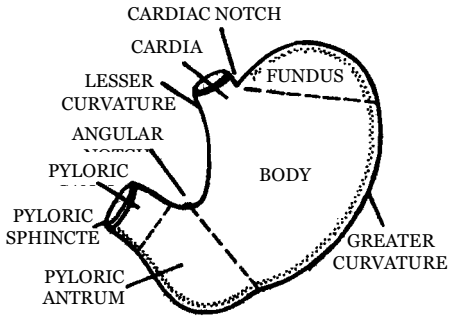



***Fig. – Human stomach***

(2) **Histology :** Outermost layer is serosa. Muscular layer is three – layered with outer longitudinal, middle circular and inner oblique. Muscles are involuntary and unstriated. Epithelial lining is made up of simple columnar epithelial cells and specialized cells present in the gastric glands. The nomenclature of gastric glands is according to the parts of the stomach. The various type of gastric glands and the cells present in them are as follows –

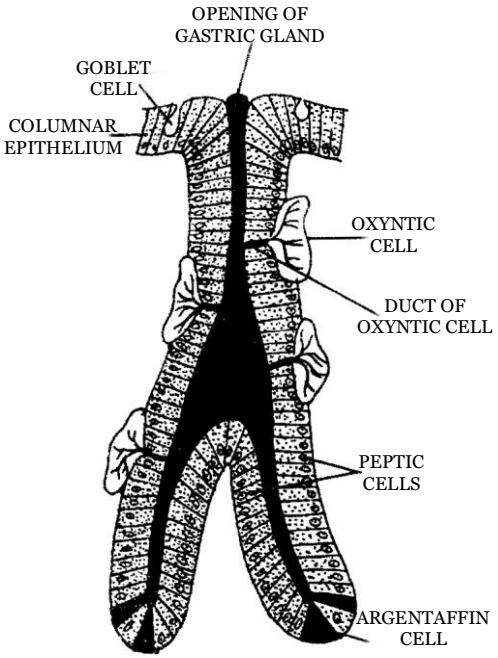



***Fig. – L.S. Gastric gland***

**Anterior part :** Cardiac gastric glands in rabbit and human cells present are mucous neck cells secreting mucous.

**Middle part :** Fundic gastric glands in rabbit and corpus in human has at least four distinct types of cells –

(i) **Peptic or zymogenic or chief or central cells :** Secretes two digestive proenzymes pepsinogen and prorenin.

(ii) **Oxyntic or parietal cells :** Secretes *HCl* and castle's intrinsic factor required for the absorption of vitamin $B_{12}$. Hyperacidity is a abnormally high a degree of acidity due to the secretion of large quantity of HCl i.e. gastric juice.

(iii) **Mucous neck cells :** Secretes alkaline mucous.

(iv) **Argentaffin cells or Kultchitsky or enterochromaffin cells :** Responsible for the secretion of vasoconstrictor seratonin.

**Posterior part :** Pyloric gastric glands in rabbit and human-cells are mucous neck cells secreting mucous and some cells, called "gastrin" or "G" cells, secrete a hormone, named gastrin, which increases the motility of gastric wall and stimulates gastric glands for active secretion.

(3) **Functions**

(i) Storage of food.

(ii) Trituration or churning of food to mix with gastric juice.

(iii) Functions of gastric juice (discussed along with gastric juice).

(4) **Stomach of ruminants (cud-chewing mammals) :** The stomach of cattles have four parts, as rumen (paunch), reticulum(honeycomb), omasum (psalterium) and abomasum (rennet). Some authors believe that first three chambers are parts of the oesophagus, the fourth chamber is the real stomach secretes *HCl* and enzymes. The embryological studies have proved that all the chambers are parts of the real stomach.

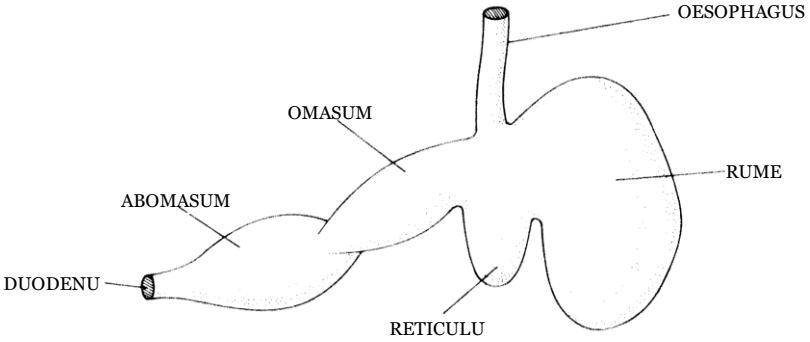



***Fig. – The compound stomach of a ruminant***

The cattles rumen stores the quickly fed food. So cud chewing animals are called ruminants. *e.g.* cow, buffaloes, goat etc. Rumen is the largest part of stomach. Primitive digestion and bacterial action takes place in rumen. Which later on moves again to buccal cavity where it is properly chewed, then this food passes into reticulum to omasum which concentrates the food by absorbing water and bicarbonates. Finally, the food reaches in the fourth chamber, abomasum. First three chamber are lined by cornified epithelium but fourth chamber abomosum is lined glandular epithelium and gastric glands, so it is true stomach. Camel and deer lack omasum. Reticulum is the smallest part and its cells are provided with water pockets for the storage of metabolic water.

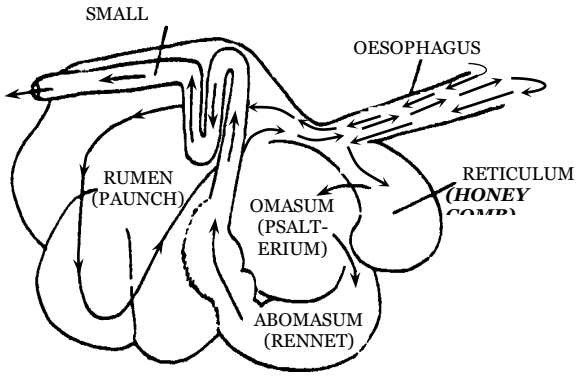



***Fig. – Arrow shows course of food***

In the rumen, food undergoes mechanical and chemical breakdown. Mechanical breakdown results from thorough churning brought about by muscular contractions and aided by cornified surface of villi. Chemical breakdown is caused by symbiotic microorganisms (bacteria and ciliates) that release enzymes, cellulase, which act on cellulose and simplify it to short-chain fatty acids, such as acetic acid, butyric acid, propionic acid. This is called microbial digestion. The fatty acids are neutralized by sodium bicarbonate of saliva and are absorbed. These two processes reduce the hard plant food to a pulp.

## Important Tips

- Lumen is the hollow space present in the middle of alimentary canal and is the site where process of digestion takes place
- Stomach of frog is unilobed with two parts as anterior cardiac (various type of cells present in it secretes mucous, pepsinogen enzyme and HCl) and posterior pyloric (cells present secretes mucous). Frogs stomach has only pyloric sphincter valve present between stomach and duodenum.
- During hunger the folds of stomach deepen are called ‘rugae’.
- The length of human alimentary canal is approximately 9–10 meters.
- The length of the alimentary canal depends on the basis of feeding habits. i.e. more complex the

food (Herbivorous condition) more the length of alimentary canal, hence smallest alimentary canal is of carnivores and medium sized in omnivores.

- Greenish faecal matter passed by infant in first two days of birth due to sterilized intestine is called meconium.
- National institute of nutrition in Hyderabad.
- Gastritis – Inflammation of stomach due to excessive intake of alcohol.
- Gastric ulcer (inflammation of mucosa of stomach) and duodenal ulcer is due to excess of acidic gastric juices.
- Amount of rennin decreases with age, then the curdling of milk is done by pepsin and chymotrypsin.
- The policeman to the abdomen is omentum.
- Removal of stomach causes dumpong syndrome.
- The inner surface of small intestine is raised into longitudinal and circular fold called valvulae.
- Chief cells of the gastric glands secreting zymogen, have well-developed rough ER.
- Argentaffin cells occur both in stomach and duodenum.
- Splanchnology is the study of the viscera.
- Achalasia cardia – condition is characterised by failure of cardiac sphincter to relax completely on swallowing causing food accumulation in oesophagus and proximal oesophagus dilates.
- Chyme is the acidic food which passes from stomach to duodenum.
- Stomach is the site for digestion of protein. Size of stomach depend on the basis of proteineous diet, in carnivorous animal stomach large than herbivorous animal.
- Oesophagus does not secrete any enzyme.
- Stomach absent in labeo, lamprey and hag fish.
- Hunger pangs – Stomach churns every 20 second, when an empty stomach churns, hunger pangs are feel.
- Liver is well developed in carnivorous animals.

(f) **Small intestine**

(1) **Structure :** Endodermal, longest part of alimentary present in the abdominal cavity, supported by a peritoneal membrane called mesentery. Wall of jejunum and ileum has circular or spiral internal fold called fold of kerckring or valvulae conniventes. Also numerous finger like projection called villi project from the wall of lumen, increasing internal surface are about eight time. The distal end of ileum is leads into the large intestine by ileo-caecal valve in man but in rabbit sacculus rotundus and ileo-coecal valve both are present.

(2) **Parts :** It is approximately 6 metres in human. It is divisible into three parts. In man small intestine divided into three parts –

| Duodenum (Proximal part) | Jejunum (Middle part) | Ileum (Posterior part) |
|---|---|---|
| 2.5 *cm.* Long<br>Forming *U*-shaped loop before leading to jejunum pancreas lies in the loop. | About 2.4 *m* long and about 4 *cm.* wide.<br>Wall is thicker and more vascular.<br>Villi thicker and tongue-like.<br>Plicae best developed.<br>Peyer's patches are lacking. | About 3.6 *m* long and about 3.5 *cm.* wide.<br>Wall is thinner and less vascular.<br>Villi thinner and finger-like.<br>Plicae less developed.<br>Peyer's patches are present. |

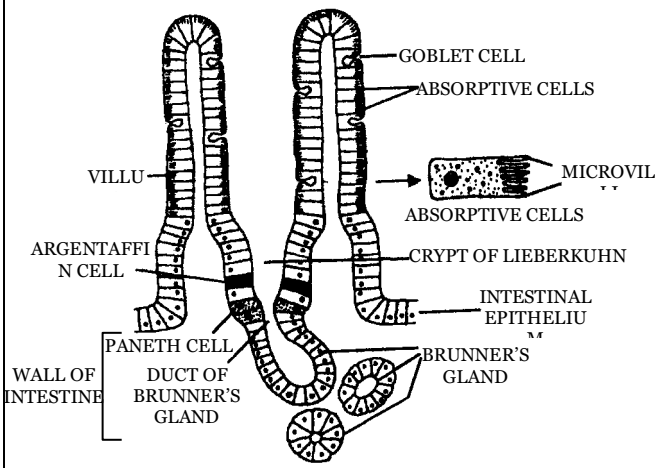



***Fig. – Intestinal glands***

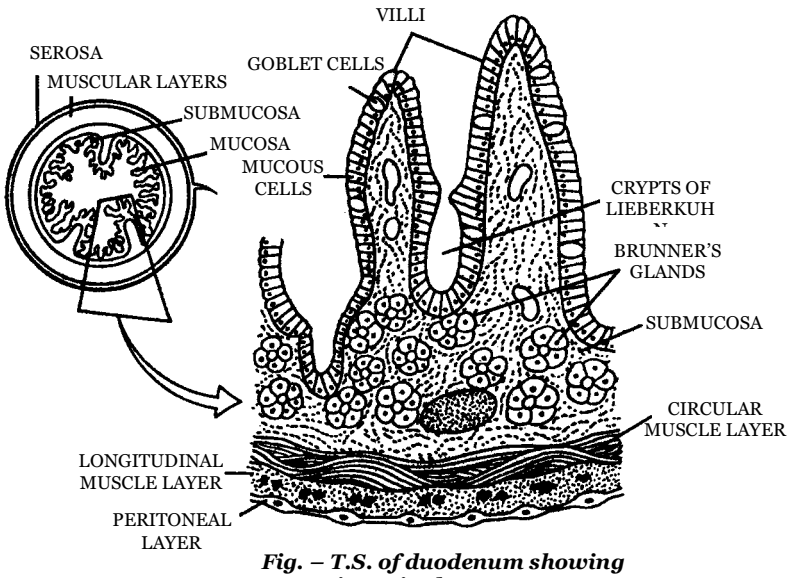



***Fig. – T.S. of duodenum showing intestinal structure***

(3) **Histology :** Serosa is the outer most covering. Muscular layer is generalized with involuntary, unstriated muscles. The cells present in the epithelial lining are simple columnar epithelial cells, which are brush- bordered *i.e.* provided with villi and microvilli to increase the surface area. The folds present are longitudinal and are called folds of kerckring or valvulae canniventes. Goblet cells secrete mucous. Payer's patches are the oval, rounded masses of lymphatic tissue present in between lamina propria and epithelial lining. They produce lymphocytes. Brunner's glands or Duodenal glands are the multicellular mucous glands present in the submucosa of duodenum only. They secrete mucous. In addition there are also found granular arogyrophil cell.

(4) **Glands of small intestine**

| Brunner's glands | Payer's patches | Crypts of Leiberkuhn |
|---|---|---|
| Found in duodenum only.<br>Mucus secreating gland as so known as mucus gland. | These are lymph nodules.<br>They produce lymphocytes. Lymphocytes are phagocyte in nature which destroy harmful bacteria. | Known as intestinal gland.<br>Found in duodenum and ilium only.<br>Secrete succus entericus *i.e.* intestinal juice.<br>Formed by folding of lamina |

| | | |
|---|---|---|
| | | propia. |

Each gland has three types of cells : (i) Undifferentiated epithelial cell (ii) Zymogenic cell (paneth cell) and (iii) Argentaffin (Enterochromaffin cell).

(5) **Function :** Digestion and absorption of food.

(g) **Large intestine :** The name large intestine is due to large diameter.

(1) **Structure :** Endodermal, approximately 1.5-1.75 metre long.

(2) **Parts :** They are following –

(i) **Caecum :** Spirally coiled 10-15 cm long in human and 45 cm long in rabbit. Its posterior end is present as a blind sac in abdominal cavity called vermiform appendix. Vermiform appendix is vestigeal but contains lymphatic tissue. Caecum in human is concerned with passage of food whereas in rabbit it is concerned with cellulose digestion and conduction of food. Vompyrella bacteria helps cellulose digestion. Vermiform appendix produce antibody. It is functional in ruminents and vestigeal in man. If food may collect and decay in it or intestinal worms may settle in it and causes inflammation or appendicitis in man, in such case its removed by operation known as appendictomy.

(ii) **Colon :** Single endodermal approximately 1.3 *m* long in human distinguished into four limbs as ascending, transverse, descending and pelvic or sigmoid limb. Colon posses two specialized structures as Taeniae (present in the middle of colon) and Haustra**,** (dilated sac-like or pockets like structures surrounding taeniae).

Serosa is the outer most layer. The serious layer (visceral peritoneum) forms small pendulous projections, the appendices epiploicae filled with adipose tissue. Muscular layer is two layered contain involuntary unstriated muscles. The innermost lining is made up of columnar epithelial cells. Goblet cells and absorptive cells are also present. Cells are without villi and microvilli *i.e.* not brush–bordered. Colon is concerned with absorption of water (80-85%), salts, vitamins etc. hence concerned with faeces formation. Colon bacteria also synthesized vit. *B* and *K*.

**Differences between small and large intestines**

| Small intestine | Large intestine |
|---|---|
| Longer (about 6 *m.*) but narrower than large intestine. | Shorter (about 1.5 *m.*) but wider than small intestine. |
| Differentiated into duodenum, jejunum and ileum. | Differentiated into caecum, appendix, colon and rectum. |
| Mucous membrane has plicae circulares and villi. | Mucous membrane is mostly smooth (without plicae and villi). Rectum has longitudinal folds. |
| Lacks taeniae coli, haustra and epiploic appendages. | Has taeniae coli, haustra and appendices epiploicae. |
| Peyer's patches are present in the ileum. | Peyer's patches not formed, lymphoid nodules beins scattered. |
| Completes digestion and absorbs digestion | Absorbs water, forms and eliminates faeces, |

| | |
|---|---|
| products. Also produces some hormones. | produces vitamins *B* and *K* by bacterial activity and excretes certain inorganic ions. |
| Mucosal irritation due to infection causes diarrhoea. | Mucosal irritation due to infection causes dysentery. |

(iii) **Rectum :** Single small dilated sac like in human whereas large beaded in rabbit. It is concerned with storage of faeces rectum has strong sphinctor muscle in its wall. The sphinctor keeps the canal as well as anus, closed when not used for defecation.

(3) **Function :** Absorption of water from undigested food.

(h) **Anal canal and anus :** Anal canal connects rectum with anus and it is about 3 cm. long. Anus is the terminal inferior opening of alimentary canal, which is guarded by an internal involuntary sphincter and an external voluntary sphincter.

(i) **Generalized histology of alimentary canal :** The alimentary canal consist of following layers from outer to inner side:

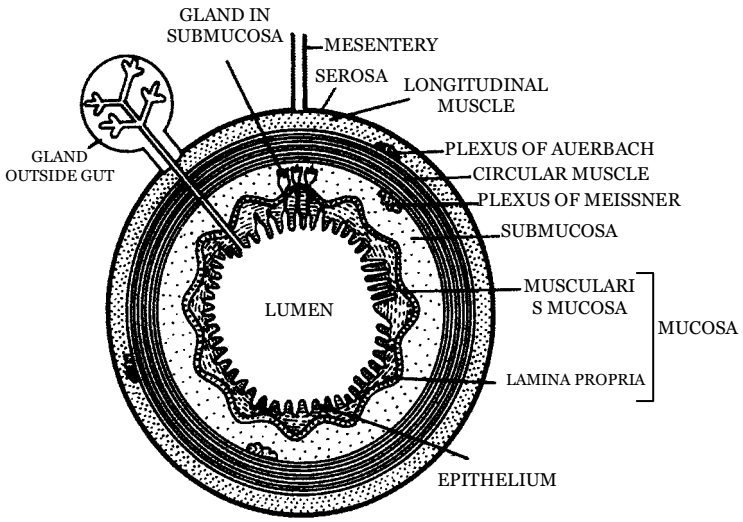



***Fig. – General structure of the wall of the mammalian gut and associated structures***

(a) **Serosa :** Outermost, mesodermal, single layered made up of squamous epithelial cells.

(b) **Muscular layer :** Mesodermal, consist of outer longitudinal and inner circular layer. Muscles are involuntary unstriated. In between the two layers there is a nerve network called the plexus of Auerbach.

(c) **Submucosa :** Mesodermal, made up of connective tissue and contains major blood vessels, lymphatic vessels, nerve fibres etc. Mucous glands are also present in some parts of alimentary canal. In this region nerve network, called plexus of Meissner.

(d) **Muscularis mucosa :** Thin layer, made up of outer longitudinal muscles and inner circular muscles. The muscles are involuntary unstriated.

(e) **Mucosa :** Inner most ectodermal in buccal cavity and anal canal whereas in the rest part of alimentary canal it is endodermal.

(f) **Tunica propria (lamina-propria) :** Outer, thin layer of connective tissue containing fine blood vessels, lymphatic vessels and nerve fibres.

(g) **Mucous membrane / epithelial lining :** Ectodermal or endodermal, single layered, made up of columnar epithelial cells. Goblet cells are also present in this layer. These cells are cup-shaped unicellular mucous glands secreting mucous. Epithelial lining is folded which are generally longitudinal and increases surface area.

## Important Tips

- *Cellulose is digested by the enzyme cellulase synthesized by the microorganisms present in the lumen.*
- *Cellulose* $\xrightarrow[\text{microbial fermentation}]{\text{Cellulase by}}$ *Acetic acid + Propionic acid + Butyric acid + Small chain fatty acid.*
- *Sacculus rotundus is a dilated sac like structure present in rabbit at the junction of ileum, caecum and colon. It contains ileo-caecal valve, which guides the direction of food from ileum to caecum. Sacculus rotundus is absent in human but ileo-caecal valve is present.*
- *The hindgut of all vertebrates (except metatherian and eutherian mammals) includes cloaca and cloacal aperture, instead of anal canal and anus.*
- *Cloaca is divided into three parts*

  (i) *Coprodaeum is a part of rectum, where faeces are stored.*

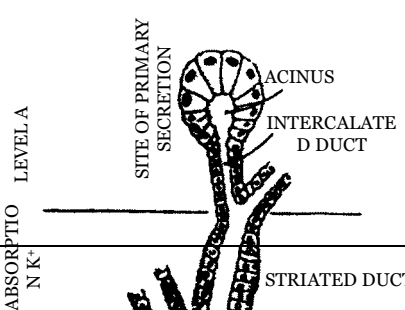
  (ii) *Urodaeum a depression in the part of cloaca where urinary duct and urinary bladder open.*

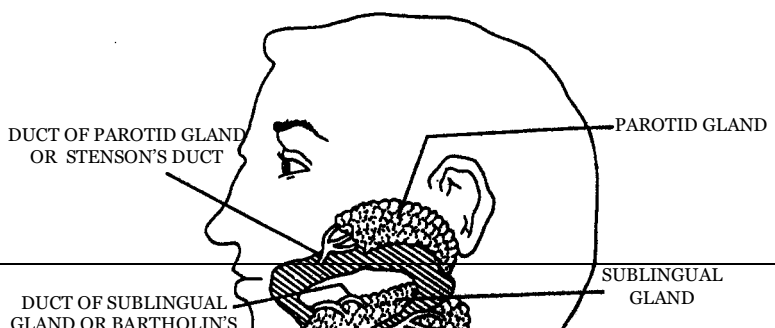
  (iii) *Proctodaeum terminal part of cloaca that is common opening for the excretion of urinary, genital and faecal matter and externally open by anus.*
- *Digestion of cellulose takes place in caecum of rabbit with the help of enzyme cellulase produced by symbiotic microorganism. Cellulose digestion does not occur in human.*
- *Peyer's patches in the intestine are the site of production of B-lymphocyte.*
- *In most of the vertebrate's protein digestion ends in ileum.*
- *The study of alimentary canal is called Enterology.*
- *Auerbach's plexus is present in small intestine.*
- *Digestion of cellulose is also found in termites (white ants). In which symbiotic flagellate Triconympha found in their intestine that secretes enzyme β-glucosidaes which hydrolyse the cellulose to sugars which are used by both symbionts.*
- *Bursa fabricus is also called cloacal thymus, is a lymphoid mass in the cloaca of birds. It is site of differentiation of B-lymphocytes. So a part of immune system.*

(ii) **Digestive glands :** The various types of digestive glands present in mammals are salivary glands, gastric glands, intestinal glands, pancreas and liver. The digestive glands secrete digestive juices. Parasympathetic nervous system increases the secretion of digestive juice whereas sympathetic nervous system decreases it.

(a) **Salivary glands :** The three pairs of salivary glands present in humans are as follows –

(1) **Parotid :** One-pair, largest salivary gland present below pinna. A stenson's duct arises from each gland, opening between the teeth of upper jaw. Parotid glands secrete enzymes. Viral infection of parotid glands causes "Mumps".



(2) **Sub-mandibular / sub-maxillary :** One-pair, present at the junction of upper and lower jaw in cheek region. A wharton's duct arises from each gland and opens on lower jaw. These are seromucous glands.

(3) **Sub-lingual :** One-pair, present in the floor of buccopharyngeal cavity. These are mucous glands 6-8 ducts, called ducts of rivinus or Bartholin's duct arises from these glands and opens below tongue on the floor of buccopharyngeal cavity. The sub-lingual and sub-maxillary glands mostly secrete a glycoprotein called mucin (mucous secretion) while parotid glands secrete a watery fluid (serous secretion) which contains a digestive enzyme, the ptyalin or salivary amylase. Both these secretions together form the saliva. Infra orbital lie below the orbit and are absent in man.

**Saliva / salivary juice :** The secretion of salivary glands is called saliva or salivary juice. Some of the characteristics are as follows –

(i) Amount : 1.5 litre/day

(ii) Chemical nature : Slightly acidic.

(iii) *pH* – 6.8

(iv) Control of secretion : Autonomic reflex (parasympathetic nervous system increases salivation while sympathetic nervous system inhibit secretion.)

(v) Chemical composition : Water (98.2%), mucous (acts as lubricant), salts (*NaCl*, $NaHCO_3$ etc.), enzymes (ptyalin, lysozyme) etc.

**Functions :** Salivary juice and its enzymes –

(i) Makes the medium slightly acidic for the action of its enzyme.

(ii) Help in taste detection, deglutition, speaking etc.

(iii) Starch $\xrightarrow[\text{(Salivary amylase)}]{\text{Ptyalin/Diastase}}$ Maltose + Isomaltose + Limit dextrin.

(iv) Bacteria (living) $\xrightarrow{\text{Lysozyme}}$ Bacteria killed.

## Important Tips

- Chlorides act as catalase and activate the ptyalin.
- Poisonous glands of snakes are modified parotid salivary glands or maxillary gland.
- Salivary glands are absent in frog, whale and dolphin etc.
- Carnivores, cattles and other cud-chewing mammals lack ptyalin enzymes in their saliva.

- Approximately 5% of food are digested in buccopharyngeal cavity.
- N-Acetyl muramidase active in saliva.

(b) **Gastric glands :** There are approximately 35 million of gastric glands present in human stomach and grouped into three categories as already described along with stomach. The gastric gland secretes gastric juice.

**Gastric juice**

(1) Amount : 2-3 liters/day.

(2) Chemical nature : Highly acidic

(3) $pH \rightarrow 1.0 : 3.5$ (due to presence of *HCl*)

(4) Control of secretion : By gastric hormone.

(5) Chemical composition : Water (99%), mucous, inorganic salts, castle's intrinsic factor, *HCl* ( 0.5%, conc.) and enzymes prorennin and pepsinogen and gastric lipase.

**Functions of gastric juice and its enzymes**

(1) Inactivates the action of saliva.

(2) Makes the medium acidic for the action of gastric enzymes.

(3) *HCl* kills micro organisms.

(4) *HCl* kills the living organism (prey etc.) if ingested.

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

(6) Prorenin (inactive) $\xrightarrow{HCl}$ Rennin (active).

(7) Pepsinogen (inactive) $\xrightarrow{\text{Pepsin}}$ Pepsin (active).

(8) Proteins + Peptones $\xrightarrow[pH\text{-}1\text{-}3]{\text{Pepsin}}$ Polypeptides + Oligopeptides.

(9) Casein (Soluble milk protein) $\xrightarrow[Ca^{++}]{\text{Chymosin/ Renin/ Rennet}}$ Calcium paracaseinate (insoluble curd–like). Above phenomenon is called "curdling of milk".

(10) Lipids $\xrightarrow[\text{negligible in human stomach acts at } pH\ 4-6]{\text{Gastric Lipaset}}$ Triglycerides + Monoglycerides.

(11) *HCl* is antiseptic.

(12) It act as preservative.

**Lactose intolerance :** Among mammals, man alone takes milk even after becoming adult. In some humans, secretion of lactase decreases or ceases with age. This condition is called lactose intolerance. Lactose intolerant persons fail to digest lactose of milk. In their large intestine, lactose fermented by bacteria, producing gases and acids. This causes flatulence (distension of stomach and intestine), intestinal cramps, abdominal pain and diarrhoea. These people can take yoghurt (yaourt)[1] and *or* curd[2] and cheese without any digestive problem. In yoghurt, lactose is fermented into lactic acid. In curd, lactose is left in the whey.

## Important Tips

- Pepsin is an autocatalytic enzymes.
- Rennet – Rennin containing tablets obtained from calf and is commercially use for curdling of milk

to make cheese.

- Enzyme rennin is found only in infant mammals but its presence is doubtful in human children. The digestion of milk is brought out by pepsin enzyme.
- Erosion of gastric epithelial lining due to effect of pepsin is called "peptic ulcers" and due to HCl, is called gastric ulcers.
- Pepsin hydrolyses the peptic bonds on c-terminus side of tyrosine, tryptophan and methionine amino acids.
- Secretion of gastric juice is controlled by gastrin hormone + vagus nerve + seratonin + histamine.
- Secretion of gastric juice stimulated by parasympathetic autonomic nervous system and inhibited by sympathetic nervous system.

(c) **Intestinal glands :** Intestinal glands in mammals is a collective name for crypts of Lieberkuhn (secretes alkaline enzymatic juice) and Brunner's glands (secretes mucous). Intestinal glands secrete intestinal juice.

(1) **Succus entericus (intestinal juice)**

(i) Amount : 1.5 – 2.0 *l*/day.

(ii) Chemical nature : Alkaline.

(iii) *pH* : 7.5-8.3

(iv) Control of secretion : Nervous and hormonal (Enterocrinin Duocrinin etc.)

(v) Chemical composition : Water (99%) mucous, inorganic salts, enzymes etc.

(vi) Function : Intestinal juice and its enzymes.

(a) Inhibits the action of gastric enzymes.

(b) Makes the medium alkaline for the action of it's enzymes.

(c) Starch $\xrightarrow{\text{Amylase}}$ Maltose + Isomaltose + limit dextrin.

(d) Maltose $\xrightarrow[(\alpha\text{-glucosidase})]{\text{Maltase}}$ Glucose + Glucose.

(e) Isomaltose $\xrightarrow{\text{Isomaltase}}$ Glucose + Glucose.

(f) Lactose (milk sugar) $\xrightarrow[(\beta\text{-galactosidase})]{\text{Lactase}}$ Glucose +Galactose.

(g) Sucrose (cane sugar) $\xrightarrow[(\beta\text{-fructosidase})]{\text{Sucrase / Invertase}}$ Glucose + Fructose.

(h) Polypeptides + Oligopeptides $\xrightarrow[(\text{Amino}-\text{peptidase})]{\text{Erypsin}}$ Amino acids.

(i) Trypsinogen (inactive) $\xrightarrow{\text{Enterokinase}}$ Trypsin (active).

(j) Lipids $\xrightarrow{\text{Lipase}}$ Fatty acids + Glycerol + Monoglycerides.

(k) Phospholipids $\xrightarrow{\text{Phospholipase}}$ phosphorous + Fatty acids + Glycerol + Monoglycerides.

(l) Organic phosphate $\xrightarrow{\text{Phosphatase}}$ Free phosphate.

(m) Nucleic acid $\xrightarrow{\text{Polynucleotidase}}$ Nucleotides.

(n) Nucleosides $\xrightarrow{\text{Nucleosidase}}$ Nitrogenous bases.

(d) **Pancreas :** Single endodermal, flat, leaf-like yellowish, heterocrine (mixed) gland, present between the ascending and descending limb of duodenum and opens into duodenum through pancreatic duct.

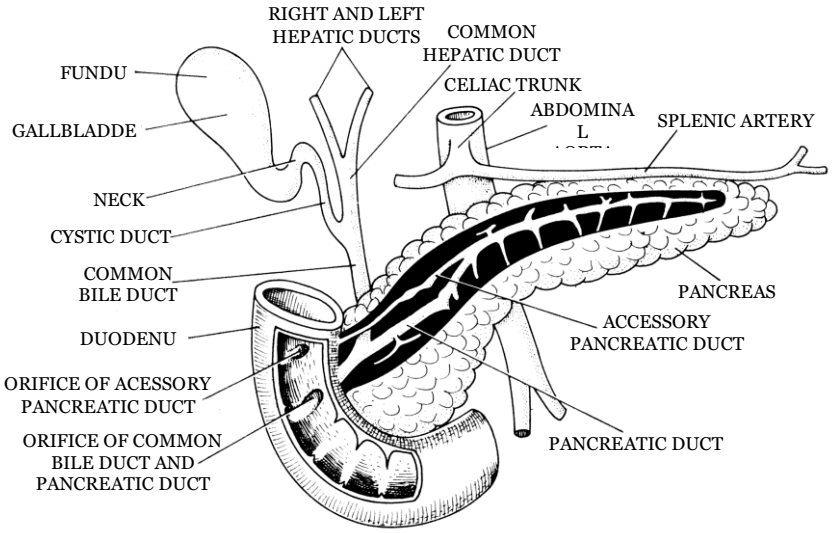
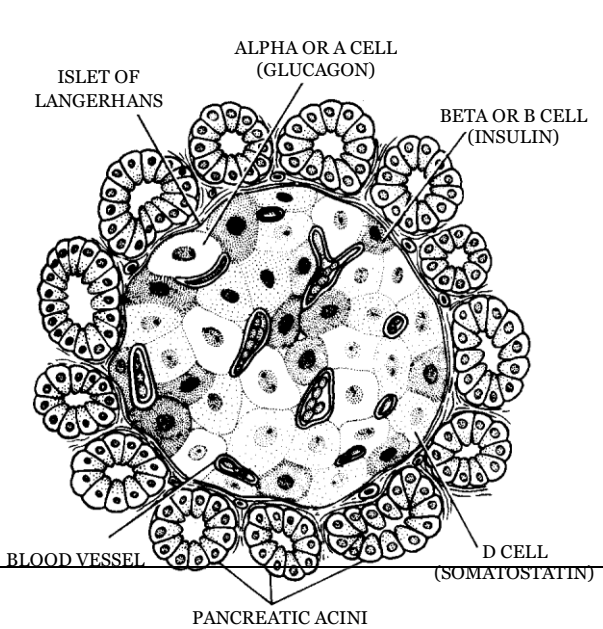


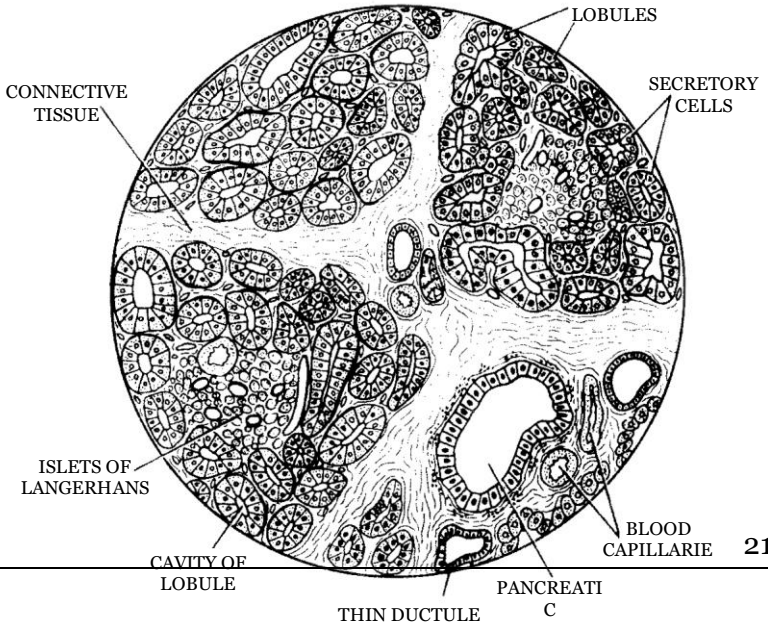

***Fig. – The gallbladder and pancreas and their systems of ducts. Both empty into the duodenum, often by a common orifice***

(1) **Parts**

(i) **Exocrine :** It is the major part of pancrease. The exocrine tissue of the pancreas consists of rounded lobules (acini) that secrete an alkaline pancreatic juice. The juice is carried by the pancreatic duct, also called duct of Wirsung, into the duodenum through the hepatopancreatic ampulla. An accessory pancreatic duct, also named duct of Santorini, may sometimes lead directly into the duodenum.

(ii) **Endocrine :** Minor part also called as islets of Langerhans scattered in the exocrine part. It consist of four various type of cells, as α(A) cells, β(B) cell and δ(D) cells. α-cells secretes glucagon hormone, β-cells secretes insulin hormone and δ cells secrets somatostatin. The secretion passes directly into blood.



(2) **Pancreatic juice**

(i) Amount : 1-1.5 *l*/day

(ii) Chemical nature : alkaline

(iii) *pH* : 8.6

(iv) Control of secretion : Hormonal

Secretin hormones stimulate the production of more alkaline pancreatic juice but low in enzyme content.

Pancreozymin stimulates the production of enzyme rich pancreatic juice.

(v) Chemical composition : Water (99%) enzymes and salts.

(3) **Functions of pancreas and its enzymes**

(i) The islets of Langerhans secrete insulin and glucagon hormones.

(ii) The exocrine part of pancreas secretes pancreatic juice.

(iii) Elastase : It act upon elastin protein.

(iv) Trypsinogen $\xrightarrow[\text{Intestinal juice}]{\text{Enterokinase of}}$ Trypsin.

(v) Trypsinogen $\xrightarrow[\text{(Autocatalysis)}]{\text{Trypsin}}$ Trypsin.

(vi) Chymotrypsinogen $\xrightarrow[\text{Autocatalysis}]{\text{Trypsin}}$ chymotrypsin.

(vii) Polypeptides + peptones $\xrightarrow[\text{(Pancreatic protease)}]{\text{Trypsin}}$ Tripeptides + Dipeptides + Oligopeptides.

(viii) Starch $\xrightarrow[\text{(Pancreatic amylase)}]{\text{Amylopsin}}$ Maltose + Isomaltose + limit dextrin.

(ix) Emulsified Lipids $\xrightarrow[\text{(Pancreatic lipase)}]{\text{Steapsin}}$ Fatty acids + Glycerol + Monoglycerides.

(x) Nucleic acid $\xrightarrow{\text{Nuclease}}$ Nucleotides + Nucleosides.

(xi) Nucleic acid $\xrightarrow{\text{Nucleasidase}}$ Purines + Pyrimidines.

(xii) Polypeptides $\xrightarrow{\text{Chymotrypsin}}$ Oligopeptides.

## Important Tips

- Trypsin hydrolyses the peptide bonds on C–terminus side of arginine and lysine.
- Trypsin is called universal enzyme as found from protozoans to mammals.
- Nucleases of pancreatic juice digest about 80% of nucleic acid.
- Pancreatic juice is called as “complete digestive juice” as it is protease enzymes can break all type of peptide bonds.
- Amylases act on glycoside linkages.
- Proteolytic enzymes are always secreted in inactive form hence prevents cell digestion. These

enzymes becomes active in the lumen of alimentary canal but are generally unable to digest the cells of epithelial lining due to continuous secretion and presence of thick mucous covering.

- Pepsin, trypsin and chymotrypsin are endopeptidases whereas carboxy peptidase is exopeptidase.
- Chymotrypsin acts on peptide bonds on C–terminus side of tyrosine, tryptophan and phenylalanine amino acid.
- Blood is digested by trypsin.
- Enterokinase is a non-digestive protease while bile is a non-enzymatic digestive juice.
- Duct of santorini is an accessory pancreatic duct.
- Pisiform cells loaded with zymogen granules can be seen in pancreas.
- Galactosemia is a disease of children in which amount of galactose increases in blood. Such children are kept on milk free diet.
- Sucrase changes dextro-rotatory sucrose to a leavo-rotatory mixture of glucose and fructose by inversion.

(e) **Liver**

(i) **Structure :** The liver is largest gland in the body. Its upper and anterior surfaces are smooth and curved to fit the under surface of the diaphragm; the posterior surface is irregular in outline.

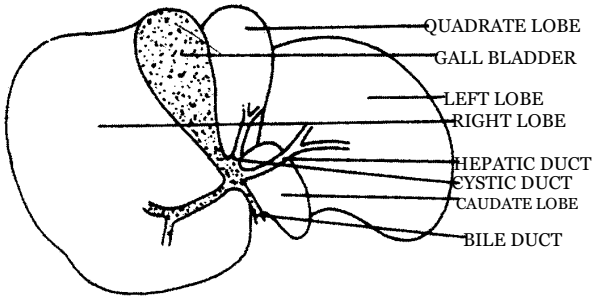



*Fig. – Liver of man (ventral view)*

It consists of three lobes in frog: right, left and median; five lobes in rabbit**:** left lateral, left central, spigelian, right central and caudate; four lobes in man: right, left, quadrates and caudate lobe. These are surrounded by a thick capsule, mostly overlaid with reflected peritoneum. It is heavier in males than females. In males it generally weights 1.4 – 1.8 kg and in females 1.2 – 1.4 kg. It is divided into two main lobes : right and left lobes separated by the falciform ligament. The latter is a membrane that is continuous with the peritoneum. The right lobe of the liver is differentiated into right lobe proper, a quadrate lobe and a caudate lobe in the inferior side. A pear-shaped sac, the gall bladder is attached to the posterior surface of the liver by connective tissue. The right and left hepatic ducts join to form the common hepatic duct. The latter joins the cystic duct, which arises from the gall bladder. The cystic duct and common hepatic duct join to form bile duct, which passes downwards posteriorly to join the main pancreatic duct to form the hepatopancreatic ampulla (ampulla of Vater). The ampulla opens into the duodenum. The opening is guarded by the sphincter of Oddi. The sphincter of Boyden surrounds the opening of the bile duct before it is joined with the

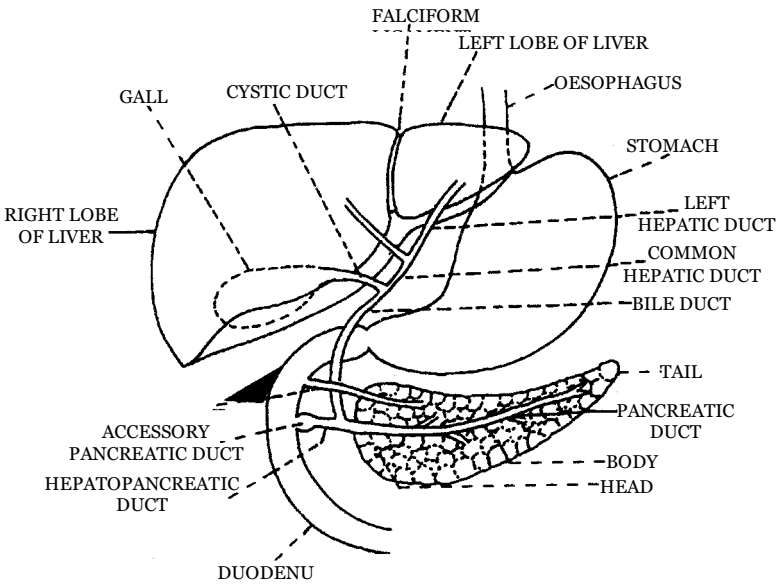



*Fig. – Liver and pancreas and their ducts*

pancreatic duct. The basic structural and functional unit of the liver is the hepatic lobule.

The liver is encapsulated in rabbit and man by two sheaths-an outer membranous serous capsule consisting of visceral peritoneum and an inner Glisson's capsule of a thin layer of dense connective tissue. In frog Glisson's capsule is absent. Numerous thin and profusely branched septa-like trabeculae extend inwards from Glisson's capsule, dividing each liver lobe into numerous minute and polyhedral units called hepatic lobules. Thus, the adjacent lobules are separated by interlobular Glisson's capsules. Each hepatic lobule is about one millimetre in diametre. A slender intralobular branch of hepatic vein, called central vein or venule, forms the axis of each lobule.

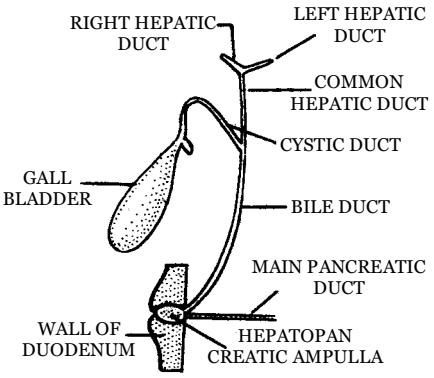



***Fig. –Showing gall bladder, different ducts and hepatopancreatic ampulla***

Each lobule is polyhedral, glycogen arranged radially aro the plates are radial blood sinusoids. At the periphery of the lobules, the branches of portal vein, hepatic artery, bile ducts, and lymphatics course together. A network of tubular spaces between the hepatocytes represents the bile canaliculi. At the periphery of the lobule the bile canaliculi empty into small hering's canals walled by cuboidal epithelium. These canals lead into bile ducts walled by columnar epithelium. The sinusoids are lined by incomplete endothelium with scattered phagocytic Kupffer cells, that eat bacteria and foreign substances.

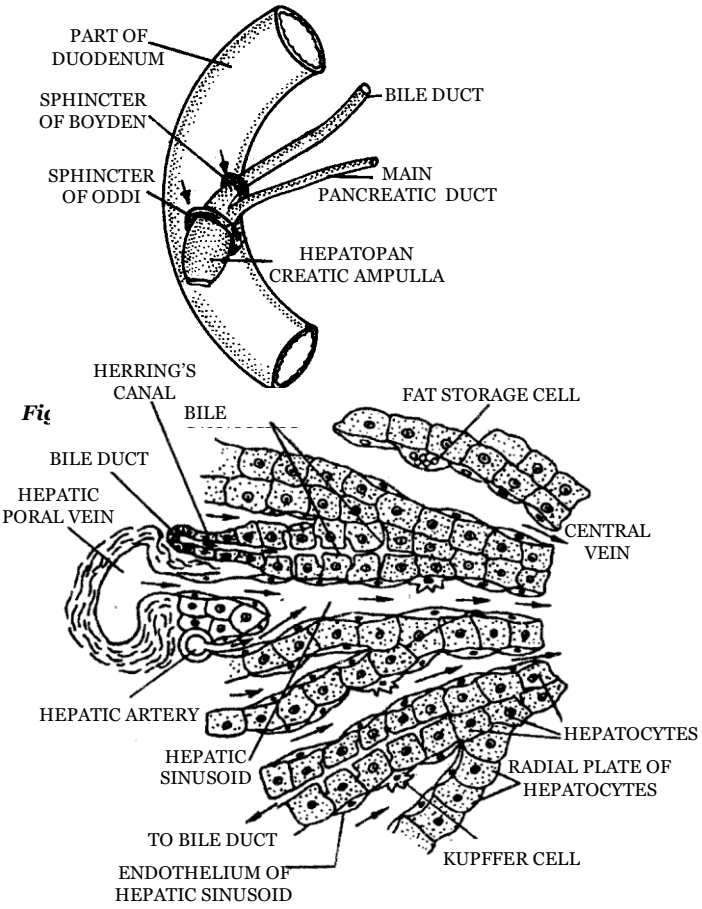



***Fig. – Structure of liver***

**Gall bladder :** The gall bladder is a slate-blue, pear-shaped sac connected with an supported from liver by a small omentum or ligament. Its distal part is called fundus, while the narrow part, continued as cystic duct, is called the neck.

(ii) **Functions of liver :** Liver, the largest gland of vertebrate body, is an essential organ, which performs many functions –

(1) **Secretion :** It secretes bile which is a complex watery fluid containing bile salts (Na taurocholate and glycocholate), bile pigments (biliverdin and bilirubin), cholesterol, mucin, lecithin and fats etc. The bile aids in intestinal digestion as it breaks and emulsifies the fat, prevents

putrefaction of food by checking the growth of bacteria, makes the chyme better suited for pancreatic digestion by neutralizing the acid in it, and helps in the absorption of fat from the intestine.

(2) **Excretion :** In the liver, haemoglobin of the worn out erythrocytes breaks down to bile pigments bilirubin and biliverdin. The liver excretes these pigments as a major constituent of bile, a part of which carried to the kidney through general circulation for excretion through urine. The bile pigments are also converted in the bowel into stercobilin which colours the faeces but, apart from this, are waste products having no other function.

(3) **Glycogenesis :** Excess quantities of carbohydrates (glucose) are converted to glycogen in the presence of insulin in the liver cells, and stored therein.

(4) **Glycogenolysis :** Glycogen is a reserve food material, which is changed into glucose and released into the blood at concentrations maintained constant by the liver. In this way, blood–sugar level is maintained under diverse dietary conditions.

(5) **Gluconeogenesis :** Under abnormal conditions, liver can convert proteins and fats into glucose by complex chemical reactions. Formation of this "new sugar" *i.e.* from non–carbohydrate sources, is called gluconeogenesis.

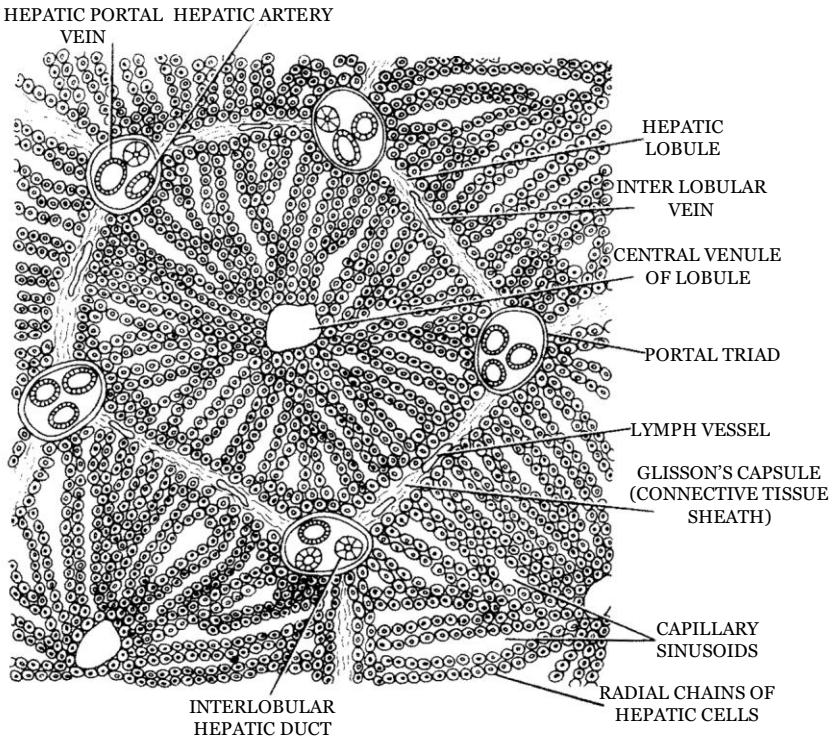



***Fig. – A part of a section of rabbit's liver***

(6) **Lipogenesis :** If the level of blood–glucose rises beyond normal even after glycogenesis and catabolism, the excess glucose is converted into fat and stored in the liver. The process is termed lipogenesis.

(7) **Transamination and deamination :** Amino acids resulting from protein digestion finally come into the liver from the intestine. They are partly released into the blood for distribution and protein synthesis, partly transaminated into other amino-acids and deaminated. Any resulting keto-acids are converted into carbohydrates or fats and the free amino-groups appear as ammonia. This is excreted as such (*e.g.*, aquatic animals) or after prior conversion to urea (*e.g.* amphibians, mammals) or uric acid (*e.g.*, insects and birds).

(8) **Haemopoiesis :** In the embryo, red blood cells are manufactured by the liver. In the adult, liver stores inorganic salts of iron, copper and vitamin $B_{12}$ (anti–anaemic factor) and thus helps in the formation of red blood cells and haemoglobin.

(9) **Store-house of blood :** Liver functions as a store–house for blood and regulates blood–volume.

(10) **Blood clotting :** Fibrinogen, prothrombin and certain other blood coagulation factors are formed in the liver which are instrumental in blood clotting. Heparin is an intravascular anticoagulant that is stored in the liver. It originates in mast cells, which are abundant in the liver, among other sites.

(11) **Production of plasma proteins :** The plasma proteins serum albumin and serum globulin are synthesized by the liver from the amino acids derived from the protein in the diet.

(12) **Synthesis and storage of vitamins :** Liver synthesizes vitamin A from the provitamins A (carotenoid pigments). Liver cells also store fat–soluble vitamins A, D, K and E. Besides, it is the principal storage organ for vitamin $B_{12}$.

(13) **Detoxification :** It is the process by which toxic substances are rapidly made excretable through different biochemical changes. The liver is the site of detoxification of different toxic substances either produced in the body or taken along with food. This is done by the process of oxidation, hydrolysis, reduction and conjugation. Many drugs like phenylbutazone pethidine, chloromycetin etc. are also made excretable by the liver enzymes.

(14) **Alcohol metabolism :** Liver is the main site of alcohol metabolism. By various enzymes in the liver, alcohol is first catabolised to acetaldehyde, which is converted into acetyl CoA. The latter may be oxidised to $CO_2$ and $H_2O$ or converted to other biochemical compounds including fatty acids through TCA cycle. The direct effect of alcohol may be alcoholic fatty liver, which results from increased fatty acid synthesis.

(15) **Desaturation of fats :** Fats is stored in the body in a saturated form (*i.e.*, they cannot take any more hydrogen into their composition). Before the saturated fats can be used by the tissues of the body, they are conveyed to the liver, which converts them into unsaturated form (by the removal of hydrogen). The unsaturated fats are then used by the tissues to provide energy.

(16) **Heat production :** A large number of chemical processes are carried out by the liver, that involve the production of a great deal of heat. It is the main heat producing organ of the body.

(17) **Phagocytosis :** Kupffer cells in the liver sinusoids phagocytose and remove bacteria, worn-out blood elements and foreign particles.

(18) **Lymph formation :** Liver is an important site of lymph formation.

(iii) **Bile/chole :**

(1) Amount : 0.6-1 litre/ day (2) Source : Secreted by hepatic cells

(3) Storage site : Gall bladder (4) Colour : Greenish-blue

(5) Chemical nature : Alkaline (6) *pH* : 7.7-8.0

(7) Control of secretion-Hormonal, hormone concerned is cholecystokinin (cck) or pancreozymin (pz).

(8) Composition –

(i) Water : 90% in (Gall bile), and 98% in hepatic

(ii) Mineral salts and $NaHCO_3$(increases alkalinity)

(iii) Mucous

(iv) Bile salts : Sodium taurocholate and sodium glycocholate causes fat emulsification

(v) Bile pigments : Bilirubin and biliverdin

(vi) Cholesterol

(vii) Lecithin

(viii) Bile pigment bilirubin (yellow colour) and biliverdin green (green colour)

(ix) The quantity of bilirubin is more in carnivorous animals but in quantity of biliverdin is more in herbivorous animal.

(9) Functions of bile

(i) Emulsification of fats.

(ii) Helps in absorption of fat-soluble vitamins.

(iii) Increases alkalinity to make the medium suitable for enzymatic action.

(iv) Elimination of heavy metals such as *Cu, Hg, Zn* etc.

(v) Elimination of excess of bile pigments.

(vi) Stercobilin and urobilin is formed by bilirubin and biliverdin is responsible for colouration of faeces.

## Important Tips

- In human and frog, the common bile duct unites with pancreatic duct to form hepato pancreatic duct or choledochous duct which in turn opens into duodenum.
- In rabbit common bile duct and pancreatic duct opens into duodenum through separate openings.
- Sphincter of boyden is absent in rabbit and frog.
- Ampulla of vater is the dilated sac like structure present near sphincter of oddi in human and rabbit.
- Digestive enzymes are absent in bile juice.
- Jaundice is the yellowing of skin, eyes, nails etc. due presence of increased level of bile pigments especially bilirubin in blood. It may be due to hepatitis or liver cirrhosis (fatty liver syndrome).
- Gall stone under certain abnormal conditions such as too much absorption of water, bile salts or lecithin from bile excess formation of cholesterol, inflammation of gall bladder tissue etc., bile cholesterol precipitates, forming solid crystals called gall stones.
- Cholecystectomy – Surgical removal of gall bladder.
- Liver does not synthesize gamma globulin.
- Phyrygian cap is associated with fundus of gall bladder.
- Bile is produced by hepatocytes.
- Liver produces biles, cholesterol and iron.
- Prussic acid formed during metabolism is rendered harmless by liver.

- Septicaemal anemia causes destruction of liver.
- Gall bladder is absent in adult lamprey, grain eating birds, rats, whales, all the perrissodactyla (odd toed hoofed mammals, such as horse and some Artiodactyla (even toed hoofed mammals).
- Bile is alkaline in man but acidic in cats and dogs.
- Choleretic are substance which increase bile secretion from liver e.g. bile salts.
- Cholagogues are substances which causes the contraction of the gall bladder.
- Sphincter of oddi is present at the terminal end of common bile duct in rabbit and choledochus duct in human but is absent in frog.
- Glisson's capsule is a fibrous connective tissue encloses the lobules of the vertebrate liver.
- Entero – hepatic circulation **–** It is related to the circulation of bile salts. Bile salts enters into the lumen of small intestine through bile. Some amount of bile salts are absorbed along with fatty acids and monoglyceride and ultimately reaches back to the liver. It is known as entero – hepatic circulation.
- Hepatopancreas is a gland found in prawn, which not only secrets an enzymes containing digestive juice but also store glycogen, fat and Ca. It thus act as both the liver and pancrease of vertebrates.
- Obstructive jaundice is the condition when hepatic or common bile duct may be obstructed and failing to be excreted bile by the bile capillaries.

## 3.3 Physiology of digestion

The process of digestion involves following steps –

(i) **Ingestion :** It is the intake of food most of the animals capture the prey/food with the help of mouth or tongue. Such as frog, rabbit, cattle etc. Some are filter–feeders such as paramecium, pila etc. In human food is ingested with the help of hands.

(ii) **Mastication :** The process occurs in the buccopharyngeal cavity of mammals with the help of teeth. During this process food is broken down into small pieces, which increases its surface area. In frog teeth are not meant for mastication but prevents the escape of prey from mouth.

(iii) **Degglutition / swallowing :** The passage of food from buccopharyngeal cavity to oesophagus/stomach. In mammals bolus of the masticated food is formed in buccopharyngeal cavity which easily slides into oesophagus. It is a voluntary reflex mechanism. Peristalsis is alternative contraction and relaxation of circular and longitudinal muscles produces the wave of contraction due to which the food passes from front to backward direction in the lumen of alimentary canal. The phenomenon is called as peristalsis. Beside alimentary canal, it is also found in vas deference, ureter etc.

Peristalsis in stomach is called trituration or pendular movement, in small intestine segmentation pendular movement. Whereas in large intestine (colon) it is called as haustration or segmentation movements. Peristalsis is maximum in oesophagus and minimum in rectum.

Antiperistalsis is the peristaltic wave occurs in the reverse direction. It occurs in alimentary canal and results in vomiting. The phenomenon is called as “Regurgitation”. The food, which passes out through mouth in vomiting, is chiefly of stomach and sometimes from the anterior part of duodenum. Vomiting may also be due to blockage of gut or amalstasis. Vomiting centre is present in medulla oblongata.

(iv) **Digestion :** The process by which complex food is converted into simple food with the help of digestive enzymes. The process of digestion in mammals starts in buccopharyngeal cavity and is found in stomach and small intestine, whereas in frog the process starts in stomach and continues in small intestine.

(a) **Digestion in buccopharyngeal cavity :** In buccopharyngeal cavity of mammals only starch is digested which is 5% of total food or 20-30% of carbohydrates.

(b) **Digestion in stomach :** Chiefly proteins is digested in stomach.

(c) **Digestion in small intestine :** All three component carbohydrates, proteins and fats digested in small intestine with the help of enzymes secreted by pancreas and intestinal glands. About 50% of starch is digested by pancreatic amylase and 10-20% by intestinal amylase. Only 60% of lipids are digested in the small intestine major part of proteins is digested in the stomach. The end product of digestion is as follows

**Summary of chemical digestion of food**

| Chemical digestion of protein | Chemical digestion of carbohydrates | Chemical digestion of fats | Chemical digestion of nucleic acid |
|---|---|---|---|
| **Protein Food**<br>↓ ← Pepsin (gastric juice)<br>**Proteoses and Peptons**<br>↓ Trypsin and Chymotrypsin (pancreatic juice)<br>**Tri and Dipeptides**<br>↓ Peptidases (intestinal juice)<br>**Amino acids** (monopeptides) | **Polysaccharides** (starches)<br>↓ ← Ptyalin (saliva)<br>↓ ← Amylase (pancreatic juice)<br>**Disaccharides** (sugars) ←<br>↓ Maltase, Lactase<br>Sucrase (intestinal juice)<br>**Monosaccharides** (glucose, fructose, galactose) | **Fat**<br>↓ ← Bile salts (bile)<br>**Emulsified Fats**<br>↓ Lipase (pancreatic and intestinal juice)<br>**Fatty acids and glycerol** | **Nucleid acid**<br>↓ (DNA and RNA) Pancreatic<br>↓<br>(DNAase & RNAase)<br>**Nucleotides**<br>Intestinal Nucleotidases and Nucleosidases<br>**Nitrogen bases**<br>Pentose sugars and inorganic phosphate |

(v) **Absorption :** Ingestion and digestion are the first two phases of the physiological processes occuring in the alimentary tract. The third phase is that of absorption by which the digested nutrients are absorb through the wall of gut into blood.

(a) **Absorption from the mouth :** Normally, there is no absorption from the mouth, but a few drugs may be absorbed into the blood through the mucous membrane, if allowed to dissolve under the tongue, *e.g.*, isoprenaline, glyceryl trinitrate.

(b) **Absorption from the stomach :** In the stomach, absorption takes place to a limited degree. The only substances normally absorbed from the stomach are some water, glucose and considerable amounts of alcohol. These substances are absorbed through the walls of the stomach into the venous circulation. Although iron absorption takes place in the

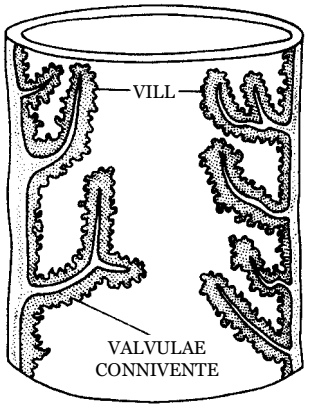



***Fig. – Valvulae conniventes and villi in human intestine***

small intestine, it is dissolved out of foods most effectively in the stomach in the presence of *HCl*.

(c) **Absorption from the small intestine :** The small intestine is the main absorptive organ. About 90% of the ingested foodstuffs is absorbed in the course of passage through the small intestine. The surface area of the intestine through which absorption can take place is vastly increased by the circular folds **(**plicae semilunares) of the mucous membrane and by the large number of villi. The intestinal wall appears very much like a Turkish towel. Surface area of the intestine is further increased by the microscopic folds, the microvilli, protruding out from the surface of the intestinal epithelial cells.

There are two general pathways for the transport of materials absorbed by the intestine; the veins of the hepatic portal system which lead directly to the liver; and the lymphatic vessels of the intestinal area, which eventually lead to the blood by way of the lymphatic system and the thoracic duct.

(1) **Absorption of carbohydrates :** The products of carbohydrate digestion is absorbed from the intestine into blood of the portal venous system in the form of monosaccharides, chiefly the hexoses (glucose, fructose, mannose and galactose). Two mechanisms are responsible for absorption of monosaccharides: active transport (against concentration gradient) and simple diffusion**.** Active transport takes place through carrier proteins and considerable amount of ATP. Sodium ions ($Na^+$) play an important role in this carrier transport system. Hence it is called $Na^+$ co-transport mechanism.

(2) **Absorption of amino acids and protein :** It is probable that under normal circumstances the dietary proteins are almost completely digested to their constituent amino acids and that these end products of protein digestion are then actively transported from the intestine into the portal blood. There are exist several different carrier systems for transporting different classes of amino acids. Some of these required $Na^+$, just as in the case of carbohydrate transport. Surplus amino acids are also withdrawn from portal blood by liver cells and deaminated into ammonia and keto acids. The ammonia is converted to urea and released into blood for excretion by kidneys, while the keto acids are converted to glucose or pyruvic acid and utilized for energy-production or for storage as glycogen and fat.

(3) **Absorption of fats :** The dietary fat is digested, by the action of the pancreatic lipase present in the intestine, partially into glycerol and fatty acids and partially to split products such as monoacyl glycerols. These products of fat digestion enter the mucosal cells of the small intestine in two forms.

(i) Some of the liberated fatty acids and monoacyl glycerols aggregate to form water-soluble particles known as micelles. The structure of a micelles is similar to that of the lipid emulsion except that these are smaller in size. Formation of micelles helps absorption of free fatty acids and monoacyl glycerols from intestinal lumen into the epithelial cells by simple diffusion.

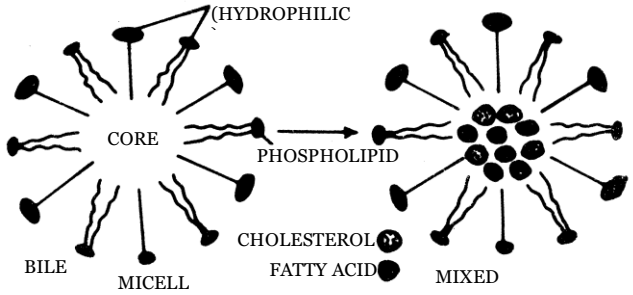



***Fig. – Formation of***

(ii) With the aid of the bile salts many fatty acids and glycerol enter the epithelial cells of the intestinal mucosa. During their passage through the epithelial cells, they combine together resulting in the resynthesis of triacylglycerides.

Coenzyme *A* + Fatty acid $\xrightarrow[\text{ATP}\quad\text{AMP + PPi}]{\text{Thiokinase}}$ Fatty acyl *Co* ~ *A*

Monoglyceride ⟶ Phosphatidic acid ⟶ ↓

Fatty acid ⟶ Diglyceride → Triglyceride (neutral fat)

The resynthesized fat then passes into the lacteals (lymph vessels) of the intestinal villi, primarily in the form of small lipid droplets about 0.5 μm in diameter, known as chylomicrons**.** These small droplets contain about 90% triglyceride and small amounts of phospholipid, cholesterol, free fatty acids and protein. By the lacteals, the fat is carried to the cisterna chyli (meaning 'the receiver of the chyle') and then by the thoracic (lymph) duct to the left branchiocephalic vein, where it enters the blood. The lymph reaching the thoracic duct from the intestines contains an excess of fat giving it a milky appearance. It is called chyle. In this way, fatty acids and glycerol are eventually brought into the blood stream and so, by a circuitous route, to the liver. In the liver, they are reorganized and recombined to form human fat.

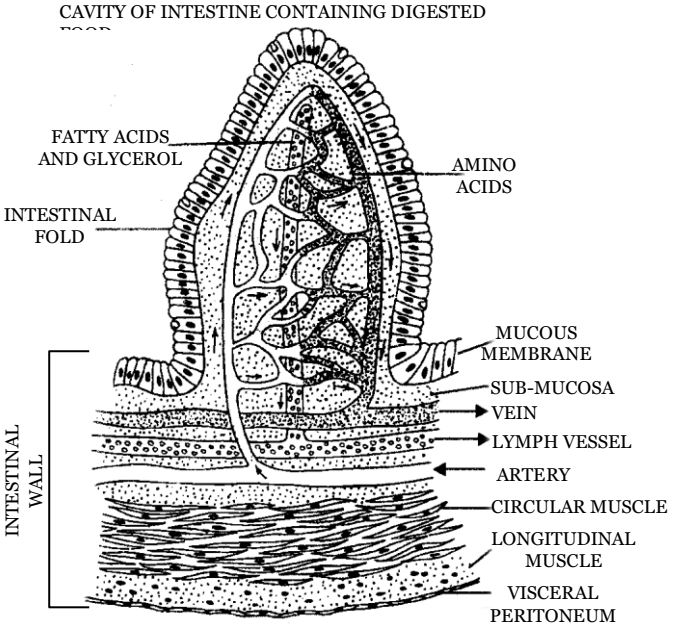



***Fig. – T.S. Intestine showing absorption of food***

(4) **Absorption of vitamins :** Water-soluble vitamins like members of B complex (except $B_{12}$) and vitamin C readily diffuse across the walls of the intestine into the blood. To move vitamin $B_{12}$ across the wall of the ileum, a special system is required. In the stomach, the vitamin combines with a special protein secreted by the gastric glands, known as the castle's intrinsic factor. During the absorption process in the ileum, vitamin $B_{12}$ is released from the intrinsic factor and enters the blood. The fat-soluble vitamins *A*, *D*, *E* and *K* are dissolved in micelles, which enter the mucosal cells of the intestine, by simple diffusion. The absorption of these fat-soluble vitamins is markedly decreased in the absence of bile.

(d) **Absorption in large intestine :** Major part of the water is absorbed in the colon. It helps in maintaining the body water level. Some amount of mineral salts and vitamins are also absorbed. The symbiotic bacteria (*E.* coli) present in the large intestine, converts the inactive vitamins into active forms (*i.e.*, they synthesizes vitamins (vitamin *B* complex and vitamin *K*) which are absorbed. It has

been also found that some amount of amino acids is also absorbed in large intestine produced due to digestion, with the help of symbiotic bacteria. The epithelial cells of large intestine secrete no digestive enzyme.

(vi) **Assimilation :** Conversion of absorbed food into active cytoplasm within cell is called as assimilation.

(vii) **Faeces formation :** The phenomenon occurs in colon due to absorption of water, salts, minerals and vitamins. The peristalsis in colon also helps in faeces formation.

**Differences between diffusion and active transport**

| Diffusion | Active transport |
|---|---|
| It is a physical process. | It is a vital process. |
| It moves small nutrient molecules across the cell membranes only down the concentration gradient. | It moves small nutrient molecules across the cell membranes independent of concentration gradient (both down and against). |
| It does not use carrier protein molecules in moving materials. | It uses carrier protein molecules in moving materials. |
| It does not utilize energy. | It consumes energy derived by hydrolysis of ATP. |
| It is a slow process. | It is a rapid process. |
| No material can be fully absorbed by diffusion. | Materials can be fully absorbed from the intestine. |

(viii) **Egestion / defaecation :** At fairly long intervals, a wave of strong peristalsis sweeps along the transverse colon forcing its contents into the descending and pelvic colons. This is known as mass movement, which is often precipitated by the entry of food into the stomach and is known as the gastro-colic reflex. When a mass movement force the contents of the pelvic colon into the rectum, the nerve endings in the walls of the rectum are stimulated the act of defaecation, while reflex in the infant, and adult is under the control of the will.

(a) **Actions during defaecation**

(1) The sphincter muscle of the anus relaxes.

(2) The muscular walls of the rectum contract.

(3) The muscles of the floor of the pelvis contract.

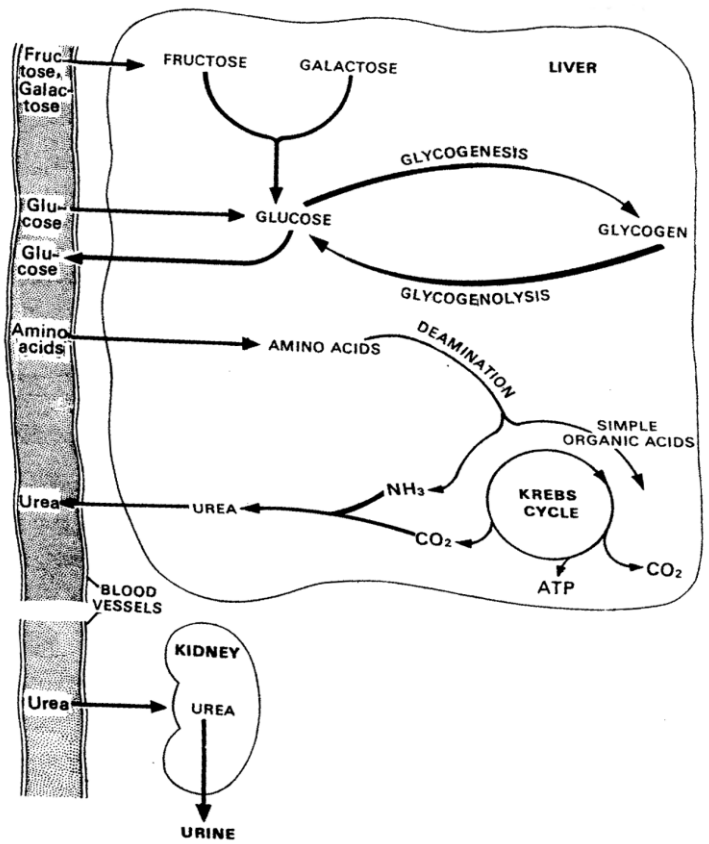



*Fig. – Transformation of absorbed nutrients in liver*

(4) The pressure within the abdomen is raised.

(5) By holding the breath and contracting the diaphragm.

(6) By contracting the muscles of the abdominal wall.

The defecation is carried out in response to the desire in children and adults, to empty the bowel production by distension of the rectum with faeces. Biliverdin and bilirubin are reduced to urobilinogen in the large intestine. Urobilinogen in the large intestine is converted to stercobilin. The odour of the stool is due to aromatic substances like indole and skatole. Indole and skatole result from the action of bacteria on amino acid tryptophan.

(b) **Constituent of faeces :** The faeces, consist of a semi-solid, paste-like mass coloured brown by stercobilin, a pigment derived from the bilirubin and biliverdin of the bile.

(1) Water (65-70% of the total bulk) (2) Undecomposed cellulose

(3) Protein residue (skatole, histidine, indole and tryptophan) (4) Dead and live micro-organisms

(5) Epithelial cells from the walls of the tract (6) Some fatty acids

(7) Mucous-secreted by the mucosa lining of the large intestine.

**Pseudo-rumination or coprophagy :** Animals swallows night faeces and recycle it through the gut to complete the digestion of cellulose and, making full use of their food. This habbit is called coprophagy. Example – Rabbit.

**Summary of physiology of digestion**

**Major gastrointestinal enzyme in mammals**

| Name of gland | Name of digestive juice & optimum pH | Name of enzyme | Site of action | Substrates | Products |
|---|---|---|---|---|---|
| Salivary glands | Saliva (6.8) | Ptyalin / Salivary amylase | Mouth | Starch, dextrins, glycogen | Dextrins, maltose, isomaltose and limit dextrin. |
| Gastric glands | Gastric Juice (1-3) | Pepsin | Stomach | Proteins, casein (Milk) | Peptones, paracasein (curd). Proteases |
| | | Rennin | Stomach | Casein | Paracasein |
| | | Gastric lipase | Stomach | Fats | Fatty acid and Glycerol. |
| Bile juice | Liver | No enzymes | Duodenum | Fat | Makes the food alkaline, emulsifies fat and kills the harmful bacteria. |

| | | | | | |
|---|---|---|---|---|---|
| Liver | Bile ( 7.7 – 8.0) | No enzyme but useful digestive juice, provides alkaline medium, stops the action of HCl. Emulsifies fats and kills – harmful bacteria. | | | |
| Pancreas | Pancreatic Juice (7.3 – 8.6) | Amylase/Diast-ase | Small intestine | Starch, dextrins, glycogen. | 'Limits' dextrins, maltose, isomaltose. |
| | | Trypsin | Small intestine | Proteins, Chymotry-psinogen (inactive) procarboxy pept- idases (inactive) Fibrinogen (blood) Casein (milk) | Peptides, Chymotrypsin (active) carboxy pepti-dases (active) Elastase (active), Fibrin (clot) Para-casein (curd) |
| | | Chymotrypsin | Small intestine | Peptones | Peptides |
| | | Carboxypeptidases | Small intestine | Peptides | Smaller peptides and Amino acids. |
| | | Lipase / Steapsin | Small intestine | Triglycerides | Mono-glycerides, fatty acids |
| | | DNA ase | Small intestine | DNA | Deoxyribonucleotides |
| | | RNA ase | Small intestine | RNA | Ribonucleotides |
| Intestinal glands | Intestinal Juice (7.6–8.3) | Enteropeptidase (enterokinase) | Small Intestine | Trypsinogen (inactive) | Trypsin (active) |
| | | Aminopeptidase | Small Intestine | Peptides | Smaller peptides and amino acid |
| | | Dipeptidases | Small Intestine | Dipeptides 'Limit' dextrins | Amino acids |

| | | | | | |
|---|---|---|---|---|---|
| | | Isomaltase | Small Intestine | Isomaltose | Glucose |
| | | Maltase | Small Intestine | Maltose | Glucose |
| | | Sucrase/Invertase | Small Intestine | Sucrose | Glucose, fructose |
| | | Lactase | Small Intestine | Lactose | Glucose, galactose |
| | | Lipase | Small Intestine | Triglycerides | Monoglycerides, fatty acids |
| | | Nucleotidase | Small Intestine | Nucleotides | Nucleosides, inorganic phosphate |
| | | Nucleoside Phosphorylases | Small Intestine | Nucleosides phosphate | Purine, pyrimidine, pentose, phosphate |

(ix) **Hormonal control of digestion :** Activities of digestive tract are coordinated by nervous and endocrine systems. Sight and smell of food stimulates nervous system which induces the salivary glands to produce large quantity of saliva, stomach to release its hormone gastrin and intestine to produce intestinal hormones. Other hormones are produced in sequential order. All of them are polypeptide hormones.

**Gastrointestinal hormones in mammals**

| Hormone | Source | Stimulus for secretion | Target organ | Action |
|---|---|---|---|---|
| Gastrin | Mucosa of pyloric stomach | Distension of stomach on food entry | Stomach | Stimulates secretion of gastric juice.<br>Constricts cardiac sphincter. |
| Enterogastrone | Duodenal epithelium | Chyme entry into duodenum | Stomach | Slows gastric contractions to delay its emptying.<br>Stops secretion of gastric juice. |
| Secretin | Duodenal epithelium | Acidic chyme entry into duodenum | Pancreas<br>Liver<br>Stomach | Release of sodium bicarbonate in pancreatic juice.<br>Steps up secretion of bile.<br>Inhibits secretion of gastrin. |

| | | | | |
|---|---|---|---|---|
| Cholecystokinin (Pancreozymin) | Duodenal epithelium | Presence of fats in duodenum | Pancreas<br>Gall Bladder | Release of enzymes in pancreatic juice.<br>Release of bile from gall bladder. |
| Villikinin | Intestinal epithelium | Food in small intestine | Intestine | Accelerates movements of villi. |
| Duocrinin | Intestinal epithelium (Duodenal mucosa) | Acidic chyme in intestine | Intestine (Brunner's gland) | Release of viscous mucous from Brunner's glands. |
| Enterocrinin | Intestinal epithelium (Duodenal mucosa) | Acidic chyme in intestine | Intestine (crypts of Lieberkuhn's) | Release of enzymes from Lieberkuhn's crypts. |

## Important Tips

- World food day (W.F.D) is 16$^{th}$ october.
- Iodine deficiency disorder day (I.D.D.D) : is 21$^{st}$ october.
- White revolution – Increased milk production.
- Blue revolution – Increased fish production.
- Yellow revolution – Increased oil production.
- High cholesterol patients are avoided to use groundnut oils, margarine and vegetable oils.
- The foul & flatus odour of the faeces is due to presence of gases such as $CH_4$, $NH_3$, $H_2S$, $CO_2$ etc. and presence of indole, skatole and mercaptones amines formed due to decarboxylation of tryptophan amino acid.
- Digestion of fat is slowest and never completed.
- Main aim of nucleic acid digestion is to release phosphate molecule.
- Villus is the unit of absorption of food.
- Fructose and mannose are absorbed by facilitated diffusion.
- Role of bile salts is to form water soluble mixed micelles is called hydrotrophic action.
- Chyle is the alkaline food, which passes from small intestine to lacteals.
- It takes about 2-6 hours after a meal for the stomach to empty.
- Aminopeptidase, a digestive enzyme produces smaller peptides.
- In most of the vertebrates protein digestion ends in ileum.
- The enzymes that converts glucose to glucose 6-phosphate is hexokinase.
- Amylopsin act on carbohydrates.

- Most of the fat digestion occurs in small intestine.
- Lipase hydrolyse ester bond.
- Protein digestion is necessary because it cannot be absorbed as such.
- Carbohydrate are digested in duodenum.
- Amylase broken 1,4 glycosidic bonds of starch.
- Loose bond of enzymes between proteinous and prosthetic groups can be separated by the process of dialysis.
- Enzyme, vitamins and hormones are biological chemicals which aid in the regulating mechanism.
- Enzymes accelerate the rate of chemical reactions.
- Human insulin is known as Humulin.
- Stimulation of acid secretion of stomach is due to gastrin, histamine and vagal activation.
- The end product of carbohydrate metabolism is $CO_2$ and $H_2O$.
- Mammals also get water from the oxidation of glucose.

## 3.4 NUTRITION

The substance used for nutrition are called nutrients. Nutreology is the study of food and their use in diet and therapy.

(i) **Types of nutrition**

(a) **Autotrophic / Holophytic :** The individuals, which synthesizes their own food. It can be grouped into two following categories –

(1) **Photoautotrophs :** The individual, which synthesizes their own food from $CO_2$ and $H_2O$ in presence of sunlight. These individuals have a specialized pigment chlorophyll in their cells. Examples – Green plants, euglena, green sulphur bacteria, chlorobium.

(2) **Chemoautotrophs :** The individuals which synthesizes their food with the help of chemical. The energy consumed in synthesis of nutrients is obtained from oxidation of hydrogen gas, ammonia, methane, hydrogen sulphide, nitrites etc. Examples – Sulphur bacteria, nitrite bacteria, nitrate bacteria, nitrosomonas, nitrifying bacteria– nitrosomonas, nitrobacter etc.

(b) **Heterotrophic :** The animals derive organic food materials by consuming bodies or products of other living or dead plants or animals. Heterotrophs are of following three types on the basis of their mode of feeding.

(1) **Holotrophic or Holozoic :** These individuals ingest mostly solid food. Example – Animals.

(2) **Saprotrophic or Saprobiotic :** They feed on dead organic matter. They absorb food through their body surface, organic fluids formed due to putrefaction of dead organism. These are called saprozoic if the putrefying organism is an animal and saprophytic**,** if the later is a plant. Saprobionts usually themselves pour out certain enzymes which hydrolyses the complex molecules of putrefied food and help in absorption. Saprozoic nutrition involves absorption of food by osmosis, *i.e.*, through

general body surface. This method of food-getting is referred to as osmotrophy and animals are called osmotrophs. Example – Bacteria, fungi, some protozoans etc.

(3) **Parasitic :** These individuals derive their food from the body of their host. These may live inside or upon the bodies of their hosts, or may only periodically visit them for feeding.

(c) **Myxotrophic nutrition :** They carry out autotrophic as well as heterotrophic nutrition. Example – euglena.

(ii) **Modes of animal nutrition :** On the basis of food, holozoic or holotrophic or ingestive nutritionally animals are classified into following –

(a) **Herbivorous :** The animal which exclusively feeds on plants. Their length of alimentary canal is more as compared to others. Examples – Tadpole larva of frog, rabbit, cow, horse, sheep etc.

(b) **Carnivorous :** The animal which kills and feeds on other animals. The length of their alimentary canal is minimum. Examples – Tiger, lion etc.

(c) **Omnivorous :** The animal which can take both plant and animal product as food. They have maximum type of digestive enzymes. Example – Human.

(d) **Insectivorous :** The animal which feeds on insects. Example – Frog.

(e) **Sanguivorous :** The animal which feeds on blood of other animal. Examples – Leech, body louse.

(f) **Carrion Eaters (scavengers) :** They feeds on dead animals also termed as scavengers. Examples – Hyaena, neltura, kites etc.

(g) **Cannibalus :** Organisms which feeds on its own species. Examples – Cockroaches, some fishes, frog, snakes etc.

(h) **Detritus :** Animals feed chiefly upon organic matters present in the humus. Examples – Earthworm.

(i) **Coprophagus or pseudorumination or refection :** Animals which feeds on their own faeces. Example – Rabbit.

(j) **Larvivorous :** Feeds on larva. Example – Gambusia (mosquito fish).

(k) **Frugivorous :** Feeding on fruits. Example – Parrot.

(iii) **Feeding mechanism**

(a) **Feeding mechanism in liquid feeders (fluid feeders)** are as follows –

(1) **Diffusion :** Many parasitic organisms (protozoans, tapeworm) absorb the dissolved organic food through general body surface.

(2) **Pinocytosis (cell drinking) :** Ingestion of liquid food by invagination through surface of body. Pinocytosis channels are formed at body surface to enclose the fluid food from surrounding medium. Lower ends of channels are pinched off as pinocytic vesicle or pinosomes.

(3) **Blood sucking :** Their mouthparts are modified for sucking blood. Examples – Vampire bat, mosquito etc.

(b) **Feeding mechanism in microphagus animals (filter feeders) :** The food of such animals (paramecium, sponges, corals, bivalves, tadpole etc.) is suspended in water fluid and they have filtering devices (clusters of pseudopodia, cilia, flagella, sheets of mucous etc.) or feeding on small microscopic animals like – Amoeba, paramacium etc.

## 3.5 Nutritional requirements

(i) **Food :** All living organism needs food, animal are unable to synthesize their own food hence they obtain it from outside sources. Animals require food for three main purposes, such as food as a fuel which provides energy and material for body maintenance, food for movement of body includes muscles contraction etc., food for growth as well as for the synthesis of body substances.

(ii) **Components of food :** These are following types –

(a) **Carbohydrates** (b) **Lipids and fats** (c) **Proteins** (d) **Nucleic acid**
(e) **Water** (f) **Vitamins** (g) **Minerals**

(a) **Carbohydrates :** They are made up of *C* : *H* : *O*, having *H* and *O* in the ratio of 2 : 1 and the general formula is $C_nH$ They are the chief source of energy. The source of carbohydrates in our food is cereals and pulses.

(1) **Classification of carbohydrates :** Carbohydrates are grouped into three categories –

(i) **Monosaccharides :** Simplest carbohydrates. They are of following types –

(a) **Trioses :** $(C_3H_6O_3)$; Example – Glyceraldehyde, dihydroxyacetone.

(b) **Tetroses :** $(C_4H_8O_4)$; Example – Erythrose.

(c) **Pentoses :** $(C_5H_{10}O_5)$; Example – Xylose, ribose, arabinose.

(d) **Hexoses :** $(C_6H_{12}O_6)$; Example – Glucose, fructose, galactose.

(e) **Heptoses :** $(C_7H_{14}O_7)$; Example – Sedoheptulose.

(ii) **Oligosaccharides :** They contain 2 – 9 molecules of monosaccharides. They are of following types –

(a) **Disaccharides :** Examples – Maltose (malt sugar), sucrose (cane sugar), lactose (milk sugar), etc.

(b) **Trisaccharides :** Example – Raffinose, mannotriose etc.

(c) **Tetrasaccharides :** Example – Stachyose, scordose etc.

(d) **Pentasaccharides :** Example – Verbascose.

(iii) **Polysaccharides :** Two types –

(a) **Homosaccharides :** When polysaccharides are made up of single kind of monosaccharide. Examples – Starch, glycogen, cellulose, agar-agar and dextrin etc.

(b) **Heterosaccharides :** When polysaccharides are made up of two or more kind of monosaccharides or their derivatives. Examples – Mucopolysaccharides, chitin, peptidoglycan and heparin etc.

(2) **Specific features**

(i) Storage amount : 900 gm approx.

(ii) Storage site : Chiefly liver and muscles.

(iii) Daily requirement : 500 gm approx.

(iv) Source : Chiefly cereals (rice, wheat, maize), pulses, potato, fruits, sugarcane, milk, honey, sugar etc.

(v) Caloric value : 4.1 *k cal./gm*

(vi) Physiological value : 4.0 *k cal./gm*

(vii) Carbohydrates may have an aldehyde (aldoses) or ketone (ketoses) group.

(viii) Simple carbohydrates having free aldose or ketose group are called reducing sugars.

(ix) Reducing sugars can reduces cupric ion to cuprous state (Fehling's or Benedict's solution)

(x) Fructose (levulose) is fruit sugar while glucose (dextrose) is grape sugar as well as blood sugar.

(xi) Two monosaccharides are linked by means of 'glycosidic bond' (*C–O–C*) in formation of a disaccharide. This is a dehydration or condensation reaction.

(xii) Comparing to the milk of cow, buffalo and goat, lactose is highest in human milk.

(xiii) Chitin is a polysaccharide found in the exoskeleton of arthropods. Its basic unit is not glucose but *N*-acetylglucosamine.

(xiv) Our food mostly contains carbohydrates.

(3) **Functions of carbohydrates :**

(i) **As respiratory fuels :** Carbohydrates, especially glucose, are the main respiratory fuels. About 60% of our total energy needs is provided by the breakdown of carbohydrates. Caloric fuel value of one gram of carbohydrates is 4.1 *k cal* of energy while physiological fuel value of one *gram* of carbohydrates is 4.0 *k cal* (17 *kJ*) of energy. To provide energy, the glucose undergoes biological oxidation in the mitochondria (power house) of the cell to produce about 36 or 38 molecules of ATP. So the theoretical recovery of energy from one glucose molecule is 40%. Main reasons for the glucose being chief respiratory fuel are its presence in abundance and its easy oxidisability.

(ii) **Monosaccharides as structural components**

(a) Ribose (Pentose sugar) is component of RNA; coenzymes like NAD, FAD etc., and energy carriers like ATP, GTP etc.

(b) 2'-Deoxyribose (Pentose) is component of DNA.

(c) Galactose is a structural component of medullary sheath.

(iii) **As building blocks :** Monosugars act as monomers for the formation of disaccharides and polysaccharides.

(iv) **Reserve foods :** There are two main polysaccharides which act as reserve foods *e.g.* starch is a storage polysaccharide of plants and is stored as granules in amyloplasts. Glycogen (animal starch) is the principal reserve food of animals and is mainly stored in liver (about 500 *gms.*) and skeletal muscles. Liver glycogen is used to regulate blood sugar level by the process of glycogenolysis or glycogenesis as required while the muscle-glycogen provides energy for muscle contraction.

(v) Excess of glucose may also be changed into fats (lipogenesis) and stored in liver, adipose tissue and mesenteries.

(vi) Glucose has antiketogenic role as it prevents the incomplete oxidation of fats and formation of ketonic bodies in the blood.

(vii) Glucose spares the amino acids for protein synthesis.

(viii) Sucrose is the major form in which sugar is transported in the plant body. Sucrose is storage sugar of sugarcane and sugar beet.

(ix) **Polysaccharides as structural components**

(a) Cellulose, hemicellulose etc. are the main components of cell wall of plants.

(b) Chitin is main component of cell wall of fungi and exoskeleton of crustaceans.

(x) **Anticoagulants :** Heparin prevents the blood clotting inside the blood vessels.

(xi) **Protective coat :** Glycoproteins form a protective layer, glycocalyx, on intestinal cells.

(xii) **Hyaluronic acid :** It acts as a lubricating fluid in the synovial joints between the limb bones.

(xiii) Blood antigens like *A, B* and Rh-factor are glycoproteinaceous and provide immunity to the individual.

(xiv) Sugars are also important components of some glycoproteinaceous hormones like FSH (Follicular stimulating hormone), LH (Luteinizing hormone) etc. FSH controls gametogenesis while LH controls the ovulation and formation of corpus luteum.

(xv) Carbohydrates may be changed into amino acids.

(xvi) Oligosaccharides of cell membrane help in cellular recognition.

(xvii) Cellulose forms roughage of food which stimulates the secretion of digestive juices. It also helps in peristalsis.

(xviii) Cellulose nitrate is used in explosives.

(xix) Carboxy-methyl cellulose is used in cosmetics and medicines.

(xx) Cellulose acetate is used in preparing cellulose plastics, shatter-proof glass, fabrics etc.

**Differences between caloric fuel value and physiological fuel value**

| Characters | Caloric fuel value | Physiological fuel value |
|---|---|---|
| Site of production | Energy in *kcal* produced by the complete combustion of 1 *gm.* of substance in a bomb calorimeter. | Energy in *kcal* produced by the oxidation of 1 *gm.* of substance in the body tissues. |
| Amount of | 1 *gm.* of carbohydrates provide 4.1 *kcal.* | 1 *gm.* of carbohydrates provide 4.0 *kcal.* |

| | | |
|---|---|---|
| energy | of energy. | of energy. |

(b) **Lipids and fats :** Fats and all fat like substances are called lipids. They are composed of *C, H* and *O*. They are insoluble in water but soluble in ether, alcohol, chloroform etc.

(1) **Types of lipids**

(i) **Simple lipids :** Examples – Fats in the body in the form of adipose tissues, fatty acids, wax.

(ii) **Complex lipids :** Examples – Phospholipids, glycolipids etc.

(iii) **Derived lipids :** Obtained by hydrolysis of simple or complex lipids. Examples – Cholesterol, ergosterol.

(2) **Specific features**

(a) Source : Butter, ghee, liver oil, vegetable cooking oil etc.

(b) Daily requirement : 50 *gm.*

(c) Storage site : Subcutaneous fat, adipose cells.

(d) Caloric value : 9.45 k *cal*/*gm.*

(e) Actual value : 9.0 *k cal*/*gm.*

(3) **Functions of lipids**

(i) The fats acts as concentrated fuel. The caloric fuel value of 1 *gm* of fats is 9.45 *kcal*, while the physiological fuel value of 1 *gm* of fats is 9.0 *kcal* (37 *kJ*), which is about 2.25 times more than the energy provided by same amount of glucose.

(ii) The fats are also highly suitable for storage as the reserve food material. It is mainly stored in the liver, beneath the skin, in the brown deposits and in the fat bodies. Normally, the fats constitute about 4% of liver by weight.

(iii) Fats stored in the subcutaneous tissue insulate the body against the loss of heat energy, so conserve the body heat. Thus, fats help in homeothermy.

(iv) Medullary sheath is formed of white fatty substance, myelin, which insulates the nerve fibres and prevents the loss of energy.

(v) Fats from the protective shock absorbing cushions around a number of organs like the eye balls, kidneys (renal fat), ovaries, etc.

(vi) These help in the absorption of fat-soluble vitamins like *A*, *D*, *E* and *K.*

(c) **Proteins :** They are composed of *C. H. O. N* and some of in addition contain *S* and *P.* They are complex, versatile, macromolecules with very high molecular weight. Their unit is amino acids. Out of the 20 amino acids, required in human to build proteins, half of them are essential and rest are non-essential amino acid. Essential amino acids are those, not synthesized by human body and are present in food. The non-essential amino acids are those which can be synthesized by human body.

**Amino acids**

| Dispensable or Essential amino acids | Non-dispensable or Nonessential amino acids |
|---|---|
| *Arginine | Glycine |
| *Histidine | Alanine |
| Isoleucine | Serine |
| Leucine | Aspartic acid |
| Methionine | Asparagine |
| Phenylalanine | Cysteine |
| Threonine | Glutamic acid |
| Tryptophan | Glutamine |
| Lysine | Proline |
| Valine | Tyrosine |

Arginine and histidine are considered semi indispensable amino acids. These two are not essential in the adult organisms.

(1) **Classification of proteins :** They are following types –

(i) **On the basis of structure of molecules**

(a) **Fibrous :** Examples – Collagen, myosin, keratin, fibrin of coagulated blood etc.

(b) **Globular :** Examples – Albumin, globulin, haemoglobin, enzymes, snake venom etc.

(ii) **On the basis of their chemical nature :** The proteins are divided into three categories –

(a) **Simple proteins :** These are formed of peptide chains and yield only amino acids on hydrolysis. On the basis of shape, these may be fibrous proteins *e.g.* collagen of white fibres, elastin of yellow fibres, keratin of exoskeletal structures like nails, horns, hoofs, hair, feather etc.; globular proteins *e.g.* albumins and globulin of blood plasma, protamines, histones, glutelins etc.

(b) **Conjugated proteins :** These are formed of a proteinaceous and a non-proteinaceous prosthetic group. These include nucleoproteins (of chromosomes-DNA and proteins; and ribosomes-RNA and proteins), glycoproteins (of blood-antigens), phosphoproteins (casein of milk), lipoproteins (lipovitellin of egg-yolk), chromoproteins (haemoglobin of RBCs), haemocyanin, rhodopsin (visual purple), iodopsin (visual violet), cytochromes), metalloproteins (carbonic anhydrase enzyme with $Zn^{2+}$) etc.

(c) **Derived proteins :** These are formed by the partial hydrolysis of simple proteins and include peptones, proteoses etc.

(2) **Functions of protein**

(i) Many proteins act as structural proteins and take part in building and repairing of the body tissues so these are essential for the growth, especially for the growing children. These include ossein of the bones, chondrin of the cartilages, collagen of white fibres, elastin of yellow fibres etc.

(ii) Certain proteins act as functional proteins and regulate the metabolism. These includes enzymes like pepsin, trypsin etc. hormones like insulin, TSH etc., carrier proteins acting as permeases in active transport etc.

(iii) During the deficiency of carbohydrates and fats, the proteins are hydrolysed into amino acids which act as respiratory fuels to provide the energy. Caloric fuel value of 1 *gm* of protein is 5.65 *kcal.* while the physological fuel value of 1 *gm* of proteins is 4.0 *kcal*.

(iv) Some proteins take part in the formation of useful products :

(a) Globin protein combines with four haem prosthetic groups to form haemoglobin which transports 97-99% of $O_2$ from the lungs to the body cells.

(b) Actin and Myosin are main structural and functional proteins of the muscles and help in muscle contraction, so in movements and locomotion.

(c) Rhodopsin and Iodopsin proteins are the components of rod and cone cells respectively and help in night and day vision respectively.

(v) $\gamma$-globulins of blood plasma act as antibodies which provide immunity against the microbes.

(vi) Prothrombin and fibrinogen proteins of blood plasma are involved in blood-clotting to prevent excessive bleeding at the injuries.

(vii) Certain proteins of blood act as buffers (*e.g.* haemoglobin) which help in the constancy of *pH* of the body fluids.

(viii) Amino acids of the proteins may transform into carbohydrates and fats.

(ix) Exoskeletal elements like epidermal scales of reptiles; feathers of birds; and hair, nails, claws etc. of mammals are formed of keratin protein. These elements are protective in function.

(x) Hormone receptors are always proteinous in nature and help in biological response from the target cells.

(xi) Some proteins act as reserve food *e.g.* zein of maize and glutein and gliadin of wheat etc. Thus, the proteins are essential for the body growth. Their acute deficiency in the food causes retardation of physical and mental growth. Deficiency of proteins causes two diseases in infants : marasmus and kwashiorkor.

(xii) Protein acts as a building material.

(xiii) As an enzymes & coenzymes.

(xiv) As a hormones.

(xv) As a carrier proteins.

(xvi) As a component of tissue and cell organelles.

(xvii) As a fuel material and biological buffer.

(3) **Specific features**

(i) Source **:** Chief source is pulses, egg, milk, meat, fish, leafy vegetables, soyabean, groundnut etc.

(ii) Daily requirement : 70-100 *gm*.

(iii) Caloric value **:** 5.6 *k cal*/*gm.*

(iv) Physiological caloric value **:** 4 *k cal*/*gm.*

(v) Caloric value and Physiological fuel value and complete combustion of one *gram* of substance produces energy in *kcal* in a bomb calorimeter is called the caloric value of substance, while complete oxidation of one *gram* of substance produces in *kcal* in the body is called physiological fuel value of substance.

| Nutrient | Caloric value | Physiological fuel value |
|---|---|---|
| Carbohydrates | 4.1 *kcal* | 4.0 *kcal* |
| Proteins | 5.65 *kcal* | 4.0 *kcal* |
| Fats | 9.45 *kcal* | 9.0 *kcal* |

(d) **Nucleic acids :** These are compounds of carbon, hydrogen, oxygen, nitrogen and phosphorus. These occur in all body cells and transmit coded informations of all morphological and functional hereditary characteristics from one generation to the next. The molecules of nucleic acids are long-chain polymers of nucleotide monomers. These megamolecules are called polynucleotides. These are the largest and most complex molecules of nature.

Nucleic acids are of two types : Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Only nine types of nucleotide monomers occur in cells; only four of these link by “phosphopdiester bonds” forming polynucleotide chains (megamolecules) of DNA and another four of RNA. Each nucleotide is itself a complex molecule formed by linking of a nitrogenous base, a pentose sugar and a phosphate group. “Phosphodiester bonds” are also dehydration or condensation linkages. Hence, in digestion, nucleic acids of food are hydrolysed first into nucleotides. Then the nucleotide molecules are further degraded to their component nitrogenous bases, pentose sugars and phosphate groups.

(e) **Water :** Water is an essential constituent of protoplasm, which forms the physical basis of life, though it does not yield any energy. The water is an inorganic compound, composed of hydrogen and oxygen in the ratio of 2 : 1. Protoplasm has nearly 90% water, but the human body has approximately 60–70% of water.

(1) **Functions**

(i) Water act as a best solvent.

(ii) Involve in so many metabolic process.

(iii) Act as temperature stabilizer.

(iv) Remove excess of body heat through sweating.

(v) It also act as dispersion medium ioniser, diffusion medium.

(2) **Specific features**

(i) Sources : Metabolic water, liquid food and drinking water.

(ii) Daily requirement : 5- 6 glasses (4-5 *litre*).

(f) **Vitamins**

(1) **Historical review**

(i) N. I. Lunin (1881) discovered vitamins.

(ii) The term 'vitamin' was first used by Funk in 1912.

(iii) Hopkins and Funk (1912) propounded a 'vitamin theory'.

(2) **Definition** : Vitamin are complex organic compounds needed daily in minute quantities and act as growth and metabolic regulatory substances.

(3) **Sources** : Vitamins can only be synthesized by green plants, hence animals depend for their vitamin requirement upon the plants. Human body manufactures vitamin *D* using ultraviolet rays of sunlight and can store A, D and $B_{12}$. The chemical compositions of vitamins are known and it is possible to synthesize them.

(4) **Importance** : The vitamins are not a sources of energy. They regulate the various metabolic processes. They mostly act as the constituents of coenzymes in the cells.

(5) **Type** : Vitamins are divided into two groups –

(i) **Fat soluble vitamin :** *A, D, E* and *K.*

(ii) **Water soluble vitamin :** *B* complex and *C*.

**Fat soluble vitamins**

| Name of vitamins and chemical formula | Discovery | Sources | Daily requirement per day | Functions | Name of Deficiency Disease | Symptoms | Other Features |
|---|---|---|---|---|---|---|---|
| **Vitamin** | Mc- | Vegetabl | 2 mg | Part of | Xerophthal | – Drying | Synthesized |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **A** or **Retinol** or anti xero-phthalmic or anti infection vitamin $C_{20}H_{29}O$ | Collumn and Davis (1913) | es butter liver oils egg yolk, mango and orange, carrot. | | visual pigment, maintenance of epithelia and prevention of keratini-zation of epitheliu m. | mia Night blindness or nyctalopia Keratomalacia. Dermatosis | of eyeball – Unable to see in dim light – Epitheli um keratini sed – Dry scaly skin | and stored in the liver. Destroyed by - strong light. |
| **Vitamin D** or Ergocalci ferol or sunshine vitamin or anti rachitic vitamin $C_{28}H_{44}O$ | Steenbock and Hess 1924**)** | Cod liver oil, butter, fish, eggs, milk, brain, lung, and spleen. | 0.01 mg | Facilitates absorptio n of calcium and phosphor us by intestine and their retention in body and deposition in bones. | Rickets in children Osteomalac ia in adults. | Deformitie s of bones like bowlegs pigeon chest Weak bones liable to easy fracture | Synthesized in the body on exposure of skin (7-hydroxy cholesterol) to light. Destroyed by – oral contracepti ves |
| **Vitamin E** or α Tocopher ol or anti sterility vitamin $C_{29}H_{50}O_2$ | Evan and sore **(**1922**)** | Fresh green vegetable s, meat, yolk, vegetable oils, butter and cheese, peanuts | 20 mg | Antioxida nt and some role in ETS. | Anaemia Sterility Muscular atrophy | Destructio n of RBC. In male causes sterility and in female abortion may occur of offspring. Effect not | Destroyed by UV – rays. It is also used for curing tumour and cancer |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | proved in man.<br>Degeneration of muscles | |
| **Vitamin K** or<br>Phylloquinone or<br>anti haemorrhagic vit-amin<br>$C_{31}H_{46}O_2$ | Dam and Droisy **(**1935**)** | Fresh green vegetables. to matoes, liver, soyabean, cheese, egg. | 0.07 – 0.14 mg | Synthesis of prothrombin for normal clotting of blood. | Haemorrhage | Reduced ability of blood to clot and also leads to haemorrhages. | Vitamin K is synthesised by intestinal microbes present in the intestine.<br>Destroyed by– prolonged use of antibiotics. |

**Water soluble vitamins**

| **Name of Vitamins and Chemical Formula** | **Discovery** | **Sources** | **D.R.** | **Function** | **Name of Deficiency Disease** | **Symptoms** | **Other Features** |
|---|---|---|---|---|---|---|---|
| Vitamin $B_1$ or Thiamine or anti neuritic or antiberiberi<br>$C_{12}H_{16}N_4SO$ | C. Funk **(**1926**)** | Branrice, whole wheat flour, egg, meat, liver yeast etc. | 1-1.5 mg | Act as co-enzyme in cellular respiration, role in nutrition of nerve cells.<br>Essential for carbohydra | Beri- beri – or Dry beri - beri (man)<br>Polyneuritis or (animals) wet beri - beri<br>Cardiovascular | Loss of appetite and weight, retarded growth, muscular dystrophy.<br>Nerves to become extremely irritable. | Beri-beri disease was discovered by Eijkman<br>Destroyed by – cooking |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | te metabolism, protein synthesis and control water balance in body. | atrophy | Heart enlargement | |
| **Vitamin** $B_2$ or G or yellow enzyme or Riboflavin or Lactoflavin or ovaflavin or hepatoflavin $C_{17}H_{26}N_4O_6$ | Warburg and Christain | Cheese, egg, yeast, meat, liver, cereals, green, vegetable. | 1-2 mg | Required for cell growth. Form pair of coenzyme (FMN, FAD). | Cheilosis<br>Glossitis<br>Keratitis | Cracking of skin at corners of mouth<br>Inflammation of tongue<br>Inflammation of skin | Stored in liver, Excess of this is eliminated in urine.<br>It is associated with the physiology of vision |
| **Vitamin** $B_3$ Yeast factor or pantothenic acid or anti graying factor on chick antidermatitis factor $C_9H_{17}O_5N$ | Williams **(**1933**)** | All foods, more in yeast, kidney, liver, egg, meat, milk, ground nut | 5-10 mg | Part of co-enzyme A. needed for cell respiration, necessary for normal skin and nerves. | Burning feet syndrome,<br>Nervous disorder | Nerve degeneration | It occurs in all types of plants and animal tissues.<br>Its deficiency cause graying of hair |
| **Vitamin** $B_5$ or Niacin or Nicotinic | Goldberger (1912) | Fresh meat, liver, fish, milk, | 16-20 mg | It is an essential component of NAD | Pellagra, Dermatitis, | Rough skin<br>Inflammation of skin | It is characterised by 3D's *i.e.* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| acid or pellagra preventing factor $C_6H_5NO_2$ | | cereals, pulses, yeast etc. | | and NADP thus form coenzymes, metabolism of carbohydrates, functioning of gastrointestinal tract and nervous system | Diarrhoea<br>Dementia<br>Death (4-D syndrome) | which becomes scaly and papillated<br>Dehydration<br>Neural deterioration which may lead to madness | dermatitis diarrhoea and dementia<br>Destroyed by – cooking<br>Pellagra preventing factor<br>Goldberger also called Goldberger's p-p factor<br>It is also synthesized by colon bacteria |
| **Vitamin** $B_6$ or pyrido-xine or Rat anti dermat-ities factor $C_8H_{11}O_3N$ | Gyorgyi **(**1928**)** | Brewer's yeast, liver, egg, yolk, kidney, milk, and vegetables. | 2 mg | It is essential component of coenzyme pyridoxal phosphate. It promotes growth in rats used for curing tuberculosis. | Anaemia<br>Dermatitis, paralysis & death of rats.<br>Mental disorder<br>Dermatitis | Nausea, lack of RBC (blood)<br>Disturbance of central nervous system<br>Skin leisons | Term $B_6$ was coined by Gyorgy.<br>Destroyed by – cooking and oral contraceptives |
| **Vitamin H** or $B_7$ or Biotin or coenzyme R or Avidin $C_{10}H_{16}N_2O_3S$ | Bateman and Allison **(**1916**)** | Yeast, vegetables and egg yolk | 150-300 mg | It acts as coenzymes and essential for fat synthesis and energy production | Dermatitis | Scaly and itchy skin | It is synthesized by intestinal bacteria<br>Destroyed by – prolonged use of |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | . | | | antibiotics |
| **Folic Acid or** Vitamin M or folacin or Anti anaemic factor | Day **(**1935**)** | Green vegetable (spinach) Banana, orange and Liver. | 0.4 mg | It forms coenzymes and play essential role in cell metabolism, Necessary for erythropoiesis, required for DNA synthesis. | Megaloblastic anaemia. Sprue | Enlarged RBCs Ulceration of mouth | It is also synthesized by intestinal bacteria Destroyed by - cooking |
| **Vitamin** $B_{12}$ or Cyanocobalamine or Animal protein factor (APF) or Intrinsic factor of castle $C_6H_{66}O_{14}N_{14}PCo$ | Rickets **(**1948**)** | Meat, egg, liver, fish, synthesized by intestinal bacteria. | 0.003 mg | Required for chromosome duplication and formation of blood corpuscles. | Pernicious anaemia | Reduced formation of erythrocytes in bone marrow | It is also known as anti pernicious factor Also synthesized by intestinal bacteria in human colon Destroyed by – excessive heat |
| **Vitamin C** or Ascorbic Acid $C_6H_6O_6$ | Szent Gyorgyi **(**1928**)** | Citrus fruits such as lemon, mango, amla, plumes, guava. | 40-60 mg | Functions as part of oxidation-reduction system. Helps in secretion of collagen | Scurvy. | Spongy and bleeding gums, fragile blood vessels and bones. | Required by primates, all other vertebrates and some other invertebrates can |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | cement dentine.<br>Helps body to develop resistance to diseases.<br>Helps in absorption of Ca and Fe in the intestine.<br>Wound healing. | | | synthesize vitamin C. It is the earliest known vitamin.<br>It is wound healing vitamin.<br>Destroyed by –<br>Heating |

| Name of Vitamin | Function | Symptoms of deficiency |
|---|---|---|
| Inositol or mouse antialopecia factor | Stimulate growth of mice. Spectacle-eye condition in rat can be treated keep a limit on the cholesterol level in the blood of man. | Causes reduced growth and alopecia (loss of hair) in the mice. Also causes hemorrhagic degeneration of the adrenal gland. |
| Choline | It is an important lipotropic factor which prevent excessive development of fatty liver. It takes part in the formation of acetylcholine which involved conduction of nerve impulse. | Chronic deficiency causes cirrhosis in the liver also causes haemorrhagic changes in kidney. |
| Vit.P or citrin | Control the permeability and fragility of the capillary wall to plasma protein. | Its deficiency causes subcutaneous bleeding due to break down of capillary walls. |

(g) **Minerals elements :** They forms approximately 5% of body weight. They are essential to regulate the various metabolic activities of the animals. The various type of mineral are group into two categories as minor element. Examples – *Ca, S, P, Na* etc. and trace element examples – *Cu, Zn, Mn* etc. Some of these minerals are described as follows –

**Chart of important minerals required in animal bodies**

| Mineral elements | Sources | Significance | Effects of deficiency |
|---|---|---|---|
| **Minor elements**<br>(1) Calcium–*Ca* | Milk, Cereals, Cheese, Green Vegetables, Pods. | Required for formation of teeth and bones, blood clotting, functions of nerves and muscles. | Weak teeth and bones; retarded body growth. |
| (2) Phosphorus–*P* | Milk, Meat, Cereals. | Required for formation of teeth and bones and acid-base balance; component of ATP, DNA, RNA. | Weak teeth and bones; retarded body growth and physiology. |
| (3) Sulphur–*S* | Many proteins of food. | Component of many amino acids. | Disturbed protein metabolism |
| (4) Potassium–*K* | Meat, Milk, Cereals, Fruits and Vegetables. | Required for acid-base balance; water regulation and function of nerves. | Low blood pressure, weak muscles; risk of paralysis. |
| (5) Chlorine–C*l* | Table Salt. | Required for acid-base balance; component of gastric juice. | Loss of appetite; muscle cramps. |
| (6) Sodium–*Na* | Table Salt. | Required for acid-base and water balances and nervous functions. | Low blood pressure, loss of appetite; muscle cramps. |
| (7) Magnesium–*Mg* | Cereals, Green Vegetables. | Cofactor of many enzymes of glycolysis and a number of other metabolic reactions dependent upon ATP. | Irregularities of metabolism, principally affecting nervous functions. |
| (8) Iron–*Fe* | Meat, Eggs, Pods, Cereals, Green Vegetables. | Component of haemoglobin and cytochromes. | Anaemia weakness and weak immunity. |
| (9) Iodine–*I* | Milk, Cheese, Seafood, Iodized salt. | Important component of thyroxin hormone and regulate metabolism of cell. | Goitre, cretinism. |
| **Trace Elements**<br>(10) Fluorine–*F* | Drinking water, Tea, Seafood | Maintenance of bones and teeth. | Weak teeth, Larger amount causes mottling of teeth. |
| (11) Zinc–*Zn* | Cereals, Milk, Eggs, Meat, Seafood | Cofactor of digestive and many other enzymes. | Retarded growth, anaemia, rough skin, weak immunity and fertility. |

| | | | |
|---|---|---|---|
| (12) Copper–*Cu* | Meat, Dry fruits, Pods, Green Vegetables, Seafood. | Cofactor of cytochrome oxidase enzyme. Necessary for iron metabolism and development of blood vessels and connective tissues. | Anaemia, weak blood vessels and connective tissue and damage to central nervous system. |
| (13) Manganese–*Mn* | Dry fruits, cereals, Tea, Fruits and Green Vegetables. | Cofactor of some enzymes of urea synthesis and transfer of phosphate group. | Irregular growth of bones, cartilages and connective tissues. |
| (14) Cobalt–*Co* | Milk, Cheese, Meat. | Important component of vitamin $B_{12}$ | Anaemia. |
| (15) Selenium–*Se* | Meat, Cereals, Sea food. | Cofactor of many enzymes; assists vitamin E. | Muscular pain; weakness of cardiac muscles. |
| (16) Chromium–*Cr* | Yeast, Seafood, Meat, Some vegetables. | Important for catabolic metabolism. | Irregularities of catabolic metabolism and ATP production. |
| (17) Molybdenum–*Mo* | Cereals, Pods, Some Vegetable | Cofactor of some enzymes. | Irregular excretion of nitrogenous waste products. |

## Important Tips

- Fructose is the sweetest sugar found in fruits but not in grapes.
- Glucose is most common sugar.
- Glycogen is also called as "animal starch".
- Carbohydrates are the chief energy yielding substance.
- Histidine is an essential amino acid for infants but not for adult.
- Cysteine and tyrosine are considered to be semiessential amino acids. Premature infants and adults who are ill require them.
- Proteins are the "body builders" as they are the chief constituents of the protoplasm. They form approximately 14% of dry body weight in human.
- Frog never drinks water.
- Camel can live without water for a considerable day, as it uses its metabolic water, which comes from of the oxidation of fats present in hump.
- Zinc is necessary to maintain plasma concentration of vitamin A.
- Tea/Coffee inhibit the absorption of iron from the diet. Prolonged consumption of tea/coffee after meal can lead to iron deficiency anemia.
- Vertebrates cannot digest keratin protein of hair, nails, fibroin protein of silk fibers etc, but certain insects can digest these proteins so damages silken and woolen garments.
- Dyspopsia – Indigestion due to defective diet.

- Vitamin C was the first vitamin to be produced during fermentation process using wild bacteria.
- An alcoholic is always deficient of vitamin C.
- Excessive intake of vitamin A causes bone reabsorption and hypercalcemia.
- Some of the bacteria including Escherichia coli present in the large intestine or colon produce vitamin k, which is absorbed by the host and this is probably the main source of this vitamin for human.
- Vitamin $B_{17}$ is a recently discovered vitamin with anti–cancer property.
- Most of the B-complex vitamins are coenzymes.
- Presently vitamin $B_{12}$ is produced directly during the course of fermentation by propioni bacteria and certain strains of Pseudomonas.
- Vitamins, which are synthesized by the intestinal flora are vitamin K. Thiamine, Riboflavin, Pantothenic acid, Niacin, Pyridoxin, Biotin and Folic acid.
- Overcooking, excessive alcohol, tobacco and coffee, certain medicine etc. destroys vitamin.
- Effect of the reflex action due to the taste of food is the release of vagal impules.
- Gama – linolenic acid and arachidonic acids are essential fatty acid in mammals.
- Glycine is simple amino acid.
- Phenyl alanine amino acid is denoted by symbol F.
- Vitamin nicotinamide functions as reducing agent.
- Vitamin 'D' is a steroid vitamin.
- The overdosage of vitamin 'A' causes injury to lysosomes.
- Vitamin 'C' is present in large amount in the body in adrenal cortex.
- Vitamin $B_6$ is essential for transmission.
- Deficiency of vitamin H (biotin) cause rise of blood cholesterol.
- Frog tadpole is delayed in metamorphosis due to less amount of iodine in water.
- The most complex amino acid having double rings structure is tryptophan.
- The intestinal bacteria are able to synthesize both essential amino acids and vitamins in ruminants.
- Proteins which contain most of the essential amino acids are termed first class, while those do not, are called second class.
- Animal proteins are mostly first class and plant proteins are second class proteins.
- Whiptail disease is caused due to the deficiency of molybdenum.

**Composition of milk**

| Species | Water | Protein | Fat | Lactose |
|---|---|---|---|---|
| Camel | 87.2 | 3.7 | 4.2 | 4.1 |
| Cow | 87.2 | 3.5 | 3.7 | 4.9 |
| Buffalo | 78.6 | 5.9 | 10.4 | 4.3 |
| Goat | 86.5 | 3.6 | 4.0 | 5.1 |
| Human | 87.5 | 1.0 | 4.4 | 7.0 |

**Balanced diet for moderately active adult Indian**

| Name of food | Recommended amounts (*gms.* per day) | |
|---|---|---|
| | **Adult man** | **Adult woman** |
| (1) Cereals (Wheat/Rice) | 520 | 440 |
| (2) Pulses | 50 | 45 |
| (3) Milk | 200 | 150 |
| (4) Meat/Fish or Egg | 30 | 30 |
| (5) Fats (Oil, Butter, Ghee) | 45 | 25 |
| (6) Sugar/Molasses | 35 | 20 |
| (7) Root and Tubers (Raddish, Potato, etc.) | 60 | 50 |
| (8) Green leafy vegetables | 40 | 100 |
| (9) Other vegetables | 70 | 40 |

## 3.6 Nutritional imbalances and disorders

(i) **Balanced diet :** The diet which contain the various nutrients in such proportions as can satisfy all the various needs of our body, is called a "balanced diet". The proportion of carbohydrates, proteins and fats into fulfill energy requirement is 4 : 1 : 1 *i.e.* 65% of energy is obtained from carbohydrates and 10–20% each from proteins and fats. This amount of energy is fulfilled by intake of 400–600 gm of carbohydrates, 80–100 gm of proteins and 50–60 gm of fats. The balanced diet must also contain sufficient amount of minerals and vitamins.

(ii) **Metabolic rates**

(a) **Basal metabolic rate :** Amount of energy required daily by a person to maintain its basal metabolism and is about 1600 *k cal*/day.

(b) **Routine metabolic rate :** Amount of energy required daily by a person to do his routine work. It is about 2800 k cal/day for males and 2300 k cal for female.

(c) **Active metabolic rate :** Amount of energy required daily by a person to maintain its high metabolic rate during heavy physical work and is about 6000 k cal/day for males and 4500 k cal for females. It has been scientifically determined that a child of 4–6 years approximately requires 1500, a child of 13–15 years requires 2500 and a youth of 16–18 year requires 3000 k cal of energy per day. The average metabolically available energy for each gram of carbohydrate is 4.0 k cal, for proteins is 4.0 k cal and for fats, it is 9.1 k cal.

(iii) **Nutritional disorders :** Every organism requires an adequate supply of nutrients in proper proportion in their diet for proper growth and development. There are two types of nutritional disorders

(a) Under nutrition (malnutrition)

(b) Over nutrition

(a) **Diseases due to deficiency of nutrition (malnutrition)**

| Name of the Deficiency | Deficient Nutrient | Symptoms |
|---|---|---|
| Anaemia (microcytic) | *Fe* | Haemoglobin and number of erythrocytes gets reduced. |
| Megaloblastic anaemia | Folic acid and $B_{12}$ | Presence of immature erythrocytes in blood. |
| Pernicious anaemia | Vitamin $B_{12}$ | Immature RBC without Hb. This may be fatal unless treated with vitamin $B_{12}$ injection. |
| Xerophthalmia | Vitamin *A* | Thickened, keratinised, opaque ulcerated cornea. Prime cause of blindness in India, especially among children. |
| Night Blindness | Vitamin *A* | Less rhodopsin in rod cells of retina. So no vision in dim light. |
| Rickets (in children) | Vitamin *D* | Weak, soft, thin bones due to poor deposition of Ca and P. Bent long bones and painful swelling on wrist, elbow and knee joints. |
| Osteomalacia (adults) | Vitamin *D* | Weak bones of vertebral column, pelvis gets bent and deformed by body weight. |
| Sprue | Folacin | Ulceration of mouth, inflammation of bowel, indigestion, diarrhoea, weakness. |
| Pigeons breast | Vit. – D | Incomplete ossification at the end of limb bone, deformed ribs leading to pigeons breast. |
| Beri – beri | Vitamin $B_1$ (Thiamine) | Reduces aerobic carbohydrate metabolism. So peripheral nerves inflammed causing pain, numbness and weakness of limb muscles. Paralysis.<br>Fluid accumulation in tissues or oedema of hands and legs. Cardiac oedema. |
| Scurvy | Vitamin *C* | Fragile blood vessels because of defective collagen fibres in their walls. Bleeding gums, teeth fall, bones fragile. Wound healing delayed, vitamin C recommended in serious injury. |
| Bleeding disease (Hypoprothrombin | Vitamin *K* | Delayed blood clotting (s) so profuse bleeding. |

| | | |
|---|---|---|
| anaemia) | | |
| Marasmus | Protein / Malnutrition | Growth and replacement of tissue proteins imparted so emaciated body with their limbs and prominent ribs, dry, thin and wrinkled skin, Diarrhoea. |
| Kwashiorkor | Protein | Wasting muscles, thin limbs, Retarded growth of body and brain, Oedema, Diarrhoea. |
| Pellagra | Nicotinamide | Swollen lips, thick pigmented skin of hands and legs. Irritability. |
| Osteoporosis | *Ca* | Weakning of bones, tooth decay. |
| Goitre | $I_2$ | Enlargement of thyroid gland. |
| Muscular cramps | *NaCl* | Pulling of muscles due to dehydration. |
| Dental cramps | Fluorine | Tooth decay. |

**Daily Dietary Requirements of Nutrients**
**(Recommended by Indian Council of Medical Research)**

| **Individual** | **Total *kcal*** | **Protein (*gms.*)** | **Calcium (*gms.*)** | **Iron (*mgs.*)** | **Vitamin *A* (*μg.*)** | **Thiamin (*mgs*)** | **Riboflavin (*mgs.*)** | **Niacin (*mgs.*)** | **Folacin (*μg.*)** | **Vitamin $B_{12}$ (*μg.*)** | **Vitamin *C* (*mgs.*)** | **Vitamin *D* (IU)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Man Moderately active | 2800 | 55 | 0.4-0.5 | 24 | 750 | 1.4 | 1.7 | 19 | 100 | 1 | 40 | |
| (2) Woman | 2200 | 45 | 0.4-0.5 | 32 | 750 | 1.1 | 1.3 | 15 | 100 | 1 | 40 | |
| (i) Moderately active | 2700 | 59 | 1.0 | 40 | 750 | 1.3 | 1.5 | 17 | 300 | 1.5 | 40 | |
| (ii) Pregnant | 2750 | 70 | 1.0 | 32 | 1150 | 1.4 | 1.6 | 19 | 150 | 1.5 | 80 | |
| (iii) Lactating | | | | | | | | | | | | |
| (3) Boy (16-18 years) | 2820 | 53 | 0.5-0.6 | 25 | 750 | 1.4 | 1.7 | 19 | 100 | 1 | 40 | 200 |
| (4) Girl (16-18 years) | 2200 | 44 | 0.5-0.6 | 35 | 750 | 1.1 | 1.3 | 15 | 100 | 1 | 40 | 200 |

(b) **Diseases due to over nutrition**

(1) **Fluorosis :** Caused due to excess of fluorides. It results in tooth and bone decay.

(2) **Obesity :** This is over–nutritional disorder. It is caused when "energy inputs exceeds energy output". It results in deposition of excess fat in the body.

(3) **Constipation :** Slow movement of faeces down the large intestine causes accumulation of dry and hard stool is colon. It is generally caused by irregular bowel habits.

(4) **Diarrhoea :** Rapid movement of faecal matter down the large intestine causes loose stools called diarrhoea. It may be also caused by viral or bacterial infections of intestinal tract, particularly of large intestine and by nervous tension.

(5) **Piles or haemmorhoids :** Enlargement of the anal veins. It may be either hereditary or may be caused due to rapid changes in the diet.

(6) **Hypercholesterolemia :** Caused due to excess of saturated fats like butter, ghee, hydrogenated vegetable oils and eggs etc. It results in increased level of cholesterol in blood, arteriosclerosis, coronary thrombosis, heart attack etc.

(7) **Hypervitaminosis *A* :** It results in loss of appetite, body hairs, painful swelling etc.

(8) **Hypervitaminosis *D* :** It results in deposition of calcium ion in the soft tissues of the body.

**Differences between Kwashiorkor and Marasmus**

| Kwashiorkor | Marasmus |
|---|---|
| (1) It is caused by deficiency of protein in the diet. | (1) It is caused by prolonged deficiency of proteins and calories in the diet. |
| (2) It commonly affects babies between 1-3 years of age. | (2) It affects infants under one year of age. |
| (3) Subcutaneous fat persists. | (3) Subcutaneous fat is used up, making ribs very prominent. |
| (4) Oedema affects legs and face. | (4) No oedema occurs |
| (5) Skin and hair change colour. | (5) No change in skin and hair colour. |
| (6) Body becomes under weight. | (6) Body becomes very under weight. |
| (7) Appetite is reduced. | (7) Appetite is not effected. |
| (8) Patient needs proteins to recoup. | (8) Patient needs proteins as well as carbohydrates and fats to recover. |

## 3.7 Regulation of food intake

(i) **Hunger :** Hunger is defined as the intrinsic (involuntary) desire or craving for food. Hunger is associated with a number of objective sensations. For instance, food deprival for many hours causes intense rhythmic hunger contractions in stomach, which even causes intense pain (hunger pangs) send sensory impulses to a "hunger or feeding centre", located in the lateral regions of hypothalamus.

When glucose levels fall in blood, hunger centre stimulated. Hunger centre transmits impulses to wall of stomach and wall of empty stomach start contraction or hunger pangs. After taking meal satiety centre which located in hypothalamus stimulates and feeding is stopped. During high fever person does not feel like taking meal because high temperature shuts off the appetite centre.

(ii) **Thirst :** Subconscious desire for water is called thirst. It is also induced by a hypothalamic "thirst centre". When amount of water decreases in body fluids (blood, lymph, tissue fluid, cerebrospinal fluid etc.) due to fever, exercise and sweating, copious urination, diarrhoea, etc. This induces the feeling of thirst. Presumably, a fall in glucose level in the blood also induces thirst.

(iii) **Theory of regulation of food intake :** They are following –

(a) **Neuronal theory :** According to this theory, two different type of centers are present in the hypothalamus which regulates hunger. These centre are appetite and satiety. Appetite centre is often used to imply a conscious desire for specific or selected type of food. Interoceptors of stomach wall, stimulated by the muscular contraction, send sensory impulses to the hunger centre located in the lateral region of hypothalamus. Satiety is the conscious sensation of food sufficiency leading to a voluntary cessation of eating. The centre is located in the ventromedian regions of hypothalamus.

(b) **Glucostatic theory :** When the blood glucose level decreases we feel hungry. It is also caused due to low level of amino acids and fatty acids, and when the level of these substances increases in blood, satiety centre stimulates.

(c) **Thermostatic theory :** Decrease in body temperature increases hunger due to increased metabolic rate. Conversely, an exposure to heat, or increases in body temperature reduces hunger due to decreased metabolic rate. These conditions are caused by interactions between hypothalmic temperature regulating and food intake–regulating system.

# ASSIGNMENT

## ALIMENTARY CANAL

***Basic Level***

**1.** Dental formula of rabbit is

(a) $\frac{2,0,3,3}{1,0,2,3}$ (b) $\frac{1,0,2,3}{2,0,2,3}$ (c) $\frac{1,0,3,3}{2,2,0,3}$ (d) $\frac{2,1,2,3}{2,1,2,3}$

**2.** False teeth are best developed in

(a) Amphibia (b) Cyclostomes (c) Reptiles (d) Birds

**3.** Which teeth in rabbit have open pulp cavity

(a) Molar (b) Premolar (c) Incisor (d) Canine

**4.** Teeth are absent in

(a) Fishes (b) Reptiles (c) Frogs (d) Turtle

**5.** Ivory of teeth is

(a) Enamel (b) Dentine (c) Both (d) None of these

**6.** In the gut of a mammal, haustra and taeniae are the parts of

(a) Rectum (b) Colon (c) Caecum (d) Ileum

**7.** Space between incisor and cheek teeth in rabbit is

(a) Diapause (b) Diastema (c) Dialysis (d) Diapedesis

**8.** Taste buds are absent in

(a) Foliate papillae (b) Circumvallate papillae

(c)Fungiform papillae (d) Filiform papillae

**9.** Which of the following is vestigial teeth found in human

(a) Incisors (b) Premolars (c) Diphyodont (d) Wisdom tooth

**10.** Which of the following is the correct dental formula of man

(a) $\frac{2,1,3,2}{2,1,3,2}$ (b) $\frac{2,1,2,3}{2,1,2,3}$ (c) $\frac{2,2,2,2}{2,1,3,2}$ (d) $\frac{2,1,1,4}{2,1,2,3}$

**11.** Cells secreting dentine are called

(a) Osteoblasts (b) Calcoblasts (c) Chondriocytes (d) Odontoblasts

**12.** The diastema is the toothless gap (in the jaw of the rabbit)

(a) Between the right and left incisors (b) Between the incisors and premolars

(c) Between the premolars and molars (d) Behind the molars

**13.** Pulp in case of tooth is covered by

(a) Root (b) Crown (c) Enamel (d) Dentine

**14.** Pulp cavity of a tooth contains

(a) Food (b) Blood (c) Mass of capillaries (d) Odontoblasts

**15.** Bulk of the tooth in mammals is made up of

(a) Dentine (b) Enamel (c) Pulp cavity (d) Root

**16.** In mammals the lower jaw is made up of

(a) Dentaries (b) Maxilla (c) Premaxilla (d) Palatine

**17.** The hardest substance of vertebrate body is

(a) Keratin (b) Enamel (c) Dentine (d) Chondrin

**18.** If the dental formula of Rabbit is 2033/1023. What does it show

(a) Total number of teeth in Rabbit is 15

(b) Number of total incisors in Rabbit is 3

(c) Diastema is present between incisors and premolars

(d) In the formula 2033 is for adult and 1023 is for young ones

**19.** Tusk of an elephant is an enormously enlarged

(a) Upper canine (b) Lower incisor (c) Upper incisor (d) Lower canine

**20.** Diastema is associated with

(a) Presence of certain teeth (b) Absence of certain teeth

(c) Presence of tongue (d) Absence of tongue

**21.** The function of tongue is to

(a) Help in the act of swallowing (b) Help in mixing saliva with the food

(c) Help in speaking (d) All of these

**22.** Teeth in frog are

(a) Acrodont (b) Homodont (c) Polyphyodont (d) All of these

**23.** Thermo-regulation in dogs takes place by

(a) Skin (b) Sweat glands (c) Tongue (d) Deposited fat

**24.** Pulp cavity of teeth opens

(a) Below the teeth (b) In front of teeth (c) Behind the teeth (d) None of these

**25.** Layer of cells that secrete enamel of tooth is

(a) Osteoblast (b) Ameloblast (c) Odontoblast (d) Dentoblast

**26.** An animal without gall bladder is

(a) Horse (b) Cat (c) Dog (d) Human

**27.** Intestinal villi are mainly connected with

(a) Assimilation (b) Absorption (c) Secretion (d) Ultra-filtration

**28.** Part of tongue that gives feeling of sweetness is

(a) Tip (b) Lateral edges (c) Middle part (d) Posterior part

**29.** Number of canines in upper half jaw is

(a) 4 (b) 3 (c) 2 (d) 1

**30.** Gall bladder is attached to liver in the region of

(a) Quadrate lobe (b) Caudate lobe (c) Right lobe proper (d) Left lobe

**31.** The stomach takes part in

(a) Breaking food mechanically (b) Partially digesting the food

(c) Disinfecting the food (d) All of these

**32.** Uvula can close the opening of

(a) Larynx (b) Gullet (c) Internal nares (d) Eustachian tubes

**33.** Which is a common passage in swallowing food and breathing

(a) Larynx (b) Pharynx (c) Glottis (d) Gullet

**34.** Which of these terms is used for two different parts applied with a slight difference in its spelling, not in pronunciation

(a) Ileum (b) Intestine (c) Cloaca (d) Pelvis

**35.** In ruminant stomach, the rumen is the

(a) Largest chamber

(b)Chamber having cellulose fermenting microorganisms

(c) Chamber having villi with cornified surface (d) All of these

**36.** Bile can be prevented to pass into duodenum by

(a) Pyloric valve (b) Sphincter of Boyden (c) Sphincter of Oddi (d) Cardiac Sphincter

**37.** Ileum is characterised by

(a) Brunner's glands and leaf like villi (b) Brunner's glands and club shaped villi

(c) Club- shaped villi and Peyer's patches (d) Peyer's patches and Brunner's glands

**38.** An alimentary canal is absent in the animals belonging to the class

(a) Apoda (b) Cestoda (c) Gastropoda (d) Arachnida

**39.** Vestibule is

(a) Part of pharynx (b) Part of buccal cavity

(c) Space between jaw and lips (d) Part of tongue having tonsils

**40.** Uvula is part of

(a) Tongue (b) Soft palate (c) Hard palate (d) Epiglottis

**41.** Transverse rugae occur on

(a) Hard palate (b) Soft palate (c) Tongue (d) Stomach

**42.** Frenulum is

(a) Adenoid present on pharyngeal wall

(b) Tonsil found on lateral walls of soft palate

(c) *V*-shaped sulcus dividing tongue into pharyngeal and oral parts

(d) Fold attaching tongue

**43.** Monophyodont teeth occur in

(a) Humans (b) Frog (c) Whale (d) Rat

**44.** Teeth of most reptiles and amphibians are

(a) Acrodont (b) Thecodont (c) Heterodont (d) Diphyodont

**45.** Anus is absent in

(a) Unio (b) Fasciola (c) Periplaneta (d) Pheretima

**46.** The vermiform appendix is situated at the junction of

(a) Large intestine and small intestine (b) Small intestine and duodenum

(c) Anus and rectum (d) Stomach and duodenum

**47.** Appendix in man is situated in

(a) Left hypochondrium (b) Right hypochondrium (c) Left iliac fossa (d) Right iliac fossa

**48.** In vertebrates, lacteals are found in

(a) Ileum (b) Ischium (c) Oesophagus (d) Ear

**49.** Peyer's patches are associated with the intestine and vermiform appendix in mammals. These are

(a) Digestive (b) Lymphoid (c) Secretory (d) Excretory

**50.** Longest oesophagus is found in

(a) Swan (b) Crocodile (c) Snake (d) Giraffe

**51.** In man the length of alimentary canal is about

(a) 8 feet (b) 16 feet (c) 24 feet (d) 32 feet

**52.** Hernia is a disease where there is

(a) Descend of intestine into inguinal canal (b) Hardening in the muscles

(c) Weakening of thigh (d) Weakening of intestine

**53.** The muscular contraction in the alimentary canal is known as

(a) Systole (b) Diastole (c) Peristalsis (d) Metachronal

**54.** Vermiform appendix is a part of

(a) Alimentary canal (b) Nervous system

(c) Vascular system (d) Reproductive system

**55.** Narrower distal end of stomach is called

(a) Cardiac (b) Duodenum (c) Pharynx (d) Pylorus

**56.** Brush bordered epithelium is found in

(a) Trachea (b) Stomach (c) Small intestine (d) Fallopian tube

**57.** Crypts of Lieberkuhn are present throughout the

(a) Large intestine (b) Gastric mucosa

(c) Submucosa of the duodenum (d) Small intestine

**58.** Lacteals are found in

(a) Liver (b) Lungs (c) Kidney (d) Villus of intestine

**59.** The outermost layer of an alimentary canal is known as

(a) Mucosa (b) Muscular layer (c) Serosa (d) Submucosa

**60.** The main region of the alimentary canal in which digested food is absorbed

(a) The oesophagus (b) The stomach

(c) The small intestine (d) The caecum and appendix

**61.** Crypts of Lieberkuhn contain one of the following part

(a) Kupffer cell (b) Villi of ileum (c) Mast cells (d) Villi of stomach

**62.** Pylorus is situated at the junction of

(a) Oesophagus and stomach (b) Stomach and duodenum

(c) Duodenum and ileum (d) Ileum and rectum

**63.** Lacteals are central lymph vessels which are found in

(a) Liver (b) Pancreas (c) Villi (d) Spleen

**64.** The most important centre for the formation of lymph is

(a) Liver (b) Pancreas (c) Spleen (d) Kidney

**65.** Peyer's patches contain

(a) Mucus (b) Sebum (c) Lymphocytes (d) Red blood cells

**66.** Intestinal villi are more numerous and larger in posterior part of small intestine than in anterior part because

(a) Digestion is faster in posterior part (b) Blood supply is poor in posterior part

(c) There is more digested food in posterior part (d) Blood supply is rich in posterior part

**67.** Lymph tissues are present in which part of alimentary canal

(a) Buccopharyngeal cavity (b)Sacculus rotundus (c) Ileum (d) All of these

**68.** A pair of small lymphatuic tissue present at the sides of root tongue is called as

(a) Thyroid (b) Tonsils (c) Epiglottis (d) Adenoids

**69.** Crypts of Lieberkuhn are found in between the villi. They secrete

(a) Glucagon (b) Succus entericus (c) Insulin (d) None of these

**70.** Fundic part of stomach is

(a) Present in rabbit but absent in frog (b) Absent in rabbit but present in frog

(c) Absent in both rabbit and frog (d) Present in both rabbit and frog

**71.** The disease due to inflammation of vermiform appendix of digestive system is known as

(a) Amoebic dysentery (b) Intestinal cancer (c) Appendicitis (d) None of these

**72.** Removal of stomach causes

(a) Dumping syndrome (b) Turner's syndrome (c) Emphysema (d) None of these

**73.** Vermiform appendix is a part of

(a) Intestine (b) Stomach (c) Liver (d) Rectum

**74.** The inner surface of large intestine is

(a) Lined by muscular tissue (b) Provided by epithelial tissue

(c) Lined by both epithelial and muscular tissue (d) Lined by all four tissues

**75.** Epithelium that forms the inner lining of stomach wall

(a) Cuboidal (b) Ciliated (c) Squamous (d) Columnar

**76.** Ileum is a part of

(a) Pelvic girdle (b) Pectorial girdle (c) Pancreas (d) Small intestine

**77.** Crypt of Lieberkuhn is example for

(a) Simple tubular gland (b) Coiled tubular gland

(c) Compound alveolar gland (d) Compound tubular gland

**78.** Submucosa is thickest in

(a) Stomach (b) Oesophagus (c) Intestine (d) Rectum

**79.** What are the functions of goblet cells

(a) Production of enzyme (b)Production of mucin

(c)Production of hormone (d)Production of *HCl*

**80.** Inner lining of gut, stomach and liver is composed of

(a) Simple squamous epithelium (b) Simple columnar epithelium

(c) Simple cuboidal epithelium (d) Compound epithelium

**81.** The intestine of human body is about 29 *feet* long, because

(a) It provides more area for food storage

(b) Bacteria contained in food may gradually be killed

(c) More length increases food digestion and absorption (d)None of these

**82.** Sacculus rotundus is a dilated part at posterior end of

(a) Ileum (b) Ilium (c) Oesophagus (d) Colon

***Advance Level***

**83.** Pulp cavity of teeth is lined by

(a) Odontoblast (b) Chondroblast (c) Osteoblast (d) Amyloblast

**84.** Wisdom teeth in human is

(a) 3rd molar and 4 in number (b) 3rd molar and 2 in number

(c) 2nd molar and 4 in number (d) 2nd molar and 2 in number

**85.** Carnassial teeth are modified for

(a) Crushing (b) Grinding (c) Tearing (d) Cutting

**86.** At the last end of tongue, there is an area sensitive to the…..taste

(a) Sour (b) Bitter (c) Sweet (d) Salty

**87.** Vomerine teeth are present in

(a) Man (b) Reptiles (c) Frogs (d) Rabbits

**88.** Dental formula is given to show

(a) The structure of molars (b) Number and types of teeth in both jaws

(c) Homodont condition (d) Diphyodont condition

**89.** Monophyodont condition is found in

(a) Sloths (b) Toothed whales (c) Sirenians (d) All of these

**90.** Teeth are

(a) Living structure (b) Dead structure

(c) Partly dead and partly living structure (d) Exact nature is not known

**91.** How many teeth in man grows twice in life

(a) 32 (b) 28 (c) 20 (d) 12

**92.** Argentaffin cells are found in

(a) Pancreas (b) Internal ear (c) Gastric glands (d) Liver

**93.** Which of the following carries glucose from digestive tract to liver

(a) Hepatic artery (b) Pulmonary vein (c) Hepatic portal vein (d) Renal portal system

**94.** In an empty contracted stomach the mucosa forms folds known as

(a) Foveole (b) Incisura angularis (c) Rugae (d) None of these

**95.** The stomach of ruminants is mainly divided into four parts, but in camel which one part is missing

(a) Abomasum (b) Omasum (c) Recticulum (d) Rumen

**96.** The length of the alimentary canal is more in herbivorous animals than the carnivorous because

(a) Herbivorous diet contains more fat to digest

(b) Herbivorous diet contains more proteins to digest

(c) Herbivorous diet contains more carbohydrates particularly cellulose which takes more time to digest

(d) The absorption is more which requires more time

**97.** Major utility of breaking up of food into small bits during chewing is

(a) To reduce surface area of food (b) To increase surface area of food

(c) To enjoy taste of food (d) To make food soluble

**98.** In colon, constructions of its wall form a series of small packets called

(a) Haustra (b) Crypts of Lieberkuhn (c) Zymogen cell (d) Taenia

**99.** Taste buds for bitter taste are found on tongue at

(a) Tip (b) On basal surface (c) Posterior side (d) Lateral side

## DIGESTIVE GLANDS

***Basic Level***

**100.** Kupffer cells of liver are

(a) Loose connective tissue (b)Phagocytic cell (c) Mast cell (d) Fat cell

**101.** Bilirubin and biliverdin are found in

(a) Blood (b)Bile (c) Pancreatic juice (d) Saliva

**102.** Deamination occurs in liver to

(a) Get rid of urea from blood (b) Synthesise amino acids

(c) Make use of excess amino acids (d) Convert proteins to urea and uric acid

**103.** Most of the fatty acids and glycerols are absorbed with the help of bile salts in the

(a) Lacteals (b) Blood circulation (c) Wall of the ileum (d) None of these

**104.** In rabbit the colour of bile juice is

(a) Colourless due to the presence of sodium and potassium taurocholate

(b) Green due to the accumulation of biliverdin

(c) Red due to the accumulation of haemoglobin

(d) Yellow due to the presence of bilirubin

**105.** A person like to have more oils. Which of the following juice will emulsify it

(a) Bile (b) Pancreatic juice (c) Gastric juice (d) Saliva

**106.** From the point of ontogeny, liver is

(a) Ectodermal (b) Endodermal

(c) Mesodermal (d) Both ectodermal and endodermal

**107.** Bile is secreted by

(a) Pancreas (b) Kidney (c) Heart (d) Liver

**108.** Liver in our body stores

(a) Vitamin *A* (b) Vitamin *D* (c) Vitamin $B_{12}$ (d) All of these

**109.** Ptyalin is

(a) Strongly acidic (b) Slightly acidic (c) Slightly neutral (d) Strongly alkaline

**110.** Ptylin is an enzyme of

(a) Salivary juice (b) Pancreatic juice (c) Intestinal juice (d) None of these

**111.** Parotid salivary gland are present

(a) Below the tongue (b) Below the ear

(c) Below the eye orbit (d) In the angle between two jaws

**112.** The number of salivary glands in man is

(a) Two pairs (b) Three pairs (c) Four pairs (d) Five pairs

**113.** The name of an enzyme produced by the salivary gland is

(a) Pepsin (b) Rennin (c) Ptyalin (d) Pancreatic juice

**114.** Which one of the following is the matching set of gland and its secretion

(a) Pituitary gland – Thyroxin (b) Salivary gland – Amylase

(c) Adrenal cortex – Vasopressin (d) Islets of Langerhans – Secretin

**115.** Saliva converts

(a) Proteins into amino acids (b) Glycogen into glucose

(c) Starch into maltose (d) Fats into vitamins

**116.** The activator of intestinal juice is

(a) Succus entericus (b) Secretin (c) Enterocrinin (d) Enterozymase

**117.** Surgical removal of gall bladder in human beings would lead to

(a) Impairment of the digestion of fat (b) Increased acidity in the intestine

(c) Jaundice (d) None of these

**118.** Jaundice may be caused by retarded function of

(a) Lungs (b) Kidneys (c) Heart (d) Liver

**119.** "Chief cells" of "Zymogen cells" secrete the enzymes of the gastric juice, are found in the

(a) Isthmus of the gland (b) Neck of the tubular gland

(c) Base of the tubular region (d) All of these

**120.** Amylolytic enzymes are produced from

(a) Salivary glands and liver (b) Stomach and liver

(c) Stomach and pancreas (d) Salivary glands and pancreas

**121.** Fat digestion is facilatated by

(a) Bile juice (b) Pancreatic juice (c) Gastric juice (d) None of these

**122.** If pancreas is removed, the compound which remain undigested is

(a) Carbohydrates (b) Fats (c) Proteins (d) All of these

**123.** Liver sinusoids are lined by

(a) Parenchymal cells (b) Endothelial cells (c) Kupffer cells (d) Goblet cells

**124.** The duct of gall bladder in rabbit is known as

(a) Choleoductus duct (b) Stenson's duct (c) Cystic duct (d) None of these

**125.** Action of bile can be best affected by

(a) Esterification (b) Oxidation (c) Emulsification (d) None of these

**126.** Gall bladder is stimulated by

(a) Secretin (b) Cholecystokinin (c) Enterogastrone (d) Enterokinase

**127.** Kupffer cells are found in

(a) Mouth (b) Liver (c) Kidney (d) Stomach

**128.** Bile aids in digestion and absorption because it contains

(a) Lipase (b) Bile pigments (c) Bile salts (d) All of these

**129.** *pH* of the pancreatic juice is about

(a) 6.4 (b) 8.4 (c) 12.0 (d) 7.0

**130.** Trypsinogen is an inactive enzyme secreted by the pancreas. It is activated by

(a) Pepsin of stomach (b) Chymotrypsin (c) Bile (d) Enterokinase

**131.** A good source of lipase is

(a) Saliva (b) Gastric juice (c) Bile (d) Pancreatic juice

**132.** The trypsin enzyme is secreted by

(a) Stomach (b) Duodenum (c) Pancreas (d) Liver

**133.** In pancreas, pancreatic juice and hormones are secreted by

(a) Same cells (b) Different cells

(c) Same cells at different times (d) None of these

**134.** The largest gland in the human body is

(a) Liver (b) Brain (c) Pancreas (d) Thyroid

**135.** Islets of Langerhans produce

(a) Insulin (b) Rennin (c) Ptyalin (d) *HCl*

**136.** Deoxyribonuclease and ribonuclease are secreted by

(a) Liver (b) Stomach (c) Pancreas (d) Kidney

**137.** How many kinds of cells are found in islet of Langerhans

(a) 1 (b) 2 (c) 3 (d) 4

**138.** Islets of Langerhans are present in

(a) Pancreas (b) Ileum (c) Oesophagus (d) Stomach

**139.** One of the digestive juices that lacks enzymes but aids digestion is

(a) Bile (b) Succus entericus (c) Chyle (d) Chyme

**140.** Liver of rabbit is made up of

(a) 4 lobes (b) 6 lobes (c) 5 lobes (d) 7 lobes

**141.** Bile juice is a

(a) Secretory product (b) Enzymatic product (c) Excretory product (d) All of he above

**142.** Which of the following hormone stimulates the secretion of gastric juice

(a) Secretin (b) Gastron (c) Cholecystokinin (d) Gastrin

**143.** The enzymes responsible for the digestion of starch in food of man is present in

(a) The salivary and gastric secretions (b) The salivary and pancreatic secretions

(c) The gastric and pancreatic secretions (d) The gastric and duodenal secretions

**144.** The amount of gastric juice secreted per day from man's stomach is about

(a) 5000 *ml* to 10000 *ml* (b) 2000 *ml* to 3000 *ml* (c) 100 *ml* to 500 *ml* (d) 10 *ml* to 15 *ml*

**145.** Zymogen cells and chief cells secrete

(a) Hydrochloric acid (b) Mucus (c) Pepsin (d) Trypsin

**146.** Gastric juice contains

(a) Pepsin, rennin, lipase (b)Pepsin, amylase, rennin

(c) Pepsin, amylase, trypsin (d) Lipase, rennin, trypsin

**147.** The bile secreted by the liver cells passes into the gall bladder through

(a) Hepato-pancreatic duct (b)Cystic duct (c) Hepatic duct (d) Hepato-gall duct

**148.** The chief function of bile is to

(a) Digest fat by enzymatic action (b) Emulsify fats for digestion

(c) Eliminate waste products (d) Regulate digestion of proteins

**149.** In man, the bile juice secreted per day is

(a) 700 *ml* (b) 800 *ml* (c) 1000 *ml* (d) 1500 *ml*

**150.** Bile salts are poured into the alimentary canal where they are necessary for the absorption of

(a) $Na^+$ and $Ca^{++}$ (b) Fat soluble vitamins

(c) Amino acids and monosaccharides (d) All the nutrients contained in chyme

**151.** Cholesterol is synthesised in

(a) Pancreas (b) Brunner's gland (c) Spleen (d) Liver

**152.** The first phase in the breakdown of glucose in animal cell is

(a) Glycolysis (b) Electron transport system (c)Fermentation (d) Krebs cycle

**153.** In which of the following proteins are absent

(a) Pancreatic juice (b) Saliva (c) Bile (d) Intestinal juice

**154.** Bile helps in

(a) Producing enzymes (b) Esterification (c) Both (a) and (b) (d) None of these

**155.** Which word best describes the action of bile on fats

(a) Neutralises (b) Digests (c) Emulsifies (d) Absorbs

**156.** The *pH* of amylase present in saliva is

(a) 6 (b) 6.8 (c) 7.2 (d) 8

**157.** Saliva is secerted from

(a) Submaxillary and sublingual glands (b) Gastric gland

(c) Pancreas (d) Gall bladder

**158.** Ptyalin is secreted by

(a) Salivary gland (b) Gastric gland (c) Digestive gland (d) Brunner's gland

**159.** When gall bladder of a man is removed

(a) Fat digestion is not possible (b)Acidity continues in duodenum

(c) Effect of pancreatic juice upon food is impaired (d)All of these

**160.** Molar glands are present in

(a) Frog (b) Cat (c) Rabbit (d) Man

**161.** Salivary glands are absent in

(a) *Anopheles maculipenis* (b)*Musca domestica* (c) *Blatta orientalis* (d) *Rana hexadactyla*

***Advance Level***

**162.** Which one of the following statements about glycogen is correct

(a) It is a disaccharide stored in liver which can react with ammonia to form proteins

(b) It is synthesised in the liver and takes part in the formation of bile and lipase, besides being a source of energy

(c) It is a polysaccharide which is synthesised and stored in liver cells

(d) It is synthesised in blood and stored in liver and muscles to provide glucose in times of need

**163.** Liver does not synthesize

(a) Fibrinogen (b) Albumin (c) Prothrombin (d) Gamma globulin

**164.** Which of the following digestive juices have the minimum *pH*

(a) Bile (b) Saliva (c) Gastric juice (d) Pancreatic juice

**165.** Synthesis of glycogen from sugar in the liver is known as

(a) Glycogenesis (b) Glycolysis (c) Glycogenolysis (d) Glucolysis

**166.** Enzyme arginase is found in

(a) Mouth cavity (b) Stomach (c) Intestine (d) Liver

**167.** The liver of carnivorous is larger than the herbivorous because in carnivorous

(a) Their body is also big

(b) The diet contains much more proteins so liver has to do more work

(c) The problem of phagocytosis by Kupffer cells are more

(d) None of these

**168.** Which of the following is not a human salivary gland

(a) Parotid (b) Submaxillary (c) Sublingual (d) Infra-orbital

**169.** Spot the salivary gland among the following

(a) Sublingual (b) Adrenal (c) Brunner (d) Lacrimal

**170.** When a piece of bread is chewed it tastes sweet because

(a) The sugar contents are drawn out (b) Saliva converts starch into maltose

(c) It does not taste sweet (d) The taste buds are stimulated by chewing

**171.** If liver becomes functionless, percentage of which will increase in blood

(a) Uric acid (b) Ammonia (c) Urea (d) Protein

**172.** The term 'humulin' is used for

(a) Human insulin (b) Isoenzyme (c) Hydrolytic enzyme (d) Powerful antibiotic

**173.** Cells of the pancreas is not digested by their own enzymes because

(a) Enzymes are secreted in inactive form (b) Cells are not lined by mucous membrane

(c) Enzymes are released only when needed (d) None of these

**174.** Which one of the following does not produce any digestive enzyme

(a) Intestinal mucosa (b) Gastric mucosa (c) Pancreas (d) Liver

**175.** Glisson's capsule is found in

(a) Pancreas (b) Liver (c) Gall bladder (d) Intestine

**176.** 'Secretin' is secreted from an

(a) Endocrine gland and acts on an endocrine gland

(b)Exocrine gland and acts on an exocrine gland

(c) Endocrine gland and acts on an exocrine gland

(d)Exocrine gland and acts on an endocrine gland

**177.** If *pH* of a protein is 1.6, which enzyme will digest it

(a) Trypsin (b) Pepsin (c) Amylase (d) Erepsin

**178.** Pisiform cells loaded with zymogen granules can be seen in

(a) Liver (b) Pancreas (c) Ovary (d) Kidney

**179.** Pancreatic juice contains

(a) Trypsin, lipase and maltase (b) Pepsin, trypsin and maltase

(c) Trypsin, chymotrypsin, amylase and lipase (d) Trypsin, pepsin and amylase

**180.** Wharton's duct in man is related with

(a) Female genital organs (b)Brunner's glands

(c) Submandibular salivary gland (d)Sublingual salivary gland

**181.** In man there are about 35,000,000 gastric pits at about

(a) $200 / mm^2$ (b) $300 / mm^2$ (c) $1000 / mm^2$ (d) $100 / mm^2$

**182.** The toxic substance are detoxicated in the human body by

(a) Lungs (b) Kidneys (c) Liver (d) Stomach

**183.** Cholecystokinin is a secretion of

(a) Stomach which stimulates pancreas to release the pancreatic juice

(b) Liver synthesised from cholesterol and controls secondary sexual characters

(c) Duodenum and makes the gall bladder to contract and release bile

(d) Goblet cell of ileum and stimulates the secretion of succus entericus

**184.** Insulin, epinephrine, glucagon collectively influence

(a) Gluconeogenesis (b) Glycerophosphate shuttle

(c) Glycolysis (d) Glycogenolysis and glycogenesis

**185.** Which of the following clotting factor is not formed by liver

(a) I (b) II (c) IV (d) VIII

**186.** The function of ductus choledochus is to carry

(a) Bile (b) Sperms (c) Ova (d) Urine

**187.** Treatment with allaxon destroys

(a) Sertoli cell (b) Leydigs cells (c) Ball of pancreatic islets (d)STH cells

**188.** The contraction of gall bladder is due to

(a) Gastrin (b) Secretin (c) Cholecystokinin (d) Enterogastrone

**189.** In gluconeogenesis

(a) Glucose is polymerized into glycogen (b) Glycogen is broken into glucose

(c) Carbohydrates are synthesized from amino acids / lipids

(d) Glucose is broken into pyruvic acid

**190.** Prussic acid formed during metabolism is rendered harmless by

(a) Pancreas (b) Stomach (c) Liver (d) All of these

**191.** The hormone 'secretin' stimulates secretion of

(a) Pancreatic juice (b) Bile juice (c) Salivary juice (d) Gastric juice

**192.** Which of the following enzyme is not secreted by pancreas

(a) Pepsin (b) Trypsin (c) Carboxy peptidase (d) Ribonuclease

**193.** Which of the following shows correct pairing for salivary glands in man

(a) Parotid $\rightarrow$ Wharton's duct; submaxillary $\rightarrow$ duct of Stensen; sublingual $\rightarrow$ duct of Rivinus

(b) Parotid $\rightarrow$ duct of Rivinus; submaxillary $\rightarrow$ duct of Stensen; sublingual $\rightarrow$ Wharton's duct

(c) Parotid $\rightarrow$ duct of Rivinus; submaxillary $\rightarrow$ Wharton's duct; sublingual $\rightarrow$ duct of Stensen

(d) Parotid $\rightarrow$ duct of Stensen; submaxillary $\rightarrow$ Wharton's duct; sublingual $\rightarrow$ duct of Rivinus

**194.** Match the names of glands listed under column-I with the location given under column-II, choose the answer which gives correct combination of the alphabets of the two columns

| | **Column-I (glands)** | | **Column-II (location)** |
|---|---|---|---|
| A | Crypts of Lieberkuhn | p | Loop of duodenum |
| B | Pancreas | q | Stomach |
| C | Adrenal gland | r | Intestine |
| D | Gastric gland | s | Kidney |

(a) A = r, B = p, C = q, D = s (b)A = r, B = p, C = s, D = q

(c) A = q, B = s, C = r, D = p (d)A = p, B = r, C = s, D = q

**195.** Number of liver lobes in man

**(a) 4** (b) 5 (c) 6 (d) 7

**196.** Structure present in man but absent in frog is

(a) Salivary glands (b) Pancreas (c) Adrenal glands (d) Thyroid gland

**197.** Weight of human liver is

(a) 6.0 *kg* (b) 5.0 *kg* (c) 3.0 *kg* (d) 1.5 *kg*

**198.** Enzyme lactase occurs in

(a) Saliva (b) Pancreatic juice (c) Intestinal juice (d) Stomach

**199.** Insulin is secreted by

(a) $\alpha$ - cells of pancreas (b) $\beta$ - cells of pancreas (c) $\gamma$ - cells of pancreas (d) Acini of pancreas

**200.** $\alpha$-cells of pancreas secerte

(a) Insulin (b) Glucagon (c) Trypsinogen (d) Amylase

**201.** The amount of saliva produced per day in humans is

(a) 200 *ml* (b) 500 *ml* (c) 750-1000 *ml* (d) 1.0-1.5 *litres*

**202.** Amount of bilirubin in jaundice would be

(a) 20 *ml*/*l* (b) 0.2 *mg*/*l* (c) 1.2 *mg*/*l* (d) 12 *mg*/*l.*

**203.** In which layer of stomach are gastric glands located

(a) Serosa (b) Mucosa (c) Submucosa (d) Muscularis mucosa

## PHYSIOLOGY OF DIGESTION

***Basic Level***

**204.** Mechanical stimulation of villi by the food produces a hormone which is known as

(a) Gastrin (b) Progesterone (c) Villikinin (d) Pancreozymin

**205.** During digestion the lymphatics of the intestine become filled with fat globules which give white colour to the lymph. This lymph is known as

(a) Chyle (b) Haemoconia (c) Fluid plasma (d) Bilirubin

**206.** Some of the free fatty acids and monoacyl glycerols aggregate in ileum to form the water soluble substance for the absorption. This is known as

(a) Chyle (b) Cargo (c) Micelles (d) Chilomicrons

**207.** Which of the following are reabsorbed in the alimentary canal as such

(a) Albumin of egg (b) Polysaccharides (c) Fat soluble vitamins (d) Proteins

**208.** Trypsin differs from pepsin in that

(a) It digest protein in alkaline medium while pepsin does so in acidic medium

(b) It digest protein in acidic medium while pepsin does so in alkaline medium

(c) Both (a) and(b)

(d) None of these

**209.** Some proteolytic enzymes are

(a) Trypsin, peptidase, pepsin (b) Amylopsin, steapsin, ptylin

(c) Amylase, lipase, zymase (d) Urease, zymase, dehydrogenase

**210.** The enzymes have proteinous and prosthetic groups connected by loose bonds. Under activity the loose bonds are separated. It is known as

(a) Diakinesis (b) Histolysis (c) Dialysis (d) Synapsis

**211.** The simplest form of food elements carbohydrates, proteins, fats are present in which part of alimentary canal

(a) Stomach (b) Ileum (c) Duodenum (d) Colon

**212.** Which of the following enzyme is not secreted by wall of alimentary canal

(a) Sucrase (b) Cellulase (c) Lipase (d) Invertase

**213.** Pepsin is secreted in the form of pepsinogen. It is activated by the…..in the stomach

(a) Gastrin (b) Amylopsin (c) *HCl* (d) Rennin

**214.** Monosaccharides and amino acids are absorbed directly into….in the ileum

(a) Lacteals (b) Cisterna chyli (c) Blood circulation (d) Wall of the ileum

**215.** Digestion of carbohydrate is affected by

(a) Erepsin (b) Steapsin (c) Pepsin (d) Amylopsin

**216.** The functional unit for the absorption of digested food is

(a) Crypts of Lieberkuhn (b)Peyer's patches (c) Villi (d) Brunner's gland

**217.** The enzyme which is found from protozoa to mammalia is

(a) Amylase (b) Trypsin (c) Pepsin (d) Lipase

**218.** Digestion of starch takes place in

(a) Stomach and duodenum (b) Buccal cavity and duodenum

(c) Buccal cavity and oesophagus (d) Duodenum only

**219.** Amylase is an enzyme for which the substrate is

(a) Starch (Polysaccharides) (b) Proteins

(c) Fats (d) Cane sugar

**220.** In rabbit, the digestion of cellulose takes place in

(a) Colon (b) Ileum (c) Caecum (d) Rectum

**221.** The major digestion in stomach of man is of

(a) Proteins (b) Carbohydrates (c) Fats (d) All of these

**222.** Which one is not matching with the others

(a) Ptyalin (b) Glucagon (c) Secretin (d) Gastrin

**223.** The enzyme pepsin of gastric juice gets activated in

(a) Neutral medium (b) Alkaline medium (c) Acidic medium (d) None of these

**224.** A test tube contains water of boiled rice. Which enzyme will digest it

(a) Maltase (b) Lipase (c) Invertase (d) Amylase

**225.** In intestine, *pH* value is

(a) 7.6 (b) 6.0 - 7.0 (c) 8.5-9.0 (d) 2.5-4.5

**226.** In man cellulose is digested in

(a) The caecum (b) The colon (c) The appendix (d) Not digested at all

**227.** Inhibition of gastric secretion is brought about by

(a) Cholecystokinin (b) Pancreozymin (c) Gastrin (d) Enterogastron

**228.** Movement of food from oesophagus to stomach is brought about by

(a) Pressure of breathing (b) Movement of diaphragm

(c) Peristalsis (d) Lubrication of food by mucous

**229.** The function of erepsin in the process of digestion is to convert

(a) Fats into amino acids (b) Polypeptides into amino acids

(c) Polysaccharides into disaccharides (d) Disaccharides into monosaccharides

**230.** The glucose is converted into glycogen in liver and stored in

(a) Liver (b) Liver and muscles (c) Liver and spleen (d) Spleen and muscles

**231.** The end product of fat digestion is

(a) Amino acid (b) Starch (c) Fatty acid (d) Glucose

**232.** Which one of the following is the matching pair of digestive enzyme and substrate**]**

(a) Rennin-Protein (b) Amylase-Lactose (c) Trypsin-Starch (d) Invertase-Maltose

**233.** One of the following is needed for the conversion of trypsinogen into trypsin

(a) *HCl* (b) Enterokinase (c) Lipase (d) Zymase

**234.** Milk protein is acted upon by a gastric enzyme

(a) Casein (b) Rennin (c) Pepsin (d) Caseinogen

**235.** Enzymes are found in all living cells. Their main function is

(a) To help in the digestion of food (b) To allow chemical reaction to food

(c) To speed up the breakdown of substance (d) To accelerate the rate of chemical reactions

**236.** The main function of the colon (large intestine) of mammals is to

(a) Temporarily store of excretory products (b) Absorb water from undigested food

(c) Absorb digested food (d) Digest cellulose

**237.** Digestion is the breaking down of large food molecules into smaller ones. The main purpose of this is to

(a) Make the food soluble

(b) Enable the digestive enzymes to be used up

(c) Provide many different types of molecules for absorption

(d) Make the passage of food along the gut easier

**238.** *HCl* is highly acidic but walls of stomach do not dissolved by its action, because it is

(a) Covered by thick layer of mucous (b) Covered by a layer of cuticle

(c) Not affected by *HCl* (d) Secreting certain enzymes against *HCl*

**239.** Amino acids produced by digestion of proteins are absorbed from intestine through

(a) Lacteals (b) Rectum

(c) Blood capillaries in the villi (d) Lacteals and blood capillaries in villi

**240.** The three secretions that mix with food in the small intestine are

(a) Saliva, gastric juice and bile (b)Gastric juice, bile and pancreatic juice

(c) Bile, pancreatic juice and intestinal juice (d)Pancreatic juice, intestinal juice and gastric juice

**241.** Rennin is found in

(a) Gastric juice in stomach (b)Kidneys (c) Pancreatic juice (d) Liver

**242.** The function of oxyntic cells is to

(a) Secrete bile juice (b) Secrete proteolytic enzymes

(c) Secrete *HCl* in stomach (d) Secrete lipolytic enzymes

**243.** Below freezing point digestive enzymes are

(a) Inactivated (b) Activated (c) Destroyed (d) Unaffected

**244.** Which will not breakdown the peptide bond of protein

(a) Ptyalin (b) Trypsin (c) Chymotrypsin (d) Peptidase

**245.** All enzymes are chemically speaking

(a) Carbohydrates (b) Proteins (c) Lipoproteins (d) Lipids

**246.** End products of protein hydrolysis are

(a) Mixture of amino acids (b)Sugars (c) Peptides (d) 25 amino acids

**247.** Intestinal villi are mainly concerned with

(a) Assimilation (b) Secretion (c) Ultrafilteration (d) Absorption

**248.** Lipase changes

(a) Proteins into peptones (b)Starch in sugar (c) Fats into fatty acids (d) None of these

**249.** One gram of fat produces

(a) 4.1 *k.calories* of chemical energy (b) 9.6 *k.calories* of chemical energy

(c) 7.0 *k.calories* of chemical energy (d) 5.0 *k.calories* of chemical energy

**250.** Mammals may drink water and also get it from

(a) Breakdown of glycogen into glucose (b)Secretion of saliva

(c) Oxidation of glucose (d)Conversion of oxyhaemoglobin into haemoglobin

**251.** End product of nucleic acid is

(a) Amino acid (b) Uric acid (c) Purines (d) Blood

**252.** Bolus of food undergoing digestion in acidic medium in stomach is called

(a) Acidified bolus (b) Bile bolus (c) Chyle (d) Chyme

**253.** Which is same as propepsin

(a) Trypsinogen (b) Peptones (c) Starch (d) Fat

**254.** Function of caecum is to

(a) Absorb water (b) Secrete enzymes (c) Digest cellulose (d) None of these

**255.** Which one of the following animals can digest milk by the presence of rennin in its stomach

(a) A calf (b) A cow (c) Any mammal (d) A man

**256.** Which of the following converts insoluble food stuff into soluble state

(a) Vitamins (b) Hormones (c) Juices (d) Enzymes

**257.** Digestion of both starch and protein is done by

(a) Gastric juice (b) Gastric lipase (c) Pancreatic juice (d) Ptyalin

**258.** The enzyme added to the starch solution may have been

(a) Maltase (b) Invertase (c) Lipase (d) Amylase

**259.** Trypsin is related with digestion of

(a) Carbohydrates (b) Proteins (c) Fat (d) None of these

**260.** Pepsinogen is secreted by

(a) Chief cells (b) Parietal cells (c) Gastric glands (d) Intestinal cells

**261.** Saccus entericus is the name given to

(a) Junction between ileum and large intestine (b) Intestinal juice

(c) Swelling in the gut (d) Appendix

**262.** Digestion is

(a) Absorption of water

(b) Absorption of food

(c) Conversion of non-diffusable food particle in diffusable food particle

(d) None of these

**263.** Pepsin acts on

(a) Fats (b) Proteins (c) Carbohydrates (d) Glucose

**264.** Lacteals are associated with

(a) Secretion of lactic acid (b)Absorption of fats (c) Production of milk (d) None of these

**265.** Which of these is not an enzyme of digestive system

(a) Enterokinase (b) Amylase (c) Trypsin (d) Enterogastrone

**266.** Emulsification of fats is brought about by

(a) Bile pigments (b) Bile salts (c) Pancreatic juice (d) *HCl*

**267.** Which makes the chyme in human digestion move towards duodenum, from the stomach

(a) Peristaltic movement (b)Gravitational pull (c) Circulation of blood (d) None of these

**268.** Which part of body secretes the hormone secretin

(a) Ileum (b) Stomach (c) Duodenum (d) Oesophagus

**269.** Enterokinase helps in the conversion of

(a) Caseinogen into casein (b) Proteins into polypeptides (c) Pepsinoge into pepsin (d) Trypsinogen into trypsin

**270.** In rabbit proteins are digested by

(a) Pepsin and tripsin (b) Tripsin and steapsin (c) Steapsin and pepsin (d) All the these

**271.** Carbohydrates are digested by

(a) Buccal cavity (b) Pharynx (c) Duodenum (d) Stomach

**272.** In human beings digestion starts in

(a) Buccal cavity (b) Stomach (c) Small intestine (d) Pharynx

**273.** In ileum which of the following is absorbed

(a) Vitamin *K* (b) Bile salts (c) Glucose (d) Fat

**274.** Which of the following is not a proteolytic enzyme

(a) Pepsin (b) Trypsin (c) Erepsin (d) All of these

**275.** Emulsified fat is digested by

(a) Lipase (b) Lipase and hydrolase (c) Bile salts (d) Bile pigments

**276.** The site of protein digestion is

(a) Gullet (b) Stomach (c) Small intestine (d) Oral cavity

**277.** The *pH* of succus entericus is

(a) 7.8 (b) 6.6 (c) 5.6 (d) 2.0

**278.** Digestion of protein takes place in

(a) Duodenum and stomach (b) Stomach and oesophagus

(c) Small and large intestine (d) Intestine and rectum

**279.** The process by which digested food of the alimentary canal passes through its mucous membrane into circulatory system is called as

(a) Absorption (b) Assimilation (c) Hydrolysis (d) Defecation

**280.** Pepsin is produced by

(a) Salivary glands (b) Stomach (c) Duodenum (d) Small intestine

**281.** In mammals, the digestion of starch starts from

(a) Mouth (b) Stomach (c) Oesophagus (d) Duodenum

**282.** Which one of the following enzymes initiates protein digestion

(a) Aminopeptidase (b) Carboxypeptidase (c) Trypsin (d) Pepsin

**283.** Muscular contraction of alimentary canal is known as

(a) Absorption (b) Digestion (c) Peristalsis (d) Circulation

**284.** Starch is converted to maltose by the action of

(a) Invertase (b) Amylase (c) Sucrase (d) Maltase

**285.** Water is largely absorbed in

(a) Stomach (b) Oesophagus (c) Small intestine (d) Colon

**286.** *HCl* is secreted by

(a) Zymogen cells (b) Oxyntic cells (c) Kupffer cells (d) Mucous cells

**287.** Rennin acts on milk proteins and converts

(a) Caseinogen into casein (b) Casein into paracasein

(c) Caseinogen into paracasein (d) Paracasein into caseinogen

**288.** A rabbit eats a lot of gram. Then its digestion starts in

(a) Mouth (b) Stomach (c) Duodenum (d) Ileum

**289.** Enzyme rennin is secreted by

(a) Cells of stomach (b)Cells of intestine

(c) The cortical cells of kidney (d)The cells of juxtaglomerular apparatus of kidney

**290.** A principal gastrointestinal hormone is

(a) Prolactin (b) Cholin esterase (c) Secretin (d) Acetyl *CoA*

**291.** Identify the correct set which shows the name of the enzymes from where it is secreted and substrate upon which it acts

(a) Pepsin-stomach wall-casein (b) Ptyalin-intestine-maltose

(c) Chymotrypsin-salivary gland-lactose (d) Ptyalin-pancreas-lipid

**292.** Which is correct about the bile of rabbit

(a) It is synthesized by gall bladder and also stored there

(b) It is an enzyme which emulsify the fats

(c) It contain bile salts and bile pigments (d) Bilirubin present in it decomposed fats

**293.** What is cholecystokinin

(a) Enzyme (b) Bile pigment

(c) Gastro-intestinal hormone (d) Lipid

**294.** Lactase is found in

(a) Saliva (b) Bile (c) Pancreatic juice (d) Intestinal juice

**295.** Hydrolysis of lipid yields

(a) Fats (b) Fatty acids and glycerol

(c)Mannose and glycerol (d) Maltose and fatty acid

**296.** Secretin hormone is secreted by

(a) Liver (b) Pancreas (c) Intestine (d) Brunner's glands

**297.** Brunner's glands are present in

(a) Ileum (b) Duodenum (c) Stomach (d) Oesophagus

**298.** When catabolism of proteins exceeds synthesis of proteins then

(a) Body become healthy (b)Body become weak

(c)No change takes place (d)None of these

**299.** Enzyme maltase in human gut acts on food at a *pH* of

(a) More than seven to change starch into maltose

(b) Less than seven to change starch into glucose

(c) More than seven to change maltose into glucose

(d)Less than seven to change maltose into glucose

**300.** The enzyme which coagulates milk is called

(a) Pepsin (b) Trypsin (c) Lactase (d) Rennin

**301.** What is the function of enterogastrone

(a) It stimulates the secretion of digestive juices in the stomach

(b) It inhibits the secretion of gastric juice

(c) It regulates the flow of bile

(d) It stimulates the flow of pancreatic juice

**302.** Enterokinase is in

(a) Bile juice (b) Intestinal juice (c) Pancreatic juice (d) Pancreatic hormone

**303.** Starch is broken down by

(a) Trypsin (b) Amylase (c) Pepsin (d) Casein

**304.** Trypsin converts

(a) Fats into fatty acids (b) Starch and glycogen into maltose

(c) Proteins into peptones (d) Sucrose in to glucose and fructose

**305.** Which one of the following will not take place when glucose is taken as food

(a) Ingestion (b) Digestion (c) Absorption (d) Assimilation

**306.** Fats, carbohydrates and proteins are completely digested in

(a) Small intestine (b) Large intestine (c) Stomach (d) Liver

**307.** The absorbed food material is converted into protoplasm by the process of

(a) Absorption (b) Assimilation (c) Defecation (d) Digestion

**308.** Fats are absorbed in the intestine

(a) As such (b) After hydrolysis

(c) After digestion (d) None of these

**309.** Function of *HCl* in stomach is to

(a) Kill micro-organisms of food (b) Facilitate absorption of food

(c) Dissolve enzymes (d) None of these

**310.** Digestion is the conversion of large molecules into small ones. This is due to

(a) Better taste (b) More saliva (c) Enzymatic action (d) None of these

**311.** The end product of fat digestion is

(a) Amino acids (b) Starch (c) Fatty acids (d) Glucose

**312.** The end product of carbohydrate metabolism is

(a) $CO_2$ and $H_2O$ (b) $NH_3$ and $CO_2$ (c) $NH_3$ and $H_2O$ (d) $CO_2$

**313.** Pepsin is an example of

(a) Hormone (b) Vitamin (c) Enzyme (d) Nutrient

**314.** Gastric enzyme pepsin reacts only in acidic medium within a limited *pH* concentration. It varies

(a) 1.20 to 1.80 (b) 1.00 to 1.50 (c) 2.00 to 2.50 (d) 1.50 to 2.60

**315.** Stomach in vertebrates is the main site for digestion of

(a) Proteins (b) Carbohydrates (c) Fats (d) Nucleic acids

**316.** Trypsin is a digestive enzyme which occurs in mammals and digests

(a) Starch in buccal cavity in an alkaline medium (b) Protein in stomach in an acidic medium

(c) Protein in duodenum in an acidic medium (d) Protein in duodenum in an alkaline medium

**317.** Green colour of bile is due to

(a) Biliverdin (b) Bilirubin (c) Sodium taurocholate (d) Sodium glycocholate

**318.** Curdling of milk in small intestine would occur with the help of

(a) Rennin (b) Erypsin (c) Trypsin (d) Chymotrypsin

**319.** Digestion of carbohydrates occurs in

(a) Buccal cavity (b) Stomach (c) Intestine (d) All of these

**320.** Proteolytic enzymes do not corrode lining of alimentary canal as

(a) They are secreted in inactive form

(b) Lining layer of alimentary canal does not contain protein

(c) The enzymes are not capable of digesting fat

(d) None of these

**321.** In small intestine, active absorption occurs in case of

(a) Glucose (b) Amino acids (c) $Na^+$ (d) All of these

**322.** Hydrolytic enzyme which acts at low *pH* is

(a) $\alpha$-amylase (b) Protease (c) Hydrolases (d) Peroxidases

**323.** Weak peristaltic waves pass along stomach wall every

(a) 20 seconds (b) 30 seconds (c) 15 seconds (d) 10 seconds

**324.** Optimum *pH* for enzyme trypsin is

(a) 5.9 (b) 4.6 (c) 8.5 (d) 7.0

**325.** Vitamin *D* is synthesised by body from

(a) LDL cholesterol (b) HDL cholesterol (c) Triglycerides (d) Cellulose

**326.** Bile acids are

(a) Steroids (b) Carbohydrates (c) Modified proteins (d) Vitamins

**327.** In case of taking food rich in lime juice, the action of ptyalin on starch is

(a) Enhanced (b) Reduced (c) Unaffected (d) Stopped

**328.** Fat absorbed from gut is transported in blood as

(a) Micelles (b) Liposomes (c) Chemomicrons (d) Chylomicrons

**329.** Bile secreted by liver passes into gall bladder through

(a) Hepatopancreatic duct (b)Hepatic duct (c) Cystic duct (d) Hepato-gall duct

**330.** In ruminants bacterial action occurs in

(a) Reticulum (b) Omasum (c) Abomasum (d) Rumen

**331.** Which is a specific gastric hormone

(a) Secretin (b) Serotinin (c) Amphetamine (d) None of these

**332.** Most of the fat digestion occurs in

(a) Rectum (b) Stomach (c) Duodenum (d) Small intestine

**333.** What will happen if bile duct gets choked

(a) Faeces become dry (b) Acidic chyme will not be neutralised

(c) There will be little digestion in intestine (d) Little absorption of fat will occur

**334.** Liver produces

(a) Bile (b) Cholesterol (c) Iron (d) All of these

**335.** A digestive enzyme functional only in infants is

(a) Lactase (b) Gastric lipase (c) Intestinal lipase (d) Chymotrypsin

**336.** Gall bladder is stimulated to pour bile by

(a) Secretin (b) Enterogastrone (c) Enterokinase (d) Cholecystokinin

**337.** Aminopeptidase, a digestive enzyme produces

(a) Dipeptides (b) Smaller peptides (c) Peptones (d) Amino acids

**338.** Which of the following are reabsorbed in the alimentary canal as such

(a) Albumen of egg (b) Polysaccharides (c) Proteins (d) Fat soluble vitamins

**339.** Which one leaves human stomach at the earliest

(a) Fat (b) Protein (c) Carbohydrate (d) Beer

**340.** Where is protein digestion accomplished

(a) Stomach (b) Ileum (c) Rectum (d) Duodenum

**341.** Lactase hydrolyses lactose into

(a) Glucose (b) Glucose and galactose (c) Fructose (d) Manose

**342.** Intrinsic factor is produced in

(a) Liver (b) Pancreas (c) Duodenum (d) Stomach

**343.** Intrinsic factor is required for

(a) Production of gastric juice (b) Absorption of $B_{12}$

(c) Peristalsis (d) Feeling of hunger

***Advance Level***

**344.** The enzyme invertase hydrolyses

(a) Sucrose into glucose and fructose (b) Cellulose into starch

(c) Glucose into sucrose (d) Starch into sucrose

**345.** Milk protein is curdled into calcium paracaseinate by

(a) Maltase (b) Rennin (c) Trypsin (d) Lactase

**346.** Which of the following belongs to the class of pepsin and trypsin

(a) Rennin (b) Sucrose (c) Thyroxin (d) Secretin

**347.** Meals which are rich in fat are not digested in the intestine in absence of

(a) Pepsin (b) Enterokinase (c) Insulin (d) Steapsin

**348.** Digestion of which component of the food is likely to be most adversely affected if the *pH* of stomach is made neutral

(a) Sucrose (b) Starch (c) Protein (d) Fat

**349.** Trypsin acts in a medium which is

(a) Neutral (b) Highly alkaline (c) Acidic (d) Slightly alkaline

**350.** Peyer's patches in the intestine are the site of production of

(a) *B*-lymphocyte (b) *T*-lymphocyte (c) Lymphoid nodules (d) Antigens

**351.** Glucose, galactose and fructose all have the same molecular size and composition and their absorption through the mucosal cells takes place

(a) At the same rate (b) Glucose is absorbed most rapidly

(c) Fructose is absorbed most rapidly (d) Galactose is absorbed most rapidly

**352.** Which cells secrete gastric enzymes in stomach

(a) Chief cells (b) Alpha cells (c) Islets of Langerhans (d) Beta cells

**353.** Fatty acid and glycerol are first taken up from alimentary canal by

(a) Villi (b) Blood capillaries (c) Hepatic portal vein (d) Lymph vessels

**354.** The epithelial cells lining the stomach of vertebrates is protected from damage by *HCl* because

(a) *HCl* is too dilute

(b) The epithelial cells are resistant to the action of *HCl*

(c) *HCl* is neutralised by alkaline gastric juice

(d) The epithelial cells are covered with a mucous secretion

**355.** When fat is in the stomach the secretion of gastrin is inhibited. This inhibition is due to

(a) Presence of fat (b) Non-stimulation of vagus

(c)Slow digestion of fat (d)Release of enterogastron

**356.** The colour of the faeces is due to the

(a) Urochrome (b) Stercobilin (c) Bilverdin (d) Bacteria

**357.** Acid secretion in stomach is stimulated by

(a) Gastrin (b) Histamine (c) Vagal discharge (d) All of these

**358.** A 1, 4 glycosidic bonds are broken when

(a) Lipid is digested by lipase (b) Protein is digested by pepsin

(c) Starch is digested by amylase (d) None of these

**359.** The exact sequence of events during digestion of protein is

(a) Proteins $\rightarrow$ peptones $\rightarrow$ acid metaproteins and peptides

(b) Proteins $\rightarrow$ proteoses and peptones $\rightarrow$ peptides $\rightarrow$ amino acids

(c) Proteins $\rightarrow$ acid metaproteins $\rightarrow$ proteoses $\rightarrow$ amino acids $\rightarrow$ peptides

(d) Proteins $\rightarrow$ primary proteins $\rightarrow$ peptides $\rightarrow$ amino acids

**360.** In people addicted to alcohol, the liver gets damaged because it

(a) Has to detoxify the alcohol (b) Store excess of glycogen

(c) Stimulated to secrete bile (d) Accumulates excess of fats

**361.** The enzyme erepsin helps the breakdown of peptones into amino acids in the

(a) Stomach (b) Ileum (c) Large intestine (d) Pancreas

**362.** The hormones affecting carbohydrate metabolism are

(a) Somatotrophin (b) Adreno-corticotrophin

(c) Thyroid stimulating hormone (d) All of these

**363.** Match the following

| **'A'** | **'B'** |
|---|---|
| A. Amylase | 1. Break down of sucrose |
| B. Pepsin | 2. Break down of lipid |
| C. Lipase | 3. Break down of protein |
| D. Sucrase | 4. Break down of starches |
| E. Mouth | 5. Digestion of proteins |
| F. Stomach | 6. Egestion |
| G. Intestine | 7. Ingestion |
| H. Anus | 8. Digestion and absorption |

The correct pairing sequence is

(a) 4, 5, 2, 1, 3, 7, 6, 8 (b) 4, 3, 2, 1, 7, 5, 8, 6 (c) 5, 4, 1, 2, 7, 3, 8, 6 (d) None of these

**364.** In rabbit peristalsis is

(a) The act of swallowing (b)An involuntary muscular contraction and relaxation

(c) Mode of nutrition (d)The secretion of digestive juices

**365.** In human body excess of amino acids are stored in

(a) Liver (b) Kidney (c) Spleen (d) None of these

**366.** At what time the sugar is maximum in the blood of man

(a) In the late evening (b) In the early morning

(c) Midway between a meal (d) Soon after a meal

**367.** Cathepsin is a type of

(a) Proteolytic enzyme working at *pH* 3.0 – 5.0 (b) Amylase that works in acidic medium

(c) Lipase that works in acidic medium (d) Secretion of liver that helps in haemostasis

**368.** For the enzyme action

(a) Value of *Km* is low (b) Value of *Ki* is low (c) Value of *Km* is high (d) Value of *Ki* is high

**369.** Which one of the following is the correct match of digestive enzyme and substrate

(a) Lactose-Renin (b) Starch-Maltose (c) Fat-Steapsin (d) Casein-Trypsin

**370.** Which of the following is a gastro-intestinal enzyme

(a) Cholinestrase (b) Enterokinase (c) Secretin (d) Prolactin

**371.** Glucagon secreted by the alpha-cells of the islets of Langerhans does this function

(a) Glucagon converts glucose into glycogen and increases the concentration of blood sugar

(b) Glucagon converts glycogen into glucose and increases the concentration of blood sugar

(c) Glucagon converts glucose into glycogen

(d) None of these

**372.** Which one of the following is the correct pairing of the site of action and the subtrate of rennin

(a) Stomach – Casein (b) Stomach – Fat

(c) Small intestine – Protein (d) Mouth – Starch

**373.** Which of the following set is the end product of carbohydrate digestion

(a) Galactose, glucose and fructose (b) Galactose, glucose and maltose

(c) Lactose, maltose and sucrose (d) Glucose, maltose and fructose

**374.** Angiotensin-Rennin system is for

(a) Glucose metabolism (b) Urea conversion into ammonia

(c) Sodium potassium retention (d) Glycoprotein synthesis

**375.** Cholecystokinin and duocrinin are secreted by

(a) Intestine (b) Pancreas (c) Adrenal cortex (d) Thyroid gland

**376.** Glucose and amino acids are absorbed in the intestine by

(a) Active transport (b) Passive transport (c) Selective absorption (d) Osmosis

**377.** Chylomicrons are

(a) Undigested proteins (b) Undigested carbohydrates

(c) Fat droplets coated with glycerol and protein (d) Fat droplets coated with phospholipids

**378.** Which of the following sugars is absorbed from the small intestine by facilitated diffusion

(a) Fructose (b) Glucose (c) Sucrose (d) Lactose

**379.** Which of the following hormones induce secretion of succus entericus

(a) Insulin (b) Secretin and cholecystokinin

(c) Glucagon (d) Secretin

**380.** Which one of the following is a matching pair of a certain body feature and its value/count in a normal human adult

(a) Urea 5-10 *mg*/100 *ml* of blood

(b) Blood sugar 80 - 100 *mg*/100 *ml*

(c) Total blood volume 3-4 *litres*

(d) *ESR* in Wintrobe method 9-15 *mm* per hour in males and 20-34 *mm* per hour in females

**381.** Digestion process in humans is

(a) Extracellular (b) Intracellular (c) Intercellular (d) Both (a) and (c)

**382.** Brunner's gland are found in which of the following layers

(a) Submucosa of stomach (b)Mucosa of ileum

(c) Submucosa of duodenum (d) Mucosa of oesophagus

**383.** The process involving the conversion of solid substances into liquid material finally results in the absorption along the gut wall, they are then incorporated into the cells as complex substances. The process is called

(a) Combination (b) Assimilation (c) Absorption (d) Defaecation

**384.** The pungent odour of faeces is due to presence of

(a) Indole (b) Skatole (c) Various gases (d) All of these

**385.** Ammonia is formed during digestion in

(a) Liver (b) Small intestine (c) Buccal cavity (d) Stomach

**386.** In grazing cattles the major portion of food, cellulose is

(a) Passed out undigested (b) Digested by animal itself

(c) Utilised directly as such (d) Digested by intestinal bacteria

**387.** Which of the following statement is correct

(a) Through secretin is an enzyme, it is not involved in digestion

(b) Secretin is an enzyme and so it helps digestion

(c) Secretin is a hormone but it plays a role in digestion

(d) Secretin is a hormone and hence it does not play any role in digestion

**388.** Nuhn's glands are related to

(a) Tongue (b) Ear (c) Nose (d) Hair

**389.** Boa's point is associated with

(a) Liver cirrhosis (b) Tuberculosis (c) Nephritis (d) Gastric ulcer

**390.** Valves of Kerckring occur in

(a) Between right auricle and right ventricle (b) Left auricle and left ventricle

(c) Stomach and duodenum (d) Intestine

## NUTRITIVE REQUIREMENT

***Basic Level***

**391.** There is national eradication programme for a disease caused by the deficiency of an element

(a) Iodine (b) Boron (c) Copper (d) Chlorine

**392.** Folic acid and pantothenic acid are vitamins belonging to group

(a) *K* (b) *A* (c) *B*-complex (d) Both (a) and (b)

**393.** Mineral deposition in bones and teeth is mediated through vitamin

(a) *A* (b) *D* (c) *E* (d) *C*

**394.** Which mineral deficiency is supplemented on a large scale in India

(a) Potassium (b) Iron (c) Iodine (d) Sodium

**395.** A steroid vitamin is

(a) *A* (b) *B* (c) *C* (d) *D*

**396.** Which one of the vitamins can be synthesised by gut bacteria

(a) *K* (b) $B_2$ (c) *D* (d) *C*

**397.** Contraction of muscle and conduction of nerve require

(a) $Na^+$ and $K^+$ (b) $K^+$ and $Mg^{2+}$ (c) $Ca^{2+}$ (d) $Ca^{2+}$ and $K^+$

**398.** Vitamin *A* is produced from carotene in

(a) Blood (b) Skin (c) Stomach (d) Liver

**399.** Water soluble vitamins are

(a) *C* and *D* (b) *A* and *C* (c) *B* and *C* (d) *A* and *D*

**400.** Exposure to sun is required for synthesis of vitamin *D* in

(a) Adipose tissue (b) Liver (c) Gall bladder (d) Skin

**401.** Fat soluble vitamins are

(a) *A*, *D* and *E* (b) *B*, *C* and *D* (c) *B*, *D* and *E* (d) *A*, *B* and *C*

**402.** Ascorbic acid is

(a) Vitamin (b) Hormone (c) Enzyme (d) Amino acid

**403.** Normal absorption of calcium and phosphate is controlled by vitamin

(a) *A* (b) *D* (c) $B_1$ (d) $B_2$

**404.** Thiamine $(B_1)$ deficiency leads to

(a) Beri-beri (b) Scurvy (c) Night blindness (d) Pellagra

**405.** Vitamin destroyed on heating is

(a) *A* (b) *B* (c) *C* (d) *D*

**406.** Vitamin containing cobalt is

(a) *A* (b) $B_1$ (c) $B_6$ (d) $B_{12}$

**407.** Vitamin $B_{12}$ takes part in

(a) Increase in blood pressure (b) Decrease in blood pressure

(c) Activating bone marrow (d) Increase in surface area of RBC

**408.** Lipase hydrolyses

(a) Ester bond (b) Glycosidic bond (c) Peptide bond (d) Hydrogen bond

**409.** Calcium occurs in

(a) Neuron (b) Bones and teeth

(c) Cells of respiratory system (d) 3% of mineral content

**410.** Tocopherol is vitamin

(a) *E* (b) *D* (c) *C* (d) *A*

**411.** Cod liver oil is source of

(a) Vitamin *B* (b) Vitamin *C* (c) Vitamin *A* (d) Iodine

**412.** Vitamin *D* is produced in human body by

(a) Muscles (b) Nerves (c) Skin (d) None of these

**413.** Vitamin often act as

(a) Holoenzymes (b) Coenzymes (c) Apoenzymes (d) Cofactors

**414.** A vitamin devoid of coenzyme activity is

(a) Biotin (b) Riboflavin (c) Tocopherol (d) Folic acid

**415.** Castle's intrinsic factor is connected with internal absorption of

(a) Pyridoxine (b) Riboflavin (c) Thiamine (d) Cobalamine

**416.** A nucleotide connected with coenzyme formation is

(a) Nicotinamide (b) Purine (c) Pyrimidine (d) None of these

**417.** Which set is similar

(a) Sebum-Sweat (b) Corpus luteum-Graafian follicles

(c) Vitamin $B_7$-Biotin (d) Bundle of His-Pace Maker

**418.** What is also called vitamin *G*

(a) Riboflavin (b) Thiamine (c) Pantothenic acid (d) Niacin

**419.** Loss of appetite, gastrointestinal disorders and muscular weakness are deficiency symptoms of

(a) Vitamin *B* (b) Vitamin *A* (c) Vitamin *E* (d) Vitamin *C*

**420.** Ascorbic acid is

(a) Amine (b) Vitamin C (c) Amide (d) Cyanocobalamine

**421.** A fat soluble vitamin group is

(a) $B_6$, *E* and *K* (b) *A*, *B*, *C*, *D* and *E* (c) *A*, *D*, *E* and *K* (d) *C*, *D*, *E* and *K*

**422.** A vital ingredient of food which does not provide energy and is required in minute quantity is**2000]**

(a) Carbohydrate (b) Protein (c) Vitamin (d) Fat

**423.** What should be taken to offset deficiency of rhodopsin

(a) Papaya and Mango (b) Orange and Amla

(c) Water melon and Strawberry (d) All of these

**424.** Vitamin required for development of erythrocytes is

(a) *D* **(b)** $B_{12}$ (c) *E* (d) *K*

**425.** Which of the vitamins is essential for normal vision

(a) Folic acid (b) Biotin (c) Riboflavin (d) Niacin

**426.** Which one of the following is the best source for vitamin *A*

(a) Apple (b) Carrot (c) Honey (d) Peanuts

**427.** The most important source for calcium and phosphorus is

(a) Meat (b) Egg (c) Cheese (d) Milk

**428.** Vitamin needed for blood coagulation is

(a) *E* (b) *D* (c) *K* (d) *C*

**429.** Daily requirement of carbohydrate by an adult is

(a) 500 *gm.* (b) 50 *gm.* (c) 150 *gm.* (d) 250 *gm.*

**430.** The term vitamin was introduced by

(a) Pasteur (b) Funk (c) Priestley (d) Lister

**431.** Which is not a source of vit. *A*

(a) Carrot (b) Yeast (c) Mango (d) Apple

**432.** Which one does not belong to vit. *B* group

(a) Riboflavin (b) Nicotinic acid (c) Tocopherol (d) Cyanocobalamine

**433.** Which is not the function of vitamins

(a) Metabolism (b) Digestion (c) Growth (d) None of these

**434.** Hydrolysis of lipids produces

(a) Glycerine and glycerol (b) Fatty acids and trihydric alcohol

(c) Glycine (d) All of these

**435.** The smallest structural units of proteins are called

(a) Amino acids (b) Peptides (c) Proteoses (d) Peptones

**436.** Name the main constituent of the food, in the absence of that one cannot live

(a) Carbohydrates (b) Mineral salts (c) Proteins (d) Vitamins

**437.** To get sufficient carbohydrates one should take

(a) Meat (b) Rice (c) Carrots (d) Ground nuts

**438.** Digestion of protein is necessary due to

(a) Proteins are not absorbed as such (b) Proteins are large molecules

(c) Proteins have complex structure (d) Proteins are made up of amino acids

**439.** Which of the following is regarded as main cellular fuel

(a) Glucose (b) Fructose (c) Protein (d) Fat

**440.** All morphological and physiological dissimilarities between two types of cells of the same body is due to different

(a) Carbohydrates (b) Lipids (c) Proteins (d) All of these

**441.** An average person not doing hard work requires energy per day about

(a) 750 *kcal* (b) 2800 *kcal* (c) 2000 *kcal* (d) 1000 *kcal*

**442.** Role of carbohydrates is to function as

(a) Catalyst (b) Source of energy (c) Enzyme (d) Building material

**443.** In vertebrate's body mainly the food is stored in the form of

(a) Fat (b) Fat and glycogen (c) Glycogen (d) Proteins

**444.** The casein contained in milk is a

(a) Bacterium (b) Carbohydrate (c) Fat (d) Protein

**445.** Non-protein part of an enzyme is called

(a) Cofactor (b) Coenzyme (c) Apoenzyme (d) All of these

**446.** Which group contains biocatalysts

(a) Peptidase, amylase, rennin (b) Myosin, oxytocin, adrenalin

(c) Rhodopsin, pepsin, steapsin (d) Glucose, amino acids, fatty acids

**447.** Which is a disaccharide

(a) Galactose (b) Fructose (c) Maltose (d) Dextrin

**448.** The fundamental requirement of food is for

(a) Growth (b) Hunger (c) Repair (d) Metabolism

**449.** Whether a nation can produce sportsman who could compete successfully in olympics, is decided by

(a) Right diet (b) Body size (c) Long life (d) Health

**450.** Milk protein is

(a) Rennin (b) Casein (c) Galactose (d) Glycine

**451.** What is the common between amino acids, fatty acids and glycerol

(a) These are all rich source of calories

(b) These are the builders of protoplasm

(c) These are the end products of digestion of two categories of food constituents

(d) These can be stored in the form of fat

**452.** A man is said to be starving when

(a) He begins to store reserve food (b) Food that he eats meet the energy loss

(c) Food that he eats doesn't meet the energy loss (d) None of these

**453.** Reserve fuel is

(a) Starch (b) Insulin (c) Glycogen (d) All of these

**454.** Which of the following can be called 'animal starch'

(a) Hemicellulose (b) Glucose (c) Glycogen (d) Chitin

**455.** Balanced diet includes

(a) Proteins and vitamins

(b) Carbohydrates, fats and proteins

(c) Carbohydrates, fats, proteins and vitamins

(d) Carbohydrates, fats, proteins, minerals, vitamins and water

**456.** Amino acids not synthesized in the body are called

(a) Non-essential (b) Active (c) Essential (d) Inactive

**457.** Obesity can be reduced by reducing the calories intake from

(a) Minerals (b) Fats and carbohydrates (c)Proteins (d) Vitamins

**458.** How many calories are required for a hard labourer male

(a) 1500 (b) 3000 (c) 4000 (d) 4500

**459.** During prolonged fasting

(a) The first to be used up are carbohydrates, next fat is withdrawn and proteins are metabolised at the last

(b) The first to be used up are the fats, next carbohydrates are withdrawn from stored glycogen in the liver and muscles and proteins are withdrawn at the last

(c) First lipids are used up, then proteins and finally carbohydrate

(d) None of these

**460.** The water soluble materials pass through the proteins called

(a) Glycoprotein (b) Glycocalyx (c) Extrinsic proteins (d) Channel proteins

**461.** A triglyceride molecule has

(a) Three fattyacids with one glycerol molecule (b) Three fattyacids with two glycerol molecule

(c) Two fattyacids with two glycerol molecules (d) One fattyacid with one glycerol molecule

**462.** Balanced diet should have approximately

(a) 1/5 protein, 3/5 fat and 1/5 carbohydrate (b) 3/5 protein, 1/5 fat and 1/5 carbohydrate

(c) 1/5 protein, 1/5 fat and 3/5 carbohydrate (d) 1/2 protein, 1/4 fat and 3/5 carbohydrate

**463.** A pound of butter contains more usable energy than a pound of sugar for a human because

(a) Sugar contains much more water than butter

(b) A fat molecule has more carbon-hydrogen bonds than a sugar molecule

(c) The butter is an animal product, where as the sugar is a plant product

(d) There is much more waste in digestion and absorption of sugar than of butter

**464.** A non-essential amino acid is

(a) Lysine (b) Methionine (c) Alanine (d) Isoleucine

**465.** Starch and cellulose are compounds of many units of

(a) Amino acids (b) Glycerol (c) Simple sugars (d) Fatty acids

**466.** The anhydro bond of proteins are called

(a) Glycosidic (b) Peptide (c) Ester (d) Diester

**467.** Which one of the following set is a polysaccharide group

(a) Glucose, fructose, lactose (b) Starch, glycogen, cellulose

(c) Sucrose, maltose, glucose (d) Galactose, starch, sucrose

**468.** Unsaturated fatty acids have

(a) Palmitic acid (b) Stearic acid

(c) Oleic acid (d) One or more double bonds

**469.** The delicious food generally makes mouth watery. It is due to

(a) Hormonal response (b) Neural response (c) Olfactory response (d) Optic response

**470.** Which of the following is a reducing sugar

(a) Sucrose (b) Galactose (c) Gluconic acid (d) $\beta$-methyl galactoside

**471.** What is common among amylase, rennin and trypsin

(a) These all are proteins (b)These all are proteolytic enzymes

(c) These are produced in stomach (d)These act at a *pH* lower than 7

**472.** Lactose is composed of

(a) Glucose + fructose (b) Glucose + glucose (c) Glucose + galactose (d) Fructose + galactose

**473.** Vitamin $B_{12}$ is absorbed primarily in the

(a) Stomach (b) Duodenum (c) Jejunum (d) Ileum

**474.** Earliest known vitamin is

(a) Thiamine (b) Ascorbic acid (c) Calciferol (d) Retinol

**475.** Vitamin *A* and *D* are stored in

(a) Bone (b) Spleen (c) Liver (d) All of these

**476.** Beauty vitamin is

(a) Vitamin *K* (b) Vitamin *C* (c) Vitamin *A* (d) Vitamin *E*

**477.** Yeast is a good source of

(a) Vitamin D (b) Riboflavin (c) Ascorbic acid (d) Niacin

**478.** Symbiotic bacteria present in the intestine of most primates which synthesize certain vitamins are**]**

(a) Entamoeba histolytica (b)Entamoeba coli (c) Entamoeba gingivalis (d)None of these

**479.** What will be happened if all bacteria of intestine died

(a) Total reabsorption of nutrient takes place in the body (b)Digestive system work very fast

(c) Synthesis of vitamin *B* complex and *K* stops (d)Irregular behaviour of man

**480.** Which of the following vitamin is a steroid synthesized from cholesterol

(a) Vitamin *A* (b) Vitamin *B* (c) Vitamin *C* (d) Vitamin *D*

**481.** Biotin and pantothenic acid belong to the category of

(a) Amino acids (b) Pyrimidines (c) Vitamin *B* group (d) Steroids

**482.** Essential amino acids are

(a) Alanine and tyrosine (b)Glycine and cysteine

(c)Leucine and isoleucine (d)Serine and proline

**483.** The yellow colour of cow's milk is due to

(a) Carotene (b) Xanthophyll (c) Riboflavin (d) Ascorbic acid

**484.** Vitamins were discovered by

(a) Funk (b) Lunin (c) Drummond (d) Buchner

**485.** Which of the following is a non-essential amino acid

(a) Tyrosine (b) Tryptophan (c) Valine (d) Leucine

**486.** Prolonged thiamine deficiency in diet leads to

(a) Loss to muscle tone and damage to nerves (b) Pellagra

(c) Haemorrhage (d) Anaemia

**487.** Recent anticancer vitamin is

(a) Vit. *Q* (b) Vit. $B_{12}$ (c) Vit. $B_5$ (d) Vit. $B_{17}$

**488.** Vitamins synthesized by intestinal bacteria and absorbed in significant quantities include

(a) Folic acid (b) Vit. $B_{12}$ (c) Riboflavin (d) Thiamine

**489.** Simplest amino acid is

(a) Tryptophan (b) Histidine (c) Glycine (d) Phenyl alanine

**490.** Most complex amino acid having ring structure is

(a) Glycine (b) Tryptophan (c) Tryosine (d) Leucine

**491.** Which one of the following amino acids is considered semi-indispensable for human nutrition

(a) Arginine (b) Lysine (c) Leucine (d) Valine

**492.** Which of the following vitamins possess virucidal properties

(a) Vit. *A* (b) Vit. *D* (c) Vit. *C* (d) Vit. *E*

**493.** Vitamin generally excreted in urine by humans is

(a) *A* (b) *C* (c) *K* (d) *E*

**494.** Which of the following is not a reducing sugar

(a) Sucrose (b) Maltose (c) Lactose (d) Fructose

**495.** Which should not be eaten too much during hot months

(a) Proteins (b) Fats (c) Vitamins (d) Mineral salts

**496.** Number of essential amino acids in man is

(a) 20 (b) 18 (c) 12 (d) 8

**497.** Sucrose is found in

(a) Milk (b) Honey (c) Orange (d) Sugarcane

**498.** Certain *B* vitamins act as

(a) Enzymes (b) Co-enzymes (c) Digestive substance (d) Hormones

**499.** During prolonged starvation, body derives nutrition from storage of

(a) Spleen (b) Lungs (c) Subcutaneous fat (d) Liver and lungs

**500.** In whose milk percentage of lactose is highest

(a) Human mother (b) Cow (c) She buffalo (d) She goat

**501.** Vitamins are

(a) Inorganic substances and cannot be synthesized by animals

(b) Inorganic substances and can be synthesized by animals

(c) Organic substances which cannot mostly be synthesized by animals

(d) Organic substances which can mostly be synthesized by animals

**502.** Which vitamin does not act as a coenzyme

(a) Folic acid (b) Riboflavin (c) Biotin (d) Tocopherol

***Advance Level***

**503.** Given below are assertion and reason. Point out if both are true with reason being correct explanation (A), both true but reason is not correct explanation (B), assertion is true but reason wrong (C) and both are wrong (D).

**Assertion :** Wounds heal slowly due to vitamin *C* deficiency.

**Reason :** Vitamin *C* is essential for collagen formation

(a) *Ar* (b) *B* (c) *C* (d) *D*

**504.** Which one is associated with vitamin *D*

(a) Tocopherol (b) Ergosterol (c) Cholesterol (d) Both (b) and (c)

**505.** Vitamin *D* is synthesised in skin by the action of sunlight on

(a) Cholesterol (b) 7-hydroxy cholesterol (c) Cephalo-cholesterol (d) All of these

**506.** Which is not available from plants

(a) Riboflavin (b) Vitamin $B_{12}$ (c) Niacin (d) Vitamin *C*

**507.** Main cation of extracellular fluid is

(a) Iron (b) Potassium (c) Calcium (d) Sodium

**508.** Which one is rich in Magnesium

(a) Milk (b) Meat (c) Soyabean (d) Apple

**509.** Cyanocobalamine is required for the formation of

(a) RBC (b) WBC (c) Lymph (d) Platelets

**510.** Vitamin nicotinamide can be synthesised in our body from

(a) Tyrosine (b) Tryptophan (c) Valine (d) Phenylalanine

**511.** Which one is essential for DNA replication and cell division

(a) Vit. *E* (b) Folic acid (c) Vit. *K* (d) Vit. *D*

**512.** Which one is a nitrogenous polysaccharide

(a) Chitin (b) Cellulose (c) Glycogen (d) Starch

**513.** Enzymes which acts similarly are called as

(a) Isoenzymes (b) Cofactor (c) Coenzymes (d) All of these

**514.** Disaccharide which gives two molecules of glucose is

(a) Lactose (b) Sucrose (c) Maltose (d) Galactose

**515.** Enzymes, vitamins and hormones can be classified into a single category of biological chemicals, because all of them

(a) Are proteins (b)Enhance the oxidative metabolism

(c) Aid the regulating mechanism (d)Are synthesised within the body of an organism

**516.** The essential mineral for the formation of body protein is

(a) Sodium (b) Iron (c) Sulphur (d) Potassium

**517.** The amount of energy liberated by oxidation in body is termed

(a) Basal metabolic rate (b) Caloric value (c) Physiological fuel value (d)Metabolic rate

**518.** Deficiency of copper causes

(a) Pellagra (b) Anaemia and damages to CNS

(c) Influenza (d) Xerophthalmia

**519.** Which of the following is related with vitamin $B_2$

(a) FMN/FAD (b) NAD (c) NADH (d) None of these

**520.** Consider the following statements :

**Assertion (*A*):** Polypeptidase acts on the peptide linkages of proteins and breaks them into smaller molecules. Water molecules are necessary for this reaction.

**Reason (*R*):** All digestive enzymes belong to hydrolase class.

Now select your answer from the answer code given below:

(a) Both (A) and (R) are true and (R) is the correct explanation of (A)

(b) Both (A) and (R) are true but (R) is not the correct explanation of (A)

(c) (A) is true but (R) is wrong

(d) (A) and (R) both are wrong

**521.** Deficiency of folic acid and vitamin $B_{12}$ leads to

(a) Xeropthalmia (b) Megaloblastic anaemia

(c)Sickle cell anaemia (d) Microcytic anaemia

**522.** Castle's intrinsic factor is connected with internal absorption of

(a) Pyridoxine (b) Riboflavin (c) Thiamine (d) Cobalamine

**523.** A nucleotide connected with coenzyme formation is

(a) Nicotinamide (b) Purine (c) Pyrimidine (d) None of these

**524.** An amino acid has the following structure $H_2\overset{1}{N}-\underset{\displaystyle R^4}{\overset{\displaystyle H^2}{\overset{|}{\underset{|}{C}}}}-COO\overset{3}{H}$

Which two group combine to form the peptide linkage

(a) 1-3 (b) 2-3 (c) 1-4 (d) 1-2

**525.** Which amino acid is denoted by symbol *F*

(a) Phenyl alanine (b) Proline (c) Tryptophan (d) Methionine

**526.** Which amino acid is denoted by symbol *K*

(a) Threonine (b) Lysine (c) Tyrosine (d) Phenyl alanine

**527.** Which amino acid is denoted by symbol *W*

(a) Methionine (b) Glycine (c) Tryptophan (d) Tyrosine

## NUTRITIVE INBALANCE OF DISORDER

***Basic Level***

**528.** A person suffering from bleeding gums should take

(a) Citrus juice (b) Carrots (c) Milk (d) Milk and eggs

**529.** Scurvy due to vitamin *C* deficiency, is characterised by

(a) Intestinal disorder (b)Nervous disorder

(c) Haemorrhage in gums (d)Malfunctioning in kidneys

**530.** Nyctalopia is caused by deficiency of vitamin

(a) *E* (b) *A* (c) *D* (d) $B_{12}$

**531.** Pellagra is caused due to the deficiency of

(a) Ascorbic acid/Vit. *C* (b) Nicotinic acid/Vit. $B_5$ (c) Pantothenic acid (d) Folic acid

**532.** Night blindness is caused by

(a) Genetic disturbance (b) Excessive drinking (c) Vitamin *A* deficiency (d) Excess secretion of adrenals

**533.** Continued consumption of diet rich in butter, red meat and eggs over long period may lead to

(a) Vitamin *A* toxicity (b) Kidney stones

(c) Hypercholesterolemia (d) Urine laden with ketone bodies

**534.** Excessive bleeding from an injury is due to deficiency of

(a) Vitamin *A* (b) Vitamin *B* (c) Vitamin *K* (d) Vitamin *E*

**535.** Deficiency of vitamin *C*/Ascorbic acid causes

(a) Rickets (b) Beri-Beri (c) Scurvy (d) Night blindness

**536.** Prolonged deficiency of nicotinic acid produces

(a) Osteomalacia (b) Xerophthalmia (c) Pellagra (d) Anaemia

**537.** Which pairing is not correct

(a) Vitamin *D*–Rickets (b) Vitamin *K*–Sterility (c) Thiamine–Beri-Beri (d) Niacin–Pellagra

**538.** Which of the following pair is characterised by swollen lips, thick pigmented skin of hands and legs, irritability

(a) Thiamine–Beri-Beri (b) Protein–Kwashiorkor

(c) Nicotinamide–Pellagra (d) Iodine–Goitre

**539.** Deficiency of vitamin *E* brings about

(a) Scurvy (b) Beri-beri (c) Slow clotting of blood (d) Impotence

**540.** Deficiency of calcium causes

(a) Rickets (b) Scurvy (c) Gigantism (d) Addison's disease

**541.** Haemorrhoids are

(a) Small pouches of colon (b)Enlarged rectal veins

(c)Outgrowths of anal canal (d) Longitudinal folds of rectum

**542.** Following are vitamins in column I and deficiency diseases in column II

(i) *K* (A) Beri-beri

(ii) *D* (B) Haemorrhagic disease of new born

(iii) $B_1$ (C) Night blindness

(iv) *A* (D) Rickets

What is correct matching

(a) (i) – (C), (ii) – (B), (iii) – (D), (iv) – (A) (b) (i) – (A), (ii) – (B), (iii) – (D), (iv) – (C)

(c) (i) – (B), (ii) – (D), (iii) – (A), (iv) – (C) (d) (i) – (C), (ii) – (D), (iii) – (A), (iv) – (B)

**543.** A dental disease characterised by mottling of teeth due to ingredient in drinking water, namely

(a) Fluorine (b) Chlorine (c) Boron (d) Mercury

**544.** Antiscurvy vitamin is

(a) *A* (b) $B_{12}$ (c) *C* (d) *D*

**545.** Bow-shaped legs in children are due to deficiency of vitamin

(a) *D* (b) *A* (c) *B* (d) *C*

**546.** Which disease does not occur in infants younger than six months

(a) Kwashiorkor (b) Kwashiorkor and marasmus

(c) Marasmus (d) Jaundice

**547.** Which one is the correct match

(a) Calcium–beriberi (b) *Na*–Addison's disease (c) Iron–haemophilia (d) *P*–bone fragility

**548.** Which is mismatched

(a) Vitamin *K*–Beri beri (b) Vitamin *C*–Scurvy

(c) Vitamin *A*–Xerophthalmia (d) Vitamin *D*–Rickets

**549.** Beri-beri is caused by the deficiency of vitamin

(a) $B_1$ (b) $B_2$ (c) $B_6$ (d) $B_{12}$

**550.** Scurvy disease is caused by the deficiency of vitamin

(a) *B* complex (b) *C* (c) *D* (d) *K*

**551.** Pernicious anaemia is caused by the deficiency of vitamin

(a) $B_1$/Thiamine (b) $B_{12}$/Cobalamine (c) *C*/Ascorbic acid (d) *D*/Calciferol

**552.** Wound healing is enhanced by the vitamin

(a) *A* (b) *B* (c) *C* (d) *D*

**553.** Xeropthalmia in children and night blindness in adults is caused by the deficiency of

(a) Vitamin *A* (b) Vitamin *B* (c) Vitamin *C* (d) Vitamin *K*

**554.** Keratomalacia is deficiency symptom of

(a) Vitamin *A* (b) Protein energy malnutrition

(c) Phylloquinone (d) Nicotinamide

**555.** Antipellagra vitamin is

(a) Pantothenic acid (b) Tocopherol (c) Retinol (d) Nicotinamide

**556.** Blood cholesterol may rise due to deficiency of vitamin

(a) Folic acid (b) Cobalamine (c) Biotin (d) Pyridoxine

**557.** Marasmus is due to deficiency of

(a) Vitamin pyridoxine (b) Vitamin *D*/Calcium/Phosphorus

(c) Food (d) Fat

**558.** Marasmus differs from Kwashiorkor in

(a) Absence of oedema (b) Match stick legs (c) Protruded belly (d) Anaemia

**559.** Marasmus is caused by deficiency of

(a) Carbohydrates (b) Proteins (c) Vitamins (d) Fats

**560.** Gaucher's disease is related to

(a) Abnormal fat metabolism (b) Vitamin deficiency

(c) Disturbed carbohydrate metabolism (d) Abnormal protein metabolism

**561.** Which one is unrelated

(a) *Ca*–muscle contraction (b)*I*–thyroid

(c) *Co*–energy liberation (d)*Cl*–nerve conduction

**562.** Rickets is due to deficiency of vitamin

(a) *D* (b) *C* (c) *B* (d) *A*

**563.** Anaemia is mainly due to deficiency of

(a) *Ca* (b) *Fe* (c) *Na* (d) *Mg*

**564.** Which one is a correct match

(a) Iron–Ricket (b) Vitamin *A*–Scurvy (c) Iodine–Goitre (d) Calcium–Anaemia

**565.** Mark the deficiency disease

(a) Leukemia (b) Addison's disease (c) Scurvy (d) Acromegaly

***Advance Level***

**566.** Mental retardation in children suffering from galactosemia can be avoided by

(a) Giving them more milk (b) Giving them milk free diet

(c) Giving them milk fortified with vitamins (d) Giving them more proteinous diet

**567.** Lathyrism due to consumption of khesri dal is characterised by

(a) Skeletal deformation and thinning of collagen fibres

(b) Skeletal abnormalities, diabetes mellitus and reproductive failure

(c) Retarded growth, precocious puberty and renal dysfunction

(d) Cardiovascular abnormalities, mental retardation and delayed puberty

**568.** **Assertion (*A*) :** Thiamine deficiency results in beri-beri causing paralysis

**Reason (*R*) :** People eating raw fish may also suffer from paralysis due to the deficiency of vitamin $B_1$ ; cooked fish has no such effect

(a) (A) is true but (R) is wrong

(b) (A) is wrong (R) is true

(c) Both (A) and (R) are true and (R) is the correct explanation of (A)

(d) Both (A) and (R) are true but (R) is not the correct explanation of (A)

**569.** In scurvy, post-transcriptional modification of proteins fails to result in the formation of

(a) Lipoproteins (b) Tryptophan (c) Hydroxyproline (d) Histidine

**570.** **Assertion (*A*) :** Minerals are not biologically active substances

**Reason (*R*) :** Some individuals suffer from anaemia due to the deficiency of iron

(a) (A) is true but (R) is wrong

(b) (A) is wrong (R) is true

(c) Both (A) and (R) are true and (R) is the correct explanation of (A)

(d) Both (A) and (R) are true but (R) is not the correct explanation of (A)

**571.** Protein deficiency in children is called

(a) Obesity (b) Marasmus (c) Diabetes (d) Kwashiorkor

## MODES AND TYPE OF NUTRITION

***Basic Level***

**572.** The animals that can eat various plants and animal materials are called

(a) Cannibal (b) Carnivorous (c) Omnivorous (d) Herbivorous

**573.** The method of intake of food in case of ciliate *Paramaecium* is

(a) Holozoic (b) Saprozoic (c) Saprophytic (d) Parasitic

**574.** Holophytic nutrition is found in

(a) Amoeba (b) Giardia (c) Entamoeba (d) Euglena

**575.** The process of sucking of fluid from the cell surface is called as

(a) Diffusion (b) Phagocytosis (c) Pinocytosis (d) Osmosis

**576.** One who gets food and other things on the cost of other is called

(a) Parasite (b) Commensal (c) Saprophyte (d) Insectivorous

**577.** Mode of nutrition in amoeba is

(a) Saprozoic (b) Holophytic (c) Coprozoic (d) Holozoic

**578.** Organisms, which obtain energy by oxidation of reduced inorganic compounds, are

(a) Phototrophs (b) Saprozoic (c) Copro-heterotrophs (d) Chemo-autotrophs

**579.** Some of the animals eat their feaces to digest the cellulose contents again, such animals are known as

(a) Omnivourous (b) Coprophagous (c) Microphagous (d) Macrophagous

**580.** One of the following is a filter feeder

(a) Paramecium (b) Unio (c) Whale (d) All of these

***Advance Level***

**581.** Maximum number of enzymes are found in

(a) Herbivorous (b) Carnivorous (c) Omnivorous (d) None of these

**582.** Which one is detritus feeder

(a) Parrot (b) Sheep (c) Unio (d) Dung beetle

**583.** Pseudorumination is

(a) False digestion (b) Eating the faeces (c) Coprophagy (d) (b) and (c) both

**584.** E.coli in human colon behave as

(a) Parasite (b) Commensal (c) Saprophyte (d) Mutualism

**585.** Cannibals feed on

(a) Carcases (b) Blood

(c) Carnivores (d) Members of own species

**586.** Detrivores are

(a) Parasites (b) Blood sucking

(c) Feeding on organic matter (d) Feeding on carrions

## REGULATION OF FOOD INTAKE

***Basic Level***

**587.** Release of gastro-intestinal secretion and movement after ingestion of food is brought about by

(a) Sympathetic nervous system (b) Parasympathetic nervous system

(c) Central nervous system (d) Thyroid membrane

**588.** The centre which regulate the amount of food we eat or Appetite centre is located in

(a) Stomach (b) Brain (c) Cerebrum (d) Hypothalamus

**589.** Effect of reflex action due to the taste of food is the release of

(a) Vagal impulse (b) Appetite juice (c) Alkaline mucus (d) Spasms of stomach

**590.** Hunger is lost in fever

(a) Due to increased body temperature (b) Due to medicines taken by patient

(c) As the hunger centre is excited (d) None of these

**591.** Wall of oesophagus is made of

(a) Voluntary muscles (b) Involuntary muscles (c) Both of these (d) None of these

***Advance Level***

**592.** Excessive stimulation of vagus nerve in humans may lead to

(a) Hoarse voice (b) Peptic ulcers

(c) Efficient digestion of proteins

(d) Irregular contractions of diaphragm

**593.** Feeling of thirst is due to

(a) Fever (b) Exercise (c) Fall in glucose level (d) All of these

**594.** Which of the following controls the peristaltic movement of the intestine

(a) Sacral plexus (b) Brachial plexus (c) Discoidal plexus (d) Auerbach's plexus

# ANSWER

## ASSIGNMENT ( BASIC & ADVANCE LEVEL )

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a | b | c | d | b | b | b | d | d | b | d | b | d | c | a | a | b | c | c | b |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| d | d | c | a | b | a | b | a | d | c | d | c | b | a | d | b | c | b | c | b |
| 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| a | d | c | a | b | a | d | a | b | d | d | a | c | a | d | c | d | d | c | c |
| 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| b | b | c | c | c | c | c | b | b | a | c | a | a | b | d | d | a | b | b | b |
| 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
| c | a | a | a | c | b | c | b | d | c | c | c | c | c | b | c | b | a | c | b |
| 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 |
| b | c | a | b | a | b | d | d | b | a | b | b | c | b | c | c | a | d | c | d |
| 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 |
| a | d | c | c | c | b | b | c | b | d | d | c | b | a | a | c | c | a | a | c |
| 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 |
| a | d | b | b | c | a | b | b | a | b | d | a | c | d | c | b | a | a | d | b |
| 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 |
| d | c | d | c | a | d | b | d | a | b | b | a | a | d | b | c | b | b | c | c |
| 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 |
| b | c | c | d | c | a | c | c | c | c | a | a | d | b | a | a | d | c | b | b |
| 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 | 220 |
| d | d | b | c | a | c | c | a | a | c | b | b | c | c | d | c | b | b | a | c |
| 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 |
| a | a | c | d | a | d | d | c | b | b | c | a | b | a | d | b | c | a | c | c |
| 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 |
| a | c | a | a | b | a | d | c | b | c | b | d | a | c | c | d | c | d | b | a |
| 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 |
| b | c | b | b | d | b | a | c | d | a | c | a | d | d | a | b | a | a | a | b |
| 281 | 282 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 | 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 300 |
| a | d | c | b | d | b | b | b | a | c | a | c | c | d | b | d | b | b | c | d |

| 301 | 302 | 303 | 304 | 305 | 306 | 307 | 308 | 309 | 310 | 311 | 312 | 313 | 314 | 315 | 316 | 317 | 318 | 319 | 320 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| b | b | b | c | b | a | b | d | a | c | c | a | c | d | a | d | a | a | d | a |
| 321 | 322 | 323 | 324 | 325 | 326 | 327 | 328 | 329 | 330 | 331 | 332 | 333 | 334 | 335 | 336 | 337 | 338 | 339 | |
| d | b | a | c | a | a | b | d | b | d | a | d | d | d | b | d | b | d | d | |
| 340 | 341 | 342 | 343 | 344 | 345 | 346 | 347 | 348 | 349 | 350 | 351 | 352 | 353 | 354 | 355 | 356 | 357 | 358 | 359 |
| b | b | d | b | a | b | a | d | c | b | a | d | a | d | d | d | b | d | c | b |
| 360 | 361 | 362 | 363 | 364 | 365 | 366 | 367 | 368 | 369 | 370 | 371 | 372 | 373 | 374 | 375 | 376 | 377 | 378 | 379 |
| d | b | d | b | b | d | d | a | b | c | b | b | a | a | c | a | a | c | a | b |
| 380 | 381 | 382 | 383 | 384 | 385 | 386 | 387 | 388 | 389 | 390 | 391 | 392 | 393 | 394 | 395 | 396 | 397 | 398 | 399 |
| b | d | c | b | d | a | d | c | a | d | d | a | c | b | c | d | a | d | d | c |
| 400 | 401 | 402 | 403 | 404 | 405 | 406 | 407 | 408 | 409 | 410 | 411 | 412 | 413 | 414 | 415 | 416 | 417 | 418 | 419 |
| d | a | a | b | a | c | d | c | a | b | a | c | c | b | c | d | a | c | a | a |
| 420 | 421 | 422 | 423 | 424 | 425 | 426 | 427 | 428 | 429 | 430 | 431 | 432 | 433 | 434 | 435 | 436 | 437 | 438 | 439 |
| b | c | c | d | b | c | b | d | c | a | b | b | c | b | b | a | c | b | a | a |
| 440 | 441 | 442 | 443 | 444 | 445 | 446 | 447 | 448 | 449 | 450 | 451 | 452 | 453 | 454 | 455 | 456 | 457 | 458 | 459 |
| c | b | b | b | d | b | a | c | a | a | b | c | c | c | c | d | c | b | c | a |
| 460 | 461 | 462 | 463 | 464 | 465 | 466 | 467 | 468 | 469 | 470 | 471 | 472 | 473 | 474 | 475 | 476 | 477 | 478 | 479 |
| d | a | c | b | c | c | b | b | d | b | b | a | c | a | b | c | d | b | d | c |
| 480 | 481 | 482 | 483 | 484 | 485 | 486 | 487 | 488 | 489 | 490 | 491 | 492 | 493 | 494 | 495 | 496 | 497 | 498 | 499 |
| d | c | c | c | b | a | a | d | a | c | b | a | c | b | a | b | d | d | b | c |
| 500 | 501 | 502 | 503 | 504 | 505 | 506 | 507 | 508 | 509 | 510 | 511 | 512 | 513 | 514 | 515 | 516 | 517 | 518 | 519 |
| a | c | d | b | d | b | b | d | a | a | b | b | a | a | c | c | c | c | b | a |
| 520 | 521 | 522 | 523 | 524 | 525 | 526 | 527 | 528 | 529 | 530 | 531 | 532 | 533 | 534 | 535 | 536 | 537 | 538 | 539 |
| a | b | d | a | a | a | b | c | a | c | b | b | c | c | c | c | c | b | c | d |
| 540 | 541 | 542 | 543 | 544 | 545 | 546 | 547 | 548 | 549 | 550 | 551 | 552 | 553 | 554 | 555 | 556 | 557 | 558 | 559 |
| a | b | c | a | c | a | a | d | a | a | b | b | c | a | a | d | c | c | a | b |
| 560 | 561 | 562 | 563 | 564 | 565 | 566 | 567 | 568 | 569 | 570 | 571 | 572 | 573 | 574 | 575 | 576 | 577 | 578 | 579 |
| a | d | a | b | c | c | b | a | a | c | b | d | c | a | d | c | a | d | d | b |
| 580 | 581 | 582 | 583 | 584 | 585 | 586 | 587 | 588 | 589 | 590 | 591 | 592 | 593 | 594 | | | | | |
| d | c | c | d | d | d | c | b | d | a | a | c | b | d | d | | | | | |