Nutrition And Digestive System

⇒ The alimentary tract provides the body with a continual supply of water, electrolytes and nutrients. To achieve this it requires :- (1) movement of food through the alimentary tract (2) Secretion of digestive juices and digestion of food (3) absorption of water, various electrolytes and digestive products (4) circulation of blood through the gastrointestinal organs to carry away the absorbed substances and (5) Control of all these functions by local, nervous and hormonal systems.

⇒ Each part of the entire alimentary tract is adapted to its specific functions :- Some to simple passage of food, such as the esophagus, others to temporary storage of food such as the stomach, and other to digestion and absorption, such as the small intestine.

Nutrition :→ It is the process by which animals obtain essential and non-essential substances called nutrients, and utilise these to produce energy required for various life processes such as growth, repair, development, reproduction and other activities from the surrounding as food.

⇒ The way by which organisms derive their nutrients is called mode of nutrition. It is mainly of two types autotrophic and Heterotrophic.

(A) **Autotrophic or Holophytic nutrition** :→ Preparation of organic food from the inorganic materials in the organism's own body is called autotrophic nutrition. It is of two types :- photoauto-trophic and chemoautotrophic.

(i) **Photoautotrophic nutrition** :→ All green plants certain protists (Euglena viridis) and some bacteria (green sulphur bacterium chlorobium) have evolved a mechanism to directly use the energy of sunlight for preparing organic food in their own body from inorganic materials.

⇒ They take carbon dioxide and water from the environment and transform these into glucose and oxygen with the help of Sun's energy trapped by chlorophyll. This process of making organic food ~~without~~ with the help of sunlight is called photosynthesis. The organisms capable of photosynthesis are termed photo-trophs.

$$6CO_2 + 12H_2O \xrightarrow[\text{sunlight}]{\text{Chlorophyll}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

(ii) **Chemoautotrophic nutrition** :→ Some bacteria which lack the chlorophyll pigments and do not utilize light as a source of energy obtained in the form of ATP from the oxidation of inorganic chemical substances such as ammonia, nitrites, hydrogen sulphide and ferrous iron etc with molecular oxygen.

⇒ Some of the common examples of chemo-autotrophic bacteria are as follows :-

→ Sulphur bacteria e.g. Beggiatoa, Thiothrix and Thiobacillus thiooxidans etc.

→ Iron bacteria

Nitrifying bacteria e.g. Nitrosomonas and Nitrosococcus, Nitrobacter and Nitrocystis.

(B) **Heterotrophic Nutrition** :→ Animals, fungi, some protists and many bacteria cannot manufacture their food. They depend upon autotrophs directly or indirectly. These

organisms are called heterotrophs. The heterotrophic nutrition is of following types :→

(i) Holotrophic (= Holozoic) nutrition :→ Most of the animals take solid / liquid food through the mouth. This mode of taking solid or fluid via mouth is called holotrophic (G.K. holos – whole, trophe – nourishment) nutrition.
⇒ Since it is characteristic of almost all vertebrates and most invertebrates animals, it is also called holozoic nutrition.
⇒ Animals generally have a specialised digestive tract which has various parts modified for ingestion, digestion, absorption, assimilation and egestion.

(ii) Saprotrophic (or saprozoic) nutrition :→ it is derived from the Greek word – Sapros – rotten, trophe : nourishment.
⇒ In this type, the organism releases digestive enzymes to the surrounding medium to convert non-diffusible food into diffusible form. The organism then absorbs diffusible food through the body surface. This is called saprotrophic nutrition. Fungi and many bacteria are saprophytic in nutrition.

(iii) Parasitic nutrition :→ The organisms derived nourishment from the organic compounds present in the body of another living organisms called the host.
⇒ The parasite, the one that draws nourishment often lacks or reduced digestive system as it feeds on nutrients already in solution form or digestive form, from the host as in the case of gut parasites like tapeworm and round worm.
⇒ Some parasites are external parasites that is they do not live inside the body of host but feed on the fluids / tissues of the host.
⇒ Staying externally, these organisms are called ectoparasites, such as mosquito, leech etc :.

(c) Photoheterotrophic nutrition :→ Able to use light energy to synthesize organic requirements from other raw (organic) materials.
E.g. Purple non-sulphur bacteria Rhodospirillum.

Type	Feature	Example.
1) Herbivores	→ Feeding on plant food	Goat, Cow, Rabbit.
2) Carnivores	→ Feeding on other animals	→ Lion, Tiger.
3) Omnivores	→ Feeding on all types of food	→ Humans.
4) Detrivores	→ Feeding on detritrius or organic remains	→ Earthworm
5) Scavangers	→ Feeds on large masses of dead animals remains	→ Vulture.
6) Frugivores	→ Feeding on fruits	→ Parrot.
7) Sanguivores	→ Taking meal of blood	→ Leech, female mosquito, bed bug.
8) Insectivores	→ Eating insects	→ Common bats, wall lizards.
9) Cannibals	→ Eating other members of own species.	→ Many snakes, scorpions.
10) Piscivorous	→ Feed on fish	→ Some aquatic birds.
11) Coprophagus	→ Feeds own faeces	→ Rabbit.

(D) Osmotrophic nutrition :→ when ingested food material is taken by diffusion through body wall. E.g:- T. solium, Trypanosoma

(E) Myxotrophic nutrition :→ Euglena carries on both autotrophic and saprozoic nutrition. Such a dual mode of nutrition is called myxotrophic nutrition.

(F) Mutualism (Symbiosis) :→ It is a close association between individuals of two different species, both partyess benefit from the association. Example:-

(i) Nitrogen fixing bacteria such as Rhizobium can be found in root nodules of leguminous plants (Papilionaceae) such as peas and beans. They provide the plant with a supply of nitrogen in the form of ammonia and receive carbohydrates from the plant.

(ii) Colonies of cellulose-digesting organisms (E.Coli in ruminant stomach) help digest the cellulose found in cell walls by producing cellulase. Both organisms benefit from this relationship. The ruminant is able to digest the cell contents once the walls have been broken, and in return, the bacteria obtain food and shelter.

Nutritional Requirements :→ If all the components (carbohydrate, fats, proteins, vitamins, water, minerals, and roughage) are present in optimum proportion and quantity for maintaining the body in perfect state of health, activity and development then food is called balanced diet.

⇒ The study of foodstuffs, their nutritional value and requirements to keep fit and healthy is called dietetics. A person skilled in the principles of dietectics is known as Dietitian or Dietetist.

(A) Carbohydrates :→ The sources of carbohydrates in our diet are cereals (rice, wheat, maize) potatoes, Colocasia, grams, fruits (banana, mango, melon), sugar, honey, sugar cane, beet, jam and milk (Page 2)

functions :-

(i) Fuel :→ Carbohydrates form the major fuel in the cells to provide energy for life processes.

⇒ Carbohydrates form a better fuel than proteins and fats because their molecules have relatively more O_2 and therefore needs less molecular O_2 for oxidation than those of proteins and fats. Glucose is the most common fuel carbohydrates.

(ii) Reserve food materials :→ If in excess, glucose is converted into glycogen and stored in the liver and muscle cells. This conversion is called glycogenesis.

⇒ It may also be changed into fat and stored in liver, adipose tissue and mesenteries. This change is termed lipogenesis.

⇒ In case the food provides inadequate glucose, reserve glycogen is converted into glucose for use in energy production, this conversion is known as glycogenolysis.

(iii) Components of cellular compounds and organelles :→ Pentose sugar ribose is a component of ribonucleic acids (RNA), energy carriers, such as adenosine triphosphate (ATP) and certain coenzymes such as nicotinamide adenine dinucleotide (NAD). Another pentose sugar, deoxyribose is a component of deoxyribonucleic acid (DNA).

⇒ The RNA and DNA are in turn components of ribosomes and chromosomes respectively.

(iv) **Heteropolysaccharides**:→ These consist of modified mono-saccharide units. They form certain very important substances, like:-

(a) **Anti Coagulant** heparin that prevents the clotting of blood in the intact blood vessels.

(b) **Blood group substances** such as A, B, and Rh antigens of erythrocytes, that are responsible for major immunological reaction of blood.

(c) **Lubricant** hyaluronic acid present in the synovial fluid of the joints, Cerebrospinal fluid and Vitreous humour.

(d) **Protective Coats** such as glycocalyx that covers the Intestinal epithelium and mucus which covers all mucous membranes.

(e) **Luteinizing hormone** that causes ovulation, formation of Corpus luteum, and secretion of female sex hormone.

An adult man of average weight and doing moderate work needs about 350-500 gms, of Carbohydrates daily.

(B) Proteins:→ The sources of proteins in our diet are Cereals, pulses, oil seeds and nuts, meat, fish, eggs, milk, cheese, leafy vegetables, roots and tubers, fruits, soyabean, groundnut, peas and beans.

Functions:→

(i) **Building materials**:→ The principle role of proteins is to build the tissue. The proteins with this role are called Structural proteins.
⇒ They are essential for growth, repair and reproduction. The proteins are components of all organelles, tissues and exoskeletal elements.

(ii) **Regulatory substances**:→ Many proteins regulate life processes. they are called functional proteins.

(iii) **Fuel materials**:→ Proteins are used as a source of energy when carbohydrates and lipids are exhausted.

(iv) **Biological buffers**:→ Proteins assist in maintaining a balance of acidity and alkalinity in the cells by combining with excess acids and bases due to presence of polar amino acids side chains.

(v) **Raw materials**:→ Proteins may break down into amino acids to synthesize new proteins or further to form carbohydrates and fats.
⇒ Amino acids are also necessary for the formation of skin pigment melanin and purines and pyrimidines for nucleic acids.

(vi) **Osmotic pressure**:→ Proteins maintains the osmotic pressure of the cells as they generally do not leave the cells.
⇒ About 70 to 100 grams of proteins (about 70gm for an adult man, 58 gm for an adult women) are needed daily.
⇒ Growing children, pregnant women and convalescent persons need more proteins in the diet.

Types of amino acids and proteins:→
⇒ Nutritionally the amino acids are of two types.
⇒ Eight amino acids cannot be synthesized in our body and must be taken in the diet they are called essential amino acids. They include:- Isoleucine, Leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine.
⇒ other amino acids may be synthesized in the body from some amino acids or carbohydrate metabolites. They are called non-essential amino acids.

⇒ Non-essential amino acids include:- alanine, arginine, asparagine, aspartic acid, cysteine, glutamine, glutamic acid, glycine, histidine, proline, serine, and tyrosine.

⇒ out of these arginine and histidine are considered Semi-indispensable amino acids.

⇒ Animal proteins contain all the essential amino acids and are known as the "first class proteins" their sources are meat, fish, milk and eggs.

⇒ Proteins which contain adequate amounts of all the essential amino acids are termed adequate proteins. Milk, meat and eggs contain nutritionally adequate proteins.

⇒ Plant proteins may not have all the essential amino acids and are called the "second class proteins", their main sources are peas, beans and lentils.

(C) **Fats**:→ The sources of fats in our diet are vegetable cooking oil, vanaspati ghee, desi ghee, butter, cream oil seeds and nuts, milk, cheese, mutton and eggs.

Functions:→

(i) **Fuel**:→ Fats act as a concentrated fuel. Their Calorie value is 9.5 Kcal and physiological fuel value is 9 Kcal (Kau). Thus they produce 2.25 times as much energy per gram as do the carbohydrates. For uses as fuel, fats are changed into glucose.

(ii) **Reserve food materials**:→ Excess fat is stored in the liver, adipose tissue under the skin and mesenteries.

⇒ As the fats produce more energy on oxidation than glycogen, they are more suitable as stored food. Stored food is used as fuel when glucose is not available.

⇒ Store of fat can suffice for several weeks during fasting. too much fat deposit causes obesity.

(iii) **Component of cell Organelles and Compounds**:- Fats are used in the formation of cellular membranes and medullary sheath of nerve fibres.

⇒ Fats plays a role in the formation of certain hormones such as adrenal cortex and sex hormones.

⇒ Fatty acids obtained from food fats are used in synthesizing structural lipids like phospholipids, glycolipids, lipoproteins, and sterols.

(iv) **Insulation**:→ Fats stored in the subcutaneous tissue insulates the body against loss of heat. Fats insulate the nerve fibres electrically

(v) **Protection**:→ Fat forms protective and shock-absorbing cushions around many organs such as eyeballs, kidneys, gonads etc.

(vi) **Help in absorption**:→ Fats help in the absorption of fat soluble vitamins, namely A, D, E and K.

(vii) **Body form**:→ The subcutaneous fat keeps the skin firm and helps in rounding off the contour of the body.

(viii) **Palatability of food**:→ Fats impart flavour and taste to the food.

⇒ About 50 gms of fat is needed by man daily. Fats are digested slowly and delay the hunger sensation between meals

Essential and non-essential fatty acids:-

⇒ A few fatty acids are not synthesized in the body and must be present in diet. They are called essential fatty acids. They include linoleic, linolenic and arachidonic acids. They are present in unsaturated vegetable oils such as groundnut oil, Sunflower oil and safflower oil.

⇒ Non-essential fatty acids can be synthesised by the body, they may or may not supplied in the food e.g. palmitic acid and stearic acid etc.

(7) **Minerals**:→ 9n the forms of salts (ions) are known to be essential 9n the diet.

⇒ Six elements are needed 9n relatively large amounts more than 1 gram and are called macroelements. These are:- Sodium (Na), potassium (K), Calcium (Ca), magnesium (Mg) phosphorus (P), and chlorine (Cl).

⇒ Other elements are required 9n very small amounts (less than 1 gram) and are called micro or trace elements. These are:→ Copper (Cu), fluorine (F), manganese (Mn), cobalt (Co), Zinc (Zn), iron (Fe), iodine (I), molybdenum (Mo) and selenium (Se).

⇒ The minerals have small molecules and do not require digestion. They are absorbed from the alimentary canal into the blood which supplies them to the tissues.

⇒ Minerals must be taken as compounds. If taken as elements such as Sodium or potassium they prove fatal. As compound say Sodium chloride they are harmless.

⇒ The sources of minerals are milk, eggs, meat, vegetables, fruit and table salt (ex:- Sodium chloride NaCl)

⇒ Minerals are needed in very small amounts a gram or less per day.

Food sources and importance of minerals

S/No.	Mineral	Food Source.	Importance.
1.	Sodium.	Table salt, beef, spinach, cheese, wheat germ, pickles, butter.	⇒ Principle action in extra cellular fluid (ECF) ⇒ Associated with osmotic pressure ⇒ Protects against excessive loss of water. ⇒ Maintain electrical potential across the membranes (Na-K pump). ⇒ Associated with muscle function and nerve conductivity ⇒ Sodium occurs inside the cell and helps to retain water in ECF. ⇒ It is a component of bile salts which emulsify fats in the intestine. ⇒ It maintains pH balance of the body fluid. Deficiency Causes:→ Cramps, Diarrhoea, and dehydration, low blood pressure.
2.	Potassium	Molasses, banana, date, potato, spinach, orange, beans, milk etc.	⇒ Maintenance of osmotic pressure between ECF and ICF. ⇒ Principle cation inside the cell. ⇒ Active transport by K^+/Na^+ pump. ⇒ It helps to retain water in the cells. ⇒ It plays a role in muscle contraction and in the conduction of nerve impulse. Deficiency Causes:→ Muscle disorders, including Cardiac muscles and nerves, low BP.
3.	Chlorine	Table salt, Cabbage, eggs, Cheese, bread.	⇒ Principal mineral anion in ECF. ⇒ Regulation of osmotic pressure. ⇒ Formation of HCl in stomach. ⇒ Helps in transport of CO_2, along with Sodium. Deficiency Causes:→ loss of appetite, muscle cramps.
4.	Calcium	Milk, green leafy vegetables, Carrot, fishes, egg, cream, cheese, cauliflower, cereals, cereals.	⇒ Building of bones and teeth. ⇒ Help in clotting of blood. ⇒ Regulate heart, nerve and muscular activity. ⇒ Activates ATPase during muscle contraction. ⇒ Essential for action of many enzymes.

S/No.	Mineral	Food Source	Importance.
5.	Phosphorus Deficiency Causes:- Loss of bone minerals and many metabolic disorders.	Cereal grains, milk, eggs, fish, meat, peas, cheese.	⇒ Required for tooth and bone formation. ⇒ Constituent of phospholipids, nucleic acids, Coenzyme, and ATP. ⇒ Help to maintain normal blood pH. ⇒ Regulation of Heart beat.
6.	Magnesium Deficiency Causes:- Convulsions, hallucinations, irregularities of metabolism, cardiac arrythmias.	Dairy products, green leafy vegetables, Seafood, chocolate, and wheat germ.	⇒ It helps in muscle relaxation. ⇒ It also acts as a catalyst. ⇒ It helps in release of energy.
7.	Iron. Deficiency Causes:- Microcytic anaemia, weakness and weak immunity.	oatmeal, apricoat, green leafy vegetables like spinach, pulses, liver, nuts, molasses, eggs, almonds, honey dates.	⇒ Formation of hemoglobin and myoglobin. ⇒ Required in the synthesis of cytochromes. ⇒ Required in the synthesis of thyroxine hormone.
8.	Iodine. Deficiency Causes:- Goitre (an enlargement of thyroid gland), Cretinism.	onion, marine fish, seafood, Iodised table salt.	⇒ Important component of thyroxine hormone.
9.	Sulphur. Def^{n} Causes:-	Meats, dairy products, eggs.	⇒ It is a part of many proteins. ⇒ It is essential for the synthesis of vitamin B. ⇒ It helps to keep hair, skin and nails healthy.
10.	Copper. Def^{n} Causes:-	Peanuts, beef and barley, Soya-bean, peas, black gram, and onion, liver, shell fish.	⇒ It acts as a Cofactor of certain enzymes (Cytochrome oxidase enzyme) ⇒ It is also necessary for proper utilization of haemoglobin (i.e. necessary for iron metabolism) ⇒ Development of blood vessels and connective tissue.
11.	Chromium Def^{n} Cau:- Impaired glucose tolerance.	Meats and animal proteins (except fish), black gram, Soyabean, Carrots.	⇒ It promotes Insulin action in the metabolism of Sugar.
12.	Flourine Def^{n} Causes:- Weak teeth which are prone to decay.	Fish tea, city water supplies, Sea food etc^{n}.	⇒ It maintains normal enamel and check dental Caries.

S/No.	Mineral	Food Source	Importance.
13.	Zinc. Def:- Causes!→ Retarted Growth, rough skin, anaemia, weak immunity and fertility.	Soyabean, black gram, wheat, peas, beet barley, bajra, egg, coconut, almonds, groundnuts and oyster	⇒ It is a cofactor of many enzymes such as Carbonic anhydrase and alcohol dehydrogenase. ⇒ It is essential for vitamin A metabolism. ⇒ It fastens healing of wounds. ⇒ Required for protein synthesis, immune reactions and general growth↑. ⇒ It is needed for healthy skin and hair.
14.	Cobalt Deficiency Causes!- Anaemia.	Milk, meat	⇒ It is Component of vitamin B_{12}. ⇒ It helps in erythopoiesis and action of certain enzymes.
15.	Manganese. Deficiency Causes!→ Infertility, Spongy bones, menstrual problem and unpaired fat metabolism.	Liver, nuts legumes and wheat germs.	⇒ It helps in the metabolism of Carbohydrates, fats and proteins by Cooperating with many enzymes. ⇒ It is important for normal reproduction, function of mammary glands and synthesis of haemoglobin.
16.	Molybdenum :- Wheat, blackgram, peas, bajra, Cabbage, onions and potatoes. Deficiency disorder is almost unknown		⇒ It is essential for the synthesis of haemoglobin and absorption of Iron.
17.	Selenium Deficiency Causes!- Higher risk of Cancer, Cardio-vascular diseases and inflammatory disease.	wheat germ, barley, garlic and orange juice.	⇒ It acts with vitamin E as a non-specific antioxidant to protect cell membrane and tissues. ⇒ It along with vitamin E slow down the ageing process.

(E) Vitamins!→ Can be defined as naturally occurring organic substances which are required in minute amount to maintain normal health and are to be supplied in food as they Cannot be synthesized by the organism (except vitamin D which can be synthesized by the skin in the presence of sunlight). These are two main types of vitamins!—

(i) Water Soluble vitamins!→ They dissolve in water.
⇒ Present in certain vegetables and fruits.
⇒ Ex!- Vitamin B-Complex ($B_1, B_2, B_5, B_6, B_{12}$) folic acid and vitamin C.

(ii) Fat Soluble vitamins!→ Do not dissolve in water and instead dissolve in fat solvents like chloroform.
⇒ Present in animal and vegetable fats.
⇒ Ex!- Vitamin A, D, E and K.

Characteristics!→ 1) They do not provide energy. (2) They are not used as structural units.
3) They are usually required as Co-enzymes or precursors of Co-enzymes.
(4) Some of vitamin cannot be stored, some are toxic if taken in excess and hence a regular supply in diet is essential.

Types of vitamins with their functions and deficiency disease

(Page 5)

Name of vitamins / Daily need / Principle sources	Functions	Deficiency diseases
Fat Soluble vitamins:-		
1) Vitamin A Retinol (2mg) ⇒ Cod liver oil, shark liver oil, milk, butter, dairy product, yellow vegetables and crops like maize, Carrot, papaya, Green leafy vegetables like Spinach.	1) Synthesis of visual pigements like rhodopsin of rod cells and iodopsin of cone cells of retina. 2) Maintenance of normal living secretary epithelium in mucous membrane of eye. 3) Prevents Keratinisation of eye epithelium. 4) It is also required for normal growth and development of lacrimal gland. 5) It is necessary for reproduction (embryogenesis). 6) Vitamin A has anti cancer property.	1) Xeropthalmia (Drying of eyeball) 2) Night blindness (Nyctalopia). 3) Dermatosis (Dry and scaly skin). 4) Keratomalacia (Corneal epithelium becomes Keratinized and opaque and may become softened and ulcerated). ** It destroyed by strong light.
2) Vitamin D (Anti-rachitic vitamin). ⇒ Calciferol (0.01mg) ⇒ Cod liver oil, shark liver oil and eggs. ⇒ Also made by the action of Sunlight in skin.	1) Synthesised in the skin from a cholesterol derivative by UV rays of sunlight. 2) increased intestinal absorption of Calcium and phosphorus. 3) Important in bone and teeth formation. 4) Vitamin D, maintains the normal functioning of para-thormone (hormone secreted by parathyroid gland) 5) It affects the metabolism of citric acid which is a normal constituent of tissues including bones. 6) It has a specific function in kidney, tubular reabsorption of Calcium and phosphate.	1) Rickets in children (softness and deformities of bones like bow-legs) and Knock Knee in children. 2) Osteomalacia in adults (weak painful bones liable to easy fracture) 3) Dental Caries (Cavities in teeth) ** It destroyed by oral Contraceptive
3) Vitamin E (also called beauty vitamin or anti sterility vitamin) ⇒ Tocopherol (15mg) ⇒ Green vegetables, brown flour, germinated wheat and seeds, Vegetables oil and Liver.	1) Maintains normal membrane structure by inhibiting peroxide formation as antioxidant. 2) Maintains fertility. Prevents haemolysis of R.B.C. 3) Vitamin E plays a specific role in Selenium metabolism. 4) It keeps skin healthy. 5) It has anti cancer property. It is used for curing tumour, cancer. 6) It maintains normal function of Reproductive organs hence it is called fertility vitamin. 7) It maintains the muscles of the body, should be part of athletes diet. 8) It is used to prevent heart attack and treat Alzheimer disease. 9) Part of it is necessary synthesis of Co-enzyme Q which is component of electron-transport chain. 10) It helps in development and cell formation. Thus it is needed in the diet of pregnant and lactating women and for the new born infant particularly premature infants.	1) Reproductive failure, Sterility in mammals. 2) muscular dystrophy. 3) Increased haemolysis of R.B.C. 4) Anaemia. 5) Slow growth. It destroyed by Heat.

Name of vitamins/ Daily need/ Principle Sources	Functions	Deficiency disease.
4) Vitamin K Phylloquinone (0.107–0.1mg) Cabbage, spinach, Coriander, radish tops, also synthesised by bacteria in colon.	1) Required for synthesis of prothrombin (an important factor for blood coagulation) and other Clotting factors. 2) It also plays role in mitochondrial electron transport and oxidative phosphorylation.	1) Profused and prolonged bleeding. 2) Delay in blood clotting mech= condition called hypoprothrombinemia Destroyed by prolong use of antibiotics and sulpha drugs.
Water Soluble Vitamins :→		
1) Vitamin B_1 Thiamine (1.5 mg) ⇒ yeast, cereals, pulses nuts, liver, and meat. Sprouted beans.	1) Respiratory Coenzyme (TPP) required for decarbo-xylation especially during Kreb's cycle. 2) Also required for pentose synthesis and metabolism. 3) Tones the nervous system (The Ner=Sys= mainly depends upon Carbohydrate metabolism for energy) and muscles, improves and promotes growth.	Beri beri :- loss of appetite. - accumulation of keto acids in blood weak heartbeat. ## Destroyed by Cooking.
2) Vitamin B_2 Riboflavin or vitamin G yeast liver, milk, yogurt, pulses, green vegetables. (2mg)	1) Maintains healthy skin and oral mucosa. 2) Forms flavin Coenzymes like FAD and FMN required as hydrogen Carriers in cell respiration (E.T.C)	Cheilosis (or sore at the corner of mouth) Skin disorders inflammation of tongue glossitis. ⇒ Burning sensation in skin and eyes, ⇒ Dermatitis at angle of nostrils. ⇒ Keratitis of cornea Destroyed by Light.
3) Vitamin B_3 Nicotinic acid (Nicotinamide) 20mg ⇒ yeast liver, cereal grains, pulses, fish and meat. ⇒ Can be synthesised in the body from amino acid tryptophan.	Forms Coenzymes NAD and NADP required as hydrogen acceptors in cell respiration. Called 4 D Syndrome due to characterization of dermatitis, diarrhoea, dementia and death.	Pellagra skin problems, diarrhoea, gum disease. ⇒ Hartnup's disease (hereditary abnormality in metabolism of tryptophan, cha= by pellagra like symptoms.
4) Vitamin B_5 Pantothenic acid (5–10mg) ⇒ Liver, eggs, yeast, most of foods, tea, milk, groundnuts and tomatoes.	1) Forms Coenzyme A that activates Carboxylic acids in cellular metabolism. 2) This vitamin is associate with healthy skin and hair. 3) It is required for the normal functioning of adrenal glands. 4) It is needed by chickens for proper hatching.	⇒ Fatigue, Muscle Cramps, ⇒ poor motor coordination. ⇒ burning feet Syndrome. destroyed by Cooking.

Name of vitamins/ Daily need/ Principle Sources	Functions	Deficiency diseases
5) Vitamin B_6. Pyridoxine (2mg) ⇒ All animal and plant tissues.	1) Forms coenzymes for amino acids synthesis from carbo-hydrate intermediates and the process is called **trans-amination, decarboxylation** (removal of CO_2) and **racemization** (formation of an equilibrium mixture of DL-alanine from either D or L-alanine). 2) Vitamin B_6 is also useful in the treatment of nausea, and vomiting during pregnancy (morning sickness) radiation sickness and muscular dystrophy. 3) An antituberculosis drug **Isoniazed** (isonicotinic acid hydrozoide-INH) induces vitamin B_6 deficiency.	⇒ Anaemia, diarrhoea, Dermatitis, mental disorders nausea, vomiting destroyed by Cooking, Oral Contraceptives.
6) Vitamin B_{12} Cobalamine Cobalt containing vitamin (0.003mg) ⇒ Meat, kidney, liver, milk, eggs, fish ⇒ Also synth:- in human colon and in ruminant stomach of cattle.	1) Absorption of Cobalamine, requires the action of gastric enzyme!- Castle's Intrinsic factor. 2) Promotes DNA Synthesis. 3) Maturation of R.B.C. 4) Formation of myelin (It plays an important role in the stimulation of protein synthesis, especially incorporation of amino acids into proteins). 5) Vit:- B_{12} plays a role in the conversion of carbohydrate to lipid.	1) Pernicious anaemia (Great decrease in the number of RBCs formation in the bone marrow) 2) Causes nervous disorder. destroyed by:- Grilling or excessive heat.
7) Vitamin M (Folic acid 0.5mg) Leafy vegetables, liver, yeast, fish ⇒ Also synthesised by bacteria in colon.	Same as vitamin B_{12} Various Coenzyme forms of folic acid play an important role in a variety of important metabolic reactions such as!→ 1) Serine - glycine interconversion. 2) Purine and pyrimidine synthesis (helps in DNA synthesis) 3) Methyl synthesis 4) Histidine synthesis. 5) It also increases cell multiplication especially in bone marrow where there is maximum rate of cell division and multiplication normally. Thus folic acid is essential for growth and formation of RBC.	1) Megaloblastic anaemia (enlarged RBCs and low haemo-globin content). 2) Sprue characterized by ulceration of mouth, inflammation of bowel, inability to absorb (especially fats), diarrhoea, weakness and anaemia. destroyed by!- Cooking.
8) Vitamin P (Hesperidin) Citrus fruit, green vegetables, lemon ring, outer tough covering of fruits.	⇒ It is useful for maintaining resistance in the wall of blood capillaries.	

Name of vitamins/ Daily need/ Principle Sources	Functions	Deficiency diseases
9) Vitamin B_{15}. Pangamic acid ⇒ Seeds of many plants ⇒ Also been isolated from blood and liver of Horse.	⇒ It helps in the utiligation of O_2 by the cells and promotes the oxidation of alcohol in the organism. ⇒ The compound is used to treat certain Cardiac and vascular diseases.	
10) Vitamin B_{17}. Laetrile. ⇒ wheat grass juice.	⇒ Vitamin B_{17} has anticancer property.	
11) Vitamin C Ascorbic acid (50 mg) ⇒ Citrus fruits like lemon, orange, amla, guava, green vegetables.	⇒ Formation and maintainance of collagen fibres in the inter cellular connective tissue. 2) It is necessary for health gums and teeth. 3) Ascorbic acid in food helps in the absorption and utiligation of iron by converting the inorganic feoric iron to the ferrous form. 4) Adrenal cortex shows high concentration of this vitamin. So it required for the normal function of adrenal glands. 5) Also essential for the formation of RBCs and the production of antibodies. Thus it maintains immune defence system. 6) Also maintains the strength of the walls of the blood capillaries. 7) Vitamin C helps in healing of the wounds. 8) It has antioxidant property. 9) It help in the synthesis of neurotransmitters.	1) Bleeding from small vessels. 2) Scurvy (also called Sailor's disease) characterised by delay of wound healing and growth retardation, breakdown of immune defense system, fragile blood vessels, spongy and bleeding gums, and bones, high fever, etc. destroyed by :- Heat and light.
12) Vitamin H. Biotin (150-300 mg) yeast, liver, kidney	1) Required as coenzyme for carboxylation reaction in cells, involving fatty acids and various carboxylic acids. 2) Play a role in the deamination of certain amino acids. 3) Biotin plays a role in the synthesis of oleic acid by certain lactic acid producing bacteria.	Dermatitis, Skin problems.

(F) **Water**:→ water is a liquid compound made up of two parts of hydrogen and one part of oxygen.

⇒ It usually forms about 70% to 90% part of cytoplasm and 45% to 80% part of the whole body.

⇒ we loss about 2% of our body weight as water per day. We recoup this water loss in 3 ways:-

(1) By drinking water.
2) By getting water as a part of food.
3) By retaining and utilizing the water produced in metabolism.

Functions:→ 1) water is the most stable solvent in which majority of chemical compounds are dissolved or suspended to carry on various cellular functions.
2) It keeps the organ moist to enable their smooth movements.
3) It helps in the transport of food matter, waste products and other chemicals in the protoplasm.
4) water acts as temperature stabilizer to keep the temperature of particular cells relatively constant and normal.
5) water is essential for various chemical reactions.

(G) **Roughage**:→ Roughage or dietary fibre is the undigested part of the food.

⇒ cellulose of fruits and vegetables and connective tissue of meat and fish are the examples of roughage.

⇒ our body does not have enzymes to digest the cellulose to carbohydrates. So, cellulose remains undigested and being a fibrous material acts as a roughage and keeps the digestive system in order. The various functions are as follows:-

(1) Roughage helps in retaining water in the body: this is because of the fibrous nature of the roughage. Being fibrous, cellulose can absorb a lot of water and helps retain water in the body.

(2) Roughage adds bulk to the food and prevents constipation: since cellulose is bulky, it expands the intestines as it moves through them and makes the passage of food easier.

⇒ The roughage also stimulates the muscle contraction in the intestine walls causing movement of the food. Thus roughage keeps the fast moving in the intestines and hence prevents constipation.

Energy Requirement:→ It is the energy required by an individual every day. It is measured in the heat units called food Calories or nutritional Calories.

⇒ The energy requirements of various individual differ markedly due to sex, age, body size, activity and temperature of external environment etc.

⇒ The human body's requirement for energy is determined by:-

The rate of metabolism, known as basal metabolism: this is our rate of energy metabolism resting but awake, at a comfortable external temperature, after having fasted for twelve hours, and is the basic rate against which to compare energy demands of various activities.

⇒ The complete combustion of nutrients in laboratory (caloric value) and oxidation of the same in body (physiological value) differ slightly as some intermediate products are also formed in the body.

Substance.	Caloric value.	Physiological value.
1) Carbohydrate	4.1 Kcal/gm	4 Kcal/gm.
2) Proteins.	5.6 Kcal/gm.	4 Kcal/gm.
3) Fats.	9.4 Kcal/gm.	9 Kcal/gm.

Basal Metabolic Rate :→ Basal metabolic rate (or BMR) is the minimum ~~ee~~ calorific requirement needed to ~~sust~~ sustain in a resting individual.

⇒ BMR is determined by a combination of genetic and environmental factors as follows :-

1) Genetics :→ Some people are born with faster metabolisms, while some with slower metabolism.

2) Gender :→ Because men have a greater mass and a lower body fat %, they generally have a higher basal metabolic rate.

3) Age :→ BMR is greater in childhood than in adulthood. after 20 years, it drops about 2% per decade.

4) Weight :→ The more your weight the higher your BMR will be.

5) Body surface area :→ This is reflection of height and weight: the greater your body surface area factor, the heigher your BMR. Tall, thin people have higher BMRs.

6) Body fat percentage :→ People with a higher body fat %, have a lower BMR than those with a lower body fat %. :- all other things being equal.

7) Diet :→ Starvation or serious abrupt-caloric-reduction can dramatically reduce BMR by upto 30%.

8) Body temperature/ health :→ For every increase of 0.5°c in internal temperature of the body, the BMR increases about 7%. The chemically reactions in the body actually occur more quickly at higher temperature.
⇒ So a patient with a fever of 42°c (about 4°c above normal) would have an increase of about 50% in BMR.

9) External temperature :→ Temperature outside the body also affects basal metabolic rate. Exposure to cold temperature causes an increase in the BMR, seas to create the extra heat needed to maintain the body's internal temperature.

10) Glands :→ Thyroxin (produced by the thyroid gland) is a Key BMR regulator which speeds up the metabolic activity of the body.
⇒ The more thyroxine produced, the higher the BMR. If too much thyroxin is produced (a condition known as thyrotoxicosis) BMR can actually double.
⇒ Like thyroxin, adrenaline also increases the BMR but to a lesser extent.

11) Excercise :→ Physical excercise not only influences body weight by burning calories, it also helps raise your BMR by building extra muscle. So you burn more calories even when sleeping.

Nutritional Imbalance :→ Deficient nutrition is called malnutrition. The main reason behind malnutrition is poverty.
⇒ Excercise intake of a particular food is called overnutrition which also produces adverse symptoms. Thus the diet should be balanced one.

Disorders due to malnutrition :→

1) Kwashiorkor :→ It is a protein energy malnutrition. It occurs due to deficiency of proteins in the diet of children, though the diet may contain adequate amounts of carbohydrates.
⇒ It is most common among children between 1 to 3 years of age.
Causes :- The basic causes of the disease are :-
(A) Protein - deficient or inadequate diet due to ignorance and poverty.

(b) Infectious diseases such as diarrhoea, measles respiratory infections, intestinal worms, which weaken the child.

Symptoms:→ The common symptoms of Kwashiorkor are under-weight stund Stunted growth, poor brain development, loss of appetite, anaemia, protuding belly, slender legs, and bulging eyes, Oedema (fluid accumulation) of lower legs and face and change in skin and hair colour may also occur. in Kwashiorkar

2) **Marasmus:→** It is a form of prolonged malnutrition. It affects infants under one year of age It occurs due to deficiency of protein, carbohydrates and fats in the diet.

Causes:→ It may occur during prolonged malnutrition. Marasmus develops when a diet does not supply enough energy for normal body functions.

⇒ The main cause is the early replacement of mothers milk by ---- other foods deficient in protein and calorific value and less spacing between the children.

⇒ children suffering from this disorder first use body fat and then body protein as energy sources. Thus marasmus is due to deficiency of proteins and calories. (energy foods i.e. carbohydrates and fats).

Symptoms:→ Children suffering from this condition develop fewer and more abnormal cells and show mental retardation which is irreversible because nerve cells develop only during childhood.

⇒ other symptoms of the disease are as follows:-
The body becomes lean and weak. The skin becomes dry, thin, wrinkled and many suffer from diarrhoea.

⇒ However, hands feet and other parts do not show oedema and swelling. It is much common than Kwashiorkor.

Differences between Kwashiorkar and marasmus

Kwashiorkor	Marasmus
1) It develops in children whose diets are deficient of protein.	1) It is due to deficiency of proteins and calories.
2) It occurs in children between 6 months and 3 years of age.	2) It is common in infants under 1 year of age.
3) Subcutaneous fat is preserved.	3) Subcutaneous fat is not preserved.
4) There is oedema.	4) Oedema is absent.
5) Enlarged fatty liver.	5) No fatty liver.
6) Ribs are not very prominent.	6) Ribs become very prominent.
7) Lethargic.	7) Alert and irritable.
8) Appetite is poor.	8) Voracious feeder.
9) The person suffering from kwashiorkor needs adequate amount of proteins.	9) The person suffering from marasmus needs adequate amount of proteins, fats and carbohydrates.

Disorder due to Overnutrition :→ Overnutrition is also harmful for the body.

1) **Hypercholesteremia** :→ It is caused by excess intake of saturated fats like butter, ghee, vegetable oils, red meat and eggs.
⇒ It increases blood cholesterol level tremendously. As a result the blood cholesterol is deposited on the walls (atherosclerosis) of blood vessels making them harder. Thus the blood pressure rises which may cause some heart diseases.
⇒ It can be prevented by taking unsaturated oils in the diet.

2) **Obesity** :→ Obesity is defined as a condition when body weight exceeds 25% of the desirable standard, i.e. deposition of excess fat in body.
⇒ It is caused by intake of greater amount of food than the amount which can be utilised by the body for energy.
⇒ It means when 'energy (in the form of food) input exceeds energy output'.

3) **Hypervitaminosis A** :→ It is characterised by Anorexia (lack of appetite), painful swelling over long bones, sparsity of hair, pruritic rash. It disappear within a week if the vitamin is discontinued.

4) **Hypervitaminosis D** :→ It causes deposition of calcium in soft tissues.

5) **Hypervitaminosis K** :→ It is characterized by gastro-intestinal disturbances and anaemia.

6) **Hypervitaminosis C** :→ Some amount of ascorbic acid can be converted into oxalic acid which can cause stone formation in the urinary tract.

7) **Hypercalcemia** :→ When the level of calcium in the body fluids rises above normal, the nervous system is depressed and reflex activity of the CNS becomes sluggish. Also increased calcium ion concentration decreases systole of the heart and it causes constipation and lack of appetite probably because of depressed contractility of the muscle walls of the gastrointestinal tract.
⇒ Excessive intake of calcium in diet can lead to formation of kidney stones.

8) **Fluorosis** :→ Excessive intake of fluorine causes fluorosis. Fluorosis is of two types :-
(i) **Dental fluorosis** :→ It causes dental caries.
(ii) **Skeletal fluorosis** :→ In this disorder people are unable to walk upright as their skeletal muscles are gradually losing strength.
⇒ Excess amount of Sodium chloride in diet causes high blood pressure.
⇒ Increased extracellular concentration of magnesium depresses activity in the nervous system, and also depressed skeletal muscle contraction.
⇒ Excess Cobalt in diet causes the opposite of anaemia i.e. polycythemia. The polycythemic cells formed contain relatively small concentration of haemoglobin.

Digestive System

Parts of the body concerned with the digestion of food form the digestive system also called alimentary system.
⇒ The digestive system is a series of hollow organs joined in a long twisting tube from the mouth to the anus. Inside this tube is lining called the mucosa.
⇒ The digestive system consists of two sets of organ :- (1) Alimentary canal (Digestive/GI tract) and (2) Digestive glands.

The digestive System serves three major functions:→

1) Nutrition:→ The digestive tract primarily serves to provide food to the tissues of the body.

2) Breathing:→ The anterior part of the alimentary canal also plays a role in respiration in the chordates.

3) Excretion:→ The digestive System brings about some excretion too.

(A) Alimentary canal:→ The alimentary canal is a long tube (8-10cm long) which consists of several organs:- mouth, vestibule, oral or buccal cavity, pharynx, oesophagus, stomach, small intestine, large intestine and anus.

General histology of alimentary canal:→

The alimentary canal consists of 4 basic layers, from the outer surface inward to the lumen (cavity) the layers are as follows:-

(1) Visceral peritoneum (= Serous membrane/ serosa):→ It is the outer most layer made up of squamous epithelium. It is continuous with the mesentary. Peritoneum is known as "Policeman of stomach" as it forms a protecti membrane over the digestive organs.

(2) Muscular Coat:→ It is composed of outer longitudinal and inner circular muscle fibres. In the stomach an additional layer of oblique muscle fibres is found inner to the circular muscle fibres.

⇒ These muscle fibres are unstriped (smooth), in between the longitudinal and circular muscle fibre there is a network of nerve cells and parasympathet nerve fibres called the Auerbach's plexus (= myenteric plexus) which control peristalsis.

(3) Submucosa:→ It consist of loose connective tiss richly supplied with blood and lymphatic vessels and in some areas with glands.

⇒ Another network of nerve cells and sympathet nerve fibres, called Meissner's plexus (= sub mucosal plexus) is present between the muscul coat and the mucosa. This plexus controls the secretion of intestinal juice.

(4) Mucosa (= mucous membrane):→ It is so named because it secretes mucous to lubricate the inner lining of gut. It is composed of 3 layers:→

(a) The thin muscularis mucosa lies next to the submucosa, it consists of outer longitudinal and inner circular muscle fibres, both are unstriped.

(b) The laming propria the middle layer of mucosa consist of loose connective tissue, blood vessels, glands and some lymphoid tissue often rich in elastic fibres.

(c) The inner most layer is the epithelium, which forms gastric glands in stomach, and villi and intestinal glands in small intestine.

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

1) Mouth:→ The mouth is a transverse slit. It is bounded by two soft movable lips, upper and lower. The lips are covered with skin on the outer side and lined with mucous membrane on the inner side. Mouth leads into the vestibule.

2) Vestibule:→ It is a narrow space enclosed between the lips and cheeks externally and the gums and teeth internally. Its lining contains mucous glands. In the vestibule, a small median folds 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. The vestibule leads into the oral cavity.

3) Oral (Buccal) cavity:→ It is a large space bounded above by the palate, below by the throat and on the sides by the jaws, the throat supports the tongue. The jaws bear teeth. The buccal cavity is lined by stratified squamous epithelium.

4) Palate:→ Anterior part of the palate is arched and strong. It is called hard palate. It is supported by bones. It bears transverse ridges called rugae. The rugae help in keeping the food in place during mastication.

⇒ The posterior part of the palate is smooth and fleshy. It is termed soft palate. Its smooth surface makes swallowing easy. The middle of the hind free end of the soft palate hangs down as a small, conical flap the Uvula.

⇒ The latter is movable and capable of coming in contact with the posterior pharyngeal walls so as to cut off the upper nasal part of the pharynx called nasopharynx, from the lower oral part of the pharynx termed oropharynx during swallowing.

5) Tongue:→ The tongue is a voluntary muscular, sensory and glandular structure which occupies the floor of the mouth.

⇒ It is attached to the floor of the mouth by a fold called the frenulum of the tongue.

⇒ An inverted V-shaped furrow termed the sulcus terminalis divides the upper surface of the tongue into anterior oral part and posterior pharyngeal part.

⇒ The apex of the sulcus terminalis projects backward and is marked by a small median pit named the foramen Caecum.

⇒ The foramen Caecum is an embryological remnant and marks the site of the upper end of the thyroglossal duct or site of origin of thyroid gland.

⇒ Upper surface of the oral part of the tongue has a slight median groove.

Papillae:→ The upper surface of the tongue has 4 types of papillae:—

(A) Circumvallate papillae:→

⇒ Largest papillae.

⇒ 8-12 in numbers arranged inverted 'V' shape towards the base of tongue.

⇒ Each circumvallate papilla is surrounded by a groove containing taste buds.

⇒ Have around 200 taste buds.

(B) Filiform papillae :→ Smallest, most numerous, white conical shape.
⇒ Located near the centre and most of upper surface of tongue.
⇒ Lack taste buds.
⇒ Help in breaking food particles.

(C) Fungiform papillae :→ They are less numerous, than the filiform papillae.
⇒ Bright red and rounded.
⇒ Located at tip and margins of tongue.
⇒ Comprise of 8-10 taste buds.

(D) Foliate papillae :→ Red, leaf like.
⇒ Located at the side of tongue.
⇒ Human beings lack these but rabbit and other mammals possess these papillae.

⇒ The papillae have taste buds which respond to different types of taste.
⇒ The pharyngeal part of the tongue does not have papillae but has irregular lymph nodules, called lingual tonsil.
⇒ A taste bud is a piriform structure made up of modified epithelial cells. It has a small cavity opening to the surface through a gustatory pore.
⇒ Human tongue has four taste areas (sweet, salt, sour and bitter) areas of sweet and salt can overlap.

Functions of the tongue :→
1) It helps in chewing the food.
2) It aids in swallowing the food, and mixing the food and saliva.
3) It acts as a brush to clear the teeth.
4) It plays a role in speech.
5) It is an organ of taste, and can recognise four tastes i.e. Salty, Sweet, bitter and Sour.

6) Teeth :→ Teeth are hard structures which are meant for holding prey or cutting, grinding and crushing the food.

⇒ Cyclostomes, tadpoles, of amphibians and adult Platypus possess horny teeth derived from skin epidermis while other vertebrates possess true teeth derived from dermis and associated bones.
⇒ Most of the mammals have diphyodont (two set of teeth milk or deciduous and permanent) thecodont (teeth are embedded in the sockets of the jaw bones) and heterodont teeth (different types of teeth)
⇒ Human teeth are specialized for eating both plant and animal food. Viewed simply, human are carnivores in the front of the mouth and herbivores in the back.

Types of teeth :→ There are four kinds of teeth - incisors canines, premolars and molars present in the humans.

(A) Incisors :→ These are chisel shaped and possess sharp cutting edges and are located anteriorly. They are usually specialized for cutting.

(B) Canines (Cuspids) :→ They lie immediately behind the incisors. Canines are well developed in carnivores and may be absent in herbivores leaving a gap called diastema. (which is used to separate the chewed and unchewed food in mouth cavity).
⇒ They are long, sharp and pointed ends for piercing, killing and tearing off flesh.

(C) Premolars and molars :→ These are called cheek teeth which are broad, strong crushing teeth.
⇒ Last molars in human beings are called Wisdom teeth. The latter are vestigial in human being.

Teeth and their functions

Type of tooth	Number of each kind in half of each jaw	Structure	Function
Incisors (8)	⇒ 2 front teeth	⇒ chisel shaped, have flat, sharp edges	⇒ cutting and biting the food.
Canines (4)	⇒ 1	⇒ Pointed edge dagger shaped, poorly developed in man	⇒ Tearing and piercing.
Premolars (8)	⇒ 2	⇒ Bicuspid (two cusps) and have one or two roots	⇒ Crushing and grinding the food.
Molars (12)	3 (also called cheek teeth)	⇒ Four/Five cusps, have more than one root	⇒ Crushing, grinding and mastication.

Number:- → The milk or deciduous or tempory teeth are 20 in number, 10 each in the upper jaw and in the lower jaw.

⇒ The milk teeth begin to erupt when the child is about 6 months old and should all be present by the end of 24 months.

⇒ The permanent teeth begin to replace the milk teeth in the 6th year of age. These teeth are 32 and usually complete by the 24th year (each jaw contain 16 teeth).

Dental formulae:-

⇒ Milk teeth of man include 8 incisors, 4 canines and 8 molars (premolars are absent). Molar of milk teeth are shed off and premolars of permanent teeth take their place.

⇒ The permanent teeth are 8 incisors, 4 canines, 8 premolars and 12 molars. Thus 12 teeth. (8 premolars and 4 molars) are monophyodont (teeth which grow only once in life)

⇒ The dental formula gives half of the total number of teeth. This is doubled to determine the full number. Dental --- formulae of milk teeth and permanent teeth of human are given below.

(i) Milk teeth:- $\frac{2102}{2102} \times 2 = 20$ ⇒ i = 2, c = 1, m = 2.

(ii) Permanent teeth:- $\frac{2123}{2123} \times 2 = 32$ ⇒ i = 2, c = 1, pm = 2, m = 3

⇒ The the above formulae, the letter represent the type of tooth. The numerator is the number of that type of tooth in one side of upper jaw.

⇒ The denominator is the number of that type of tooth in one side of the lower jaw.

⇒ The primary function of teeth is to grasp and hold the food in the mouth cavity. They are modified for chewing the food.

⇒ with the help of teeth, tongue and jaw movement food is chewed and mixed with saliva in the mouth.

Structure of teeth: → Teeth are embedded in the jaws. Man has a fixed upper jaw and a movable lower jaw. Each tooth consists of three parts:- Crown, neck, root.

Crown: → It is the exposed portion of tooth above the gums (gingiva), the gingiva is a specialized region of the oral mucosa surrounding the neck of the teeth.

⇒ Crown is covered with the hardest substance called enamel that protects the crown.

Neck: → It is a narrow portion at the gumline.

Root: → It is embedded in the jaw bone and holds the securely in place.

⇒ Beneath the enamel is present dentine (secreted by odontoblast) which is made up of a hard substance similar to bone.

⇒ Dentine is also tough but not as tough as enamel and can decay. It has numerous canaliculi that pass radially from the pulp cavity towards the enamel. Dentine is regenerable living tissues.

⇒ Dentine forms the bulk of the tooth. There is a pulp cavity inside the dentine. It is a jelly like substance and carries the nerve fibres, blood vessels and sensory cells.

⇒ The root is fixed in the alveolus of the jaw bone by peridontal membrane and Cementum. There are two main types of cells these are dentine forming odontoblasts and enamel forming ameloblasts.

Cement: → It is a bone like hard substance around the root that holds a tooth in its socket and peridontal membrane covers the cement. These are live cells.

(7) **Pharynx:** → The mouth leads to funel shaped pharynx. The pharynx is about 12 cm. Long vertical canal beyond the soft palate. The food and air passages cross here. The pharynx may be divided into 3 parts:- nasopharynx, Oropharynx and laryngopharynx.

Dental formula of commonly asked mammals ↑

Organisms	i	C	pm	m	Dental formula	Total no. of teeth
Man (adult)	2/2	1/1	2/2	3/3	2123/2123 x2	32.
Dog.	3/3	1/1	4/4	2/3	3142/3143 x2	42.
Cat	3/3	1/1	3/2	1/1	3131/3132 x2	30.
Rat	1/1	0/0	0/0	3/3	1003/1003 x2	16.
Rabbit	2/1	0/0	3/2	3/3	2033/1023 x2	28
Cow	0/3	0/1	3/3	3/3	0033/3133 x2	32.
Bat	2/3	1/1	0/0	4/5	2104/3105 x2	32.

Types of teeth

Type	Characters	Example
1) Acrodont	Part of bone, not embedded in sockets	Reptiles, except Crocodiles.
2) Thecodont	Embedded in deep socket of some jaw bones	Mammals, crocodiles
3) Monophyodont	Teeth grow only once in life, i.e. contain only one set of teeth	Platypus, toothed whale.
4) Diphyodont.	All teeth except molar, grow twice in life i.e. contain two set of teeth (milk or temporary and permanent)	Mammals.
5) Polyphyodont	Fallen or worn out teeth can be replaced many times throughout life	Most vertebrates other than mammals e.g. frog.
6) Heterodont	More than one type of teeth, In humans 4 types (I, C, PM, M)	Mammal, Crocodiles.
7) Isodont	All teeth are similar.	Toothed whale.
8) Pleurodont	Teeth fixed by sides to lateral surfaces of jaw ridges	Reptiles.
9) Bunodont	Low cusps	Humans
10) Lophodont	Transverse ridges	Elephant, horses, Camels.
11) Selenodont	Crescent shaped cusps.	sheep.
12) Secodont.	Cusps pointed	Carnivores.

(A) Nasopharynx :→ upper part of pharynx.
⇒ Has internal nares in the roof, oval opening of Eustachian tubes and pharyngeal tonsil or adenoid (as lymphoid tissue) at the back.

(B) Oropharynx :→ Middle part of pharynx.
⇒ Has palatine tonsils (often removed in children).

(C) Laryngopharynx :→ Lower part of pharynx.
⇒ Leads to oesophagus and to pharynx through the glottis --- (opening to larynx) and epiglottis (leaf like cartilageous flap). During swallowing it cover the glottis to prevent the entry of food into it.

The function of the pharynx as a part of the digestive tract is merely to serve as a passage way for the food from the oral cavity to the oesophagus.
⇒ It has in its walls the voluntary muscles which start swallowing movements.

⇒ The lymphatic tissues of the pharynx and oral cavity are arranged in a ring like manner, which are collectively called Waldeyer's ring (= waldeyer's lymphatic ring). All these lymphoid tissues are active in production of immunoglobin - A, which forms an important part of our immune System.

⇒ The ring mainly consist of the following :-

(i) Nasopharyngeal tonsil (= pharyngeal tonsil) :- In children nasopharyngeal tonsil may become enlarged and is then referred to as the adenoids. The resulting swelling may be a cause of obstruction to normal breathing.

(ii) Tubal tonsils :- Lymphoid tissue found around the opening of each eustachian tube.

(iii) Palatine tonsils :- Located in the lateral walls of oropharynx. The palatine tonsils are often infected (tonsillitis) leading to sore throat.

⇒ Such enlarged tonsils may become a focus of infection and their surgical removal (tonsillectomy) becomes necessary.

(iv) Lingual tonsils :- Lymphoid tissue present at the base of tongue.

(2) Oesophagus :- The oesophagus is a 25cm long, narrow, muscular, straight tube lined by Stratified Squmous Epithelium containing mucous glands.

⇒ It runs downward through the neck behind the trachea and through the thorax behind the heart and passes through the diaphragm into the abdomen. Here it is sharply bends to open into the stomach.

⇒ This bend is one of the devices to check the backflow of the stomach contents into the oesophagus.

⇒ Longitudinal folds keep its cavity almost closed, except during swallowing of food. This checks the air going into it during breathing.

⇒ The oesophagus serves to convey the food by peristalsis (a series of waves of contraction that passes from one end to other and is meant for pushing the food) from the pharynx to the stomach.

(3) Stomach :- Stomach is the widest organ about 30 cm long and 15cm wide of the alimentary canal.

⇒ It is a hollow, J-shaped organ lying between the oesophagus and the small intestine.

⇒ The lesser Curvature is short and lies on the posterior surface of the stomach. The greater Curvature is on the anterior surface of the stomach.

⇒ The fold of peritoneum which attaches the stomach to the posterior abdominal wall extends beyond the greater curvature. This is called the greater Omentum which stores fat.

⇒ Inner surface of the stomach has numerous folds, the gastric rugae. These folds, by unfolding let the stomach expand to accommodate a large meal.

⇒ Unlike other parts of the digestive tract, the stomach wall contains 3 smooth muscle layers: outer of longitudinal, middle of circular and inner of oblique fibres to churn the food and to mix it with the gastric secretion.

⇒ The stomach has four parts :- Cardiac part, fundus, body and pylonic part.

(i) Cardiac part (= cardia) :- It is so called because it is present near the heart. The Cardiac sphincter lies in the opening between oesophagus and stomach. It is not a true valve, it is a functional sphincter.

(ii) Fundus :→ It extends superiorly from the Cardiac part. The fundus is commonly filled with air or gas.

(iii) Body :→ It is the main part of the stomach.

(iv) Pyloric part :→ It is the distal part of the stomach. The pyloric region is divided into the pyloric antrum and the pyloric canal. The pyloric Sphincter guards the opening between the stomach and the duodenum and periodically permits partially digested food to leave the stomach and enter the duodenum.

Functions :→

(i) Storage :→ The stomach allows a meal to be consumed and the materials released incrementally into the duodenum for digestion. It may take upto 4 hours for food from a complete meal to clear the stomach.

(ii) Chemical digestion :→ Pepsin begins the process of protein digestion cleaving large poly-peptides into shorter chains.

(iii) Mechanical digestion :→ The churning action of the muscularis causes liquefaction and mixing of the contents to produce acid chyme.

(iv) Some absorption :→ Water, electrolytes monosaccharides and fat soluble molecules including alcohol are all absorbed in the stomach to some degree.

(10) Intestine :→ Intestine is responsible for the most of the digestion and absorption of food (and usually) and formation of dry faeces. It is divided into Small and Large Intestine.

(A) Small Intestine :→ The small intestine is a narrow tube, about 6 metres long in a living adult. It is the longest part of the alimentary canal. It comprises of three parts :→ duodenum, jejunum and Ileum.

(i) Duodenum :→ It follows the stomach. It is somewhat C-shaped and about 25cm long.
⇒ It receives the hepatopancreatic ampulla of the hepatopancreatic duct formed by the union of bile duct (from liver) and pancreatic duct (from pancreas) and whose opening is guarded by Sphincter of Oddi.

(ii) Jejunum :→ The jejunum is the middle part of the small intestine. It follows the duodenum and is about 2.4 meters long.
⇒ Its wall is thicker and more vascular than that of the ileum.

(iii) Ileum :→ The Ileum forms the lower part of the small intestine. ~~It follows the duodenum and is about 2 meters long~~
⇒ It is about 3.5 meters long and opens into large intestine.
⇒ Its wall is thinner and less vascular than that of the jejunum.
⇒ The submucosa of the small intestine is thrown into a series of permanent circular folds called Valves of Kerckring or plicae circulares or valvulae conniventes.
⇒ The mucosa is raised into numerous microscopic vascular projections called the villi along with occasional mucous secreting goblet cells.
⇒ The villi are leaf-shaped in the duodenum and tongue-like in the jejunum but gradually becomes finger-like as the ileum is reached.
⇒ The villi contain blood vessels and lacteals which receive the products of digestion after (lymph capillaries) they have been absorbed.
⇒ Villi increases the internal surface area (for absorption) about 10 times in Ileum and imparting a velvetty appearance to the surface.

⇒ The free surfaces of the cells covering the villi bear innumerable brush border or microvilli hence also known as brush border epithelium, the villi and microvilli greatly increase the absorptive surface, total increase in surface area is 600 times.

⇒ Peyer's patches are a collection of large oval lymph tissues that are located in the mucus secreting lining of the small intestine. These lymph nodules are especially abundant in the lower portion of the small intestine. the ileum.

⇒ Peyer's patches contain high concentrations of white blood cells (termed lymphocytes) that help protect the body from infection and disease.

⇒ Peyers patches were named after the 17 century Swiss anatomist Hans Conrad Peyer.

Functions:- (i) The small intestine completes digestion of proteins, carbohydrates, nucleic acids and fats.

(ii) It absorbs nutrient materials into the blood and lymph and also in lubrication of food.

(iii) It secretes certain hormones such as cholecystokinin, Secretin, enterogasterone, duocrinin, entero crinin and villikinin.

(B) Large Intestine:- It's diameter varies from one region to another but is always larger than that of the small intestine. Hence it is so named. It is about 1.5 meters long and is divisible into three parts:- Caecum, Colon and rectum.

(i) Caecum and vermiform appendix:- The Caecum is a pouch-like structure which is about 6 centimeters. The junction of the ileum with the Caecum is called ileocaecal junction guarded by the ileocaecal valve which prevent the regurgitation of food from Caecum.

⇒ The vermiform appendix (Commonly called the appendix) is an outgrowth of the Caecum. It is a slightly coiled ... Its wall contain prominent lymphoid tissue.

⇒ Appendix is thought to be vestigial, the inflammation of vermiform appendix due to decay of food or worm infection is called appendicitis and rupture of appendix leads to spilling of faecal matter onto the peritoneum leading to its infection and inflammation known as peritonitis. The Caecum is well developed in herbivorous mammals like rabbits, horses etc.

(ii) Colon:- The Caecum leads into the colon, which is divided into 4 regions:- the ascending (from appendix in right groin upto a flexure at the liver) transverse (liver to spleen) descending (Spleen to left groin) and Sigmoid colon (pelvic colon is the former name).

⇒ The Sigmoid colon is S-shaped and enters the pelvis and joins the rectum. Ascending colon is the shortest part of the colon.

⇒ The right colic flexure (hepatic flexure) marks the boundary between the ascending and the transverse colon, the left colic flexure (splenic flexure) marks the boundary between the transverse and descending colon.

⇒ The colon has three longitudinal bands called taeniae coli. The latter are composed of longitudinal muscle fibres.

⇒ The taeniae coli contract and draw the remainder of the wall into small pouches called haustra (sing = haustrum) these may evaginate in the elderly to become diverticuli and infected in diverticulitis.

⇒ Deposits of fat in the serosa (peritoneum) the epiploic appendages are also characteristic of the colon.

(iii) **Rectum**:→ The sigmoid colon opens into the rectum. The rectum comprises the last 20 centimeters of the digestive tracts and terminates in the 2-centimeter long anal canal.
⇒ The mucosa of the anal canal is folded into several vertical folds called anal columns supplied with arteries and veins.
⇒ The opening of the anal canal is called anus, the anus has an internal anal sphincter composed of smooth muscle fibres and an external anal sphincter comprised of striped (voluntary) muscle fibres.
⇒ Structures formed due to enlargements of veins of anal columns in anal canal as well as anus are called haemorrhoides or piles.

Functions:→ (i) The large intestine does not secrete enzyme. It plays a minor role in the absorption of nutrients. It stores unabsorbed food remnants temporarily, concentrates the contents by absorbing water to form faeces and the movements of the colon help to void faeces through anus.
(ii) It also plays some role in digestion (cellulose digestion in herbivores) absorption and excretion.
(iii) The colon bacteria (E. Coli) produce vitamins B and K which are absorbed.

(2) Digestive Glands:→
The human digestive glands include salivary glands, gastric glands, liver, pancreas and intestinal glands.

(i) **Salivary glands**:→ There are three pairs of salivary glands parotid, sublingual, and submaxillary or submandibular.

(A) **Parotid glands**:→ These are the largest salivary glands. They lie on the sides of the face, just below and in front of the ears.
⇒ The parotid ducts also called Stensen's duct open into the vestibule opposite the upper second molar teeth. Viral infections of the parotid glands, causing swelling and pain is the disease called mumps.

(B) **Sublingual glands**:→ These lies under the front part of the tongue. The sublingual ducts also termed duct of Rivinus also open under the tongue.

(C) **Submaxillary glands**:→ These lie at the angles of the lower jaw. The submaxillary ducts also known as Wharton's ducts open under the tongue.

Saliva:→
⇒ The salivary glands secrete a viscous fluid called saliva. It contains water, salts, mucin, and an enzyme salivary amylase or ptyalin.
⇒ Its pH is nearly neutral being 6.7.
⇒ Saliva lacks amylase in domestic herbivores such as cow and buffalo and in carnivores such as dog, tiger and lion.
⇒ Pigs have ptyalin in their saliva.
⇒ The salivary glands are under neural control. Salivation (flow of saliva) is activated by the sight, smell, idea and talk of food and by the presence of food in the buccal cavity.
⇒ The salivary gland secretion is very rich in salivary amylase a starch splitting enzyme. The secretions of sublingual and submaxillary glands are rich in mucin.
⇒ About 99.5% of saliva is water. It contains two important enzymes amylase and lysozyme.
⇒ Amylase is a starch digesting enzyme, breaking starch into maltose and triose.
⇒ lysozyme causes lysis of several common bacteria that may be present in the mouth.
⇒ Mucin in saliva helps to lubricate the food for swallowing.

Functions of Saliva :→ Saliva has many functions :–

1) It moistens and lubricates the buccal mucosa, tongue, and lips thus making speech possible.
2) It also moistens food and changes it to a semi-solid mass for easy swallowing.
3) Moistening food allows it to be tasted. The taste buds are stimulated by chemicals in solution.
4) Saliva washes mouth and tongue clear of cellular and food debris. In fever, the salivary secretion is reduced and the tongue becomes dirty (coated).
5) It neutralizes acidity in the buccal cavity.
6) Its enzyme helps in digestion.
7) In dogs, evaporation of saliva from the tongue cools the body thus regulating body temperature in hot environment.

(II) Gastric Glands :→ Gastric glands, million in number, are simple branched and tubular.

⇒ They are of three types :– Cardiac glands which are located in cardiac part of stomach, the pyloric glands located in pyloric part of stomach and the fundic glands that comprise of many types of cells located in the epithelium.

⇒ These are numerous microscopic, tubular glands formed by the surface epithelium of the stomach.

Fundic glands (oxyntic glands) :→ They secrete HCl, pepsinogen, and soluble mucin – acidic secretions.

Pyloric glands :→ Secretion is rich in mucin and doesn't contain HCl.

Cardiac glands :→ Secrete mucin and very little pepsinogen.

Types of cells present in the epithelium of the gastric glands (fundic glands) are :–

(i) Peptic cells (= chief or Zymogen cells) :→ are usually basal in location and secrete gastric digestive enzymes as pro-enzymes : pepsinogen and prorennin. The chief cells also produce small amount of gastric amylase and gastric lipase.

⇒ Prorennin is secreted in young mammals. It is not secreted in adult mammals.

(ii) Oxyntic cells (= Parietal cells) :– are large and are most numerous on the side walls of the gastric glands.

⇒ They are called oxyntic cells because they stain strongly with eosin.

⇒ They are called parietal cells as they lies against the basement membrane. They secrete hydrochloric acid (HCl) and Castle's intrinsic factor.

(iii) Mucous cells (= Goblet cells) are present between other types of cells and secrete mucus.

⇒ Mucous is a glycoprotein and help to neutralize the acid in stomach and protect stomach wall against HCl action and protein digestive enzyme.

⇒ The epithelium of gastric glands also has the following two types of cells :→

(A) Endocrine cells are usually present in the basal parts of the gastric glands. These are Argentaffin cells and G-cells.

⇒ Argentaffin cells produces Serotonin (its precursor is 5-hydroxytryptamine), somatostatin and histamine.

⇒ G-cells are present in the pyloric region and secrete and store the hormone gastrin.

⇒ Serotonin is a vaso constrictor and stimulates the smooth muscles.

⇒ Somatostatin suppresses the release of hormone from the digestive tract.

⇒ Histamine dilates the walls of blood vessels.

⇒ Gastrin stimulates the gastric glands to release the gastric juice.

(2) Stem cells :→ are undifferentiated cells that are also present in the epithelium of the gastric glands. they multiply and replace other cells

⇒ They increase in number, when the gastric epithelium is damaged (e.g. when there is a gastric ulcer) and play an important role in healing.

Gastric Juice :→ The secretion of the cells of gastric glands form gastric juice with pH 2-3.7.

⇒ About 2,000 - 3000 ml of gastric juice is secreted perday.

⇒ The gastric juice contains two proenzymes :- pepsinogen (propepsin) and prorennin, and enzyme gastric lipase, mucous and hydrochloric acid.

(III) Liver (= Heper) :→

It is the largest internal gland of the body, which is reddish brown in colour.

⇒ The liver lies in the upper right side of the abdominal cavity just below the diaphragm.

⇒ It is heavier in males than females. In males it generally weighs 1.4 - 1.8 kg and in females 1.2 - 1.4 kg.

External Structure of the liver :→

⇒ The liver is covered 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.

⇒ The liver 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 like structure called gall bladder is attached to the posterior surface of the liver on the right side by connective tissue.

⇒ The main function of the gall bladder is to store and concentrate the bile secreted by the liver.

⇒ Rat and horse do not have gall bladder.

Internal Structure of the liver :→

⇒ Numerous thin branched septa like trabeculae (prominent in pig not in human liver) extend inwards from the Glisson's capsule dividing each liver lobe into numerous minute hepatic lobules (structural and functional units of the liver).

⇒ An intralobular branch of hepatic vein called central vein forms the axis of each lobule.

⇒ Around the periphery of each lobule are five to seven groups of tubes called the portal triads.

⇒ Each triads contains branch of the hepatic portal vein, hepatic artery and interlobular bile duct. The latter receives bile from the liver cells by the way of bile canaliculi.

⇒ At the periphery of the lobule the bile canaliculi empty into Herring's canals which are walled by cuboidal epithelium.

⇒ About 80% are the hepatocytes (liver parenchymal cells in the liver which form radial plates (radiating from the central vein of each lobule). Therefore, the radial plates of hepatocytes are separated by hepatic sinusoids (vascular spaces). The hepatic sinusoids are wide capillary like blood vessels lined by incomplete endothelium.

⇒ Kupffer cells (=hepatic macrophages or stellate cells) are also present in the liver lining the sinusoids which are phagocytic cells that eat bacteria and foreign substances.

⇒ Fat storage cells are also found in the liver.

⇒ Liver has high powers of regeneration.

Blood Supply :→

⇒ The blood supply to the liver from the stomach, intestine, pancreas and spleen is carried via the hepatic portal vein.

⇒ This blood makes up 80% of blood flow through the liver. The remaining 20% is made up by blood from the proper hepatic arteries which are responsible for nourishing the liver cell.

⇒ The liver parenchymal cells (hepatocyte) are bathed in mixed blood from the hepatic portal vein and proper hepatic arteries so that they receive nutrition from both.

⇒ Blood in the hepatic artery comes from the aorta, has passed through the lungs and heart and carries oxygen to the liver cells.

⇒ It also carries fat, received from the lymphatics.

⇒ Blood in the hepatic portal vein comes directly from the intestine and carries blood containing other nutrients.

Biliary System :→

⇒ The gall bladder and the ducts that carry bile and other digestive enzymes from the liver, gall bladder and the pancreas to the small intestine are called biliary system.

⇒ Duct of liver lobes are known as hepatic duct and duct of gall bladder is known as cystic duct.

⇒ The right and left hepatic ducts join to form the common hepatic duct, the latter joins the cystic duct.

⇒ The cystic duct and common hepatic duct join to form bile duct which passes downwards posteriorly to join to main pancreatic duct to form the hepato pancreatic 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 pancreatic duct.

Bile :→

⇒ The liver cells secrete bile (hepatic bile pH 8.6) via the hepatic duct to the gall bladder for storage (gall bladder bile pH is 7.6) and thence on demand via the common bile duct to an opening near the pancreatic duct in the duodenum.

⇒ The bile is an alkaline viscous greenish yellow fluid, About 500-1000 ml of bile is secreted by liver in a day. It is released into the duodenum on CCK stimulation.

⇒ Bile contains bile salts, bile pigments (mainly bilirubin essentially the non-iron part of the haemoglobin) cholesterol and phospholipid.

⇒ Bile salts (Sodium Carbonate, Sodium glycocholate, Sodium taurocholate) and phospholipids help in the digestion of fats in the small intestine by bringing about their emulsification (conversion of large fat droplets into small ones) and the rest are just being excreted. Bile salts are absorbed in the ileum.

Bile serves the following functions :→

1) Neutralization of HCl :→ Its sodium carbonate neutrilizes HCl of chyme (semifluid food found in the stomach).

2) Emulsification :→ Sodium glycocholate and sodium taurocholate break the large fat droplets into the smaller ones. This process is called emulsification.

3) Absorption of fat and fat soluble vitamins :→ It's salts help in the absorption of fat (fatty acid and glycerol) and fat soluble vitamins (A, D, E, and K).

4) Excretion :→ Bile pigements (bilirubin and biliverdin) are excretory products.

7) Prevention of decomposition :→ Bile is alkaline hence it prevents the decomposition of food by preventing the growth of bacteria on it.

8) Stimulation of peristalsis :→ Bile increases peristalsis of the intestine.

9) Activation of lipase :→ Bile contains no enzyme but activates the enzyme lipase.

Functions of Liver :→

1) Secretion of bile.

2) Deamination :→ It is a process by which the amino group ($-NH_2$) is removed from the amino acids resulting in the production of ammonia which is converted into urea, deamination is carried out by the liver cells.

3) Excretion :→ Liver synthesis urea with the help of ammonia and carbon dioxide. Urea is passed out through excretory system.

⇒ The bile contains bile pigements (bilirubin :- yellow and biliverdin - green) that are excretory products.

⇒ The liver cells also eliminate certain other waste products like cholesterol, metal ions and waste products of haemoglobin.

⇒ These waste products and bile pigements reach the duodenum through bile and pass out with faeces.

4) Glycogenesis :→ It is the conversion of the excess of glucose into glycogen by liver cells with the help of insulin secreted by the pancreas. Glycogenesis also occurs in muscles.

(5) Glycogenolysis :→ It is the conversion of the ~~excess~~ glycogen into glucose by the liver cells with the help of glucagon secreted by the pancreas.

(6) Lipogenesis :→ It is the conversion of excess of glucose and amino acids into fats which also takes place in the liver.

(7) Gluconeogenesis :→ It is the formation of glucose or glycogen from non-carbohydrate sources such as amino acids, fatty acids, glycerol etc.

⇒ It also occurs in the kidneys and striped muscle.

(8) Detoxification :→ Liver converts toxic substances into harmless substances e.g. harmful prussic acid formed during metabolism in all body cells is neutralized and rendered harmless by liver cells.

(9) Haemopoiesis :→ The process of formation of blood corpuscles is called haemopoiesis. The liver produces red blood corpuscles in the embryo.

(10) Synthesis of blood proteins :→ The liver produces blood proteins such as prothrombin and fibrinogen that help in the clotting of blood.

⇒ Clotting factor V, VII and X were also produced by liver.

(11) Secretion of heparin :→ Liver secretes heparin (anticoagulant).

(12) Lymph formation :→ Liver is an important seat of lymph formation.

(13) Synthesis of vitamin A :→ Liver secretes certain vitamin like vitamin A from β-carotene.

⇒ β-carotene is an orange-yellow substance of carrot.

(14) Secretion of enzymes :→ Liver secretes certain enzymes which play important roles in the metabolism of proteins, fats and carbohydrates in the body.

(15) Destruction of red blood Corpuscles :→ The old worn out red blood corpuscles are broken down in the liver cells. Their haemoglobin is changed into bile pigements.

(16) Phagocytosis :→ The Kupffer's cells of the liver engulf the disease causing micro-organisms, dead cells and foreign matter.

(17) Osmoregulation :→ Liver produces angiotensinogen (a protein) which helps kidneys in maintaining body fluid osmoregulation through the action of renin on angiotensin.

(18) Production of heat :→ Due to high metabolic activities of the liver, enough heat is generated, which is essential for maintaining the optimum body temperature.

(19) Storage :→ Liver store (i) glycogen (ii) fats (iii) vitamins like A, D, E, K and B_{12} (iv) bile in the gall bladder, (v) blood (vi) water (vii) iron, copper and potassium.

(20) The liver is the main organ for breaking down hormones after they have served their messanger function to their target cells. For example, if the liver does not breakdown insulin quickly enough, hypoglycemia results as the still circulating insulin continues to lower blood sugar.

⇒ If the liver does not metabolize estrogen properly, PMS (pre menstrual syndrome) will result. Failure to dispose of adrenalin ('the fight or flight' hormone) after it has outlived its usefulness may lead to chronic irritability and temper explosions.

(IV) Pancreas :→

⇒ The pancreas is soft, lobulated, greyish-pink gland which weighs about 60 grams.

⇒ It is about 2.5 centimeters wide and 12 to 15 centimeters long, located posterior to the stomach in the abdominal cavity.

⇒ The pancreas is a heterocrine gland partly exocrine and partly endocrine.

External Structure of pancreas :→

⇒ The pancreas comprises the head, body and tail. The head lies in the 'C' shaped curve of the duodenum, the body behind the stomach and the tail reaches the spleen lying in front of the left kidney.

⇒ The main pancreatic duct (= duct of Wirsung) is formed smaller ducts within the pancreas.

⇒ The main pancreatic duct opens into the hepatopancreatic ampulla (= ampulla of vater).

⇒ An accessory pancreatic duct (= duct of santorini) is also present in the pancreas and opens directly into the duodenum.

Internal Structure of Pancreas :→

It consists of two parts :- exocrine part and endocrine part.

(i) Exocrine part :→ It consists of rounded lobules (acini) that secretes an alkaline pancreatic juice with pH 8.4.

⇒ About 500-800 ml of pancreatic juice is secreted per day. The pancreatic juice is carried by the pancreatic duct into the duodenum through hepatopancreatic ampulla.

⇒ The accessory pancreatic duct directly pours the pancreatic juice into the duodenum.

⇒ The pancreatic juice contains sodium bicarbonate, three proenzymes:- trypsinogen, chymotrypsinogen and procarboxypeptidase and some enzymes such as pancreatic amylase, DNAase, RNAase and pancreatic lipase.

⇒ The pancreatic juice helps in the digestion of starch, proteins, nucleic acids and fats, therefore pancreatic juice is also called Complete digestive juice.

⇒ These proenzymes (including prorennin secreted by fundic glands) are secreted in the inactive form so that they don't start acting within the cell where they are produced which can damage/kill the cell.

(ii) Endocrine part :→ The endocrine part of the pancreas consists of groups of Islets of Langerhans. The human pancreas has about one million islets.

⇒ The islets are most numerous in the tail of the pancreas. Each islet of Langerhans consists of three types of cells which secrete hormones to be passed into the circulating blood.

⇒ Each islet is separated from the surrounding alveoli by a thin layer of reticular tissue. The islets are richly supplied with blood through a dense capillary plexus. The following 3 types of cells occur in pancreatic islets:-

(i) The (α) alpha cells :- Secreting hormone glucagon.

(ii) The (β) Beta cells :→ Secreting hormone insulin.

(iii) The (δ) delta cells :→ producing hormone gastrin and somatostatin.

⇒ In the islets of pancreas the alpha cells are arranged towards the periphery of the islets, the beta cells near the centre and the delta cells are placed peripherally.

⇒ Thus the pancreas perform two main functions i.e. secretion of pancreatic juice which contain digestive enzymes and production of hormones.

(V) Intestinal Glands :→

⇒ The intestinal glands are numerous and microscopic. They lie in the wall of small intestine. They are of two types:-

Crypts of Lieberkuhn and Brunner's glands.

The Crypts of Lieberkuhn are simple tubular gland and occurs throughout the small intestine between the villi. They secrete enzyme and mucus. They have two types of cells:-

(i) Paneth cells :- are found particularly in the duodenum. These cells are present in the bottom of crypts of Lieberkuhn.

⇒ These cells are rich in zinc and contain acidophilic granules.

⇒ The function of these cells is not certain but there is evidence that they secrete lysozyme (antibacterial substance).

(ii) Argentaffin cells :→ also known as entero-chromaffin cells is fairly common in duodenum.

⇒ It is located among epithelial cells lining the crypts of Lieberkuhn (intestinal glands)

⇒ Argentaffin cells are identified with the production of Serotonin (5-hydroxytryptamine) which is secreted into the lamina propria rather than the intestinal lumen.
⇒ Serotonin is a powerful stimulant of smooth muscle, resulting in contraction, and may play a role in stimulating peristaltic activity of the intestine.

The Brunner's glands are branched tubular glands and are confined to the duodenum. They secrete alkaline watery fluid, a little enzyme and mucus.
⇒ They open into the Crypts of Lieberkuhn, the mixture of secretions is called intestinal juice or Succus entericus.
⇒ About 2 to 3 litres of succus entericus is secreted each day. The juice contains many enzymes:- e.g. aminopeptidases, dipeptidases, intestinal amylase, maltase, isomaltase, limit dextrinase, sucrase, lactase, intestinal lipase, nucleotidases or nucleophosphatases, nucleosidases and enteropeptidase (enterokinase) These enzymes act on all types of food.

Process of Nutrition :-

⇒ Due to presence of specialized alimentary canal the process of nutrition involves the following steps:- Ingestion, Digestion, Absorption, Assimilation and Egestion.

(1) Ingestion :- Ingestion means intake of food. Feeding mechanisms varied in range of animals.
⇒ In different animals ingestion occurs by different process. On the basis of nature of ingestion process animals are of 3 types:-

1) Fluid feeder animals :-
⇒ In parasitic protozoans (e.g. Trypanosoma) Ingestion occur by diffusion.
⇒ In Sanguivorous animals (e.g. leech, mosquitoes) Ingestion occur by pinocytosis or cell drinking and by blood sucking.
⇒ In aphids, ingestion occur by sucking sap of plant.

2) Filter feeder animals (Microphagous animals)
⇒ Microphagous feeder are those animals which take small sized food particles.
⇒ Ingestion occur by maintaining a water current which bring microscopic organisms like bacteria, diatom, protozoa etc.
⇒ Filter feeder strain small particles of organic matter from water.
Type:- Pseudopodial feeder (Amoeba)
→ Ciliary feeder (Paramecium)
→ Flagellar feeder (Sponges)
→ Mucoid feeder (Nereis)
→ Tentacular feeder (Hydra).

3) Macrophagous animals :→ Macrophagous animals feed on large sized food particles.
⇒ These animals have different structures to capture and ingestion the food. Eg :-
1) Tentacles with batteries of Cnidoblasts in Coelenterates.
2) Eversible and sticky tongue (e.g. frog toad, wall lizard) to capture insects with differently adapted teeth, like well developed teeth, like well developed incisors in rabbit and well developed canines (tearing teeth) in carnivores (e.g. lion, tiger etc).

(II) Digestion :→ It is the breakdown of large complex insoluble organic food molecules into small, simple soluble and diffusible particles by the action of digestive enzymes.
⇒ Digestion begins in the mouth, when we chew and swallow, and is completed in the small intestine. The chemical process varies somewhat for different kinds of food.
⇒ Digestion is mostly carried out by the process of hydrolysis the enzymes which bring about digestion are called hydrolases.
⇒ Hydrolysis is a reaction in which a substance is split into simpler compounds by the addition or the taking up of the elements of water.
⇒ Hydrolysis of starch to glucose is one of the examples of digestion.

$$n(C_6H_{10}O_5) + nH_2O \xrightarrow{\text{Digestive enzymes}} nC_6H_{12}O_6$$
starch + water → Glucose.

Types of digestion :→ It is of following two types :→
(A) Intracellular digestion :→ Protozoans and sponges digest food in membrane-bound sacs, called food vacuoles within the cells. Lysosomes containing digestive enzymes fuse with the food vacuole. The latter is now called a digestive vacuole (phagolysosome).
⇒ The enzymes break the larger nutrient molecules into small molecules of usable size.
⇒ Now the membrane of the digestive vacuole is drawn into fine canals which transfer the products of digestion into the cytoplasm, where they are used by the cell.
⇒ Indigestible matter is thrown out of the cell. Digestion of food within food vacuoles in cell is termed as intracellular digestion.

(B) Extracellular digestion :→ In other animals, food is digested in the cavity, the lumen of a tube called alimentary canal where digestive enzymes are secreted by specialized cells.
⇒ The small nutrient molecules formed by digestion enter the cells lining the cavity. Digestion of food outside the cells in a cavity is known as extra cellular or intercellular digestion. The latter handles large food particles.
⇒ Flatworms and protochordates also undergo extracellular digestion.
⇒ In higher invertebrates and vertebrates digestive canal or alimentary canal is complete i.e. it has separate opening for taking food and eliminating waste.
⇒ The wall of the alimentary canal secretes various enzymes which help in the digestion of food thus in these animals the digestion is purely extra-cellular i.e. in the lumen of alimentary canal.

Physiology of digestion in parts of alimentary canal:→

1) Mouth:→ The food gets mixed with saliva in the mouth. Saliva moistens and lubricates the food and chewing breaks the food into smaller pieces.
⇒ The semi-solid food is moulded into a ball or bolus by tongue and is pushed into the oesophagus via pharynx.
⇒ The bolus is then pushed inward through the pharynx into the oesophagus. This process is referred to as Swallowing or deglutination which empties the mouth and ensures that food does not enter the windpipe.
⇒ Swallowing involves coordinated activity of tongue, soft palate, pharynx, and oesophagus.
⇒ The tongue blocks the mouth, soft palate closes off the nose, and the larynx rises so that the epiglottis closes off the trachea.
⇒ A travelling wave of constrictions called peristalsis pushes the luminal contents (food) downward. Peristalsis is produced by involuntary contraction of circular muscles which is preceeded by a simultaneous contraction of the longitudinal muscle, and relaxation of the circular muscle lining the gut.

2) Oesophagus:→ From oesophagus the food passes by peristaltic movement to stomach.

3) Stomach:→ The stomach has three mechanical tasks to do.
(A) First, the stomach must store the swallowed food and liquid. This requires the muscle of the upper part of the stomach to relax and accept large volumes of swallowed material.
(B) The second job is to mix up the food, liquid and digestive juice (gastric juice and HCl) produced by the stomach. The lower part of the stomach mixes these materials by its muscle action. The food is converted into a semiliquid mass called chyme.
(C) The third task of the stomach is to empty chyme slowly into the small intestine (duodenum).

4) Small intestine:→
Duodenum:→ The chyme gets mixed with pancreatic juice, bile juice and intestinal juice and is digested by enzymes.
Jejunum and Ileum:→ The food gets mixed with intestinal juice and further digestion takes place.
⇒ The digested food is absorbed and undigested food passes on to large intestine.

Digestion of food (chemically):→

(1) Carbohydrates
⇒ Carbohydrates are of three kinds:- polysaccharides, disaccharides, and monosaccharides.
⇒ Polysaccharides and disaccharides are broken down to monosaccharides during the process of digestion.
⇒ Starch and cellulose are polysaccharides that are present in cereals grains, potato, tubers and fruits.
⇒ Enzymes which act on carbohydrates are called Carbohydrases. Digestion of carbohydrates takes place in oral cavity and intestine and to sometime (about 30 min=) in stomach till gastric HCl destroys the ptyalin or salivary amylase.

(A) Oral Cavity:→ In oral cavity, the food is mixed with saliva. The saliva contains an enzyme called Salivary amylase (ptyalin) and lysozyme which converts starch into maltose, isomaltose and small dextrins called limit dextrins.
⇒ Salivary amylase is activated in the saliva by the chloride ions.

Starch $\xrightarrow[\text{amylase.}]{\text{salivary}}$ Maltose + Isomaltose + α-Dextrins

30% of starch in the food is hydrolysed in the oral cavity. Human saliva has acidic medium. It is most active at pH 6.8 and is readily inactivated at pH 4.0 or below. That is why digestive action soon stops in the acid environment of the stomach.

⇒ Since food remains in the mouth only for a short time, not more than 3-5% of all the starches are hydrolysed in the mouth by the time the food is swallowed.

(B) Stomach :- The gastric juice does not contain carbohydrate digesting enzyme.

(C) Small Intestine :→ (i) Action of pancreatic juice :→ The pancreatic juice contain starch digesting enzyme, called pancreatic amylase which converts starch into maltose, isomaltose and α-dextrins :-

Starch $\xrightarrow[\alpha\text{-amylase}]{\text{Pancreatic}}$ Maltose + Isomaltose + α-Dextrins.

Glycogen $\xrightarrow[\alpha\text{-amylase}]{\text{Pancreatic}}$ α-dextrins ⟶ Maltose + Isomaltose

(ii) Action of intestinal juices :→ Intestinal juice contains maltase, isomaltase, sucrase, lactase and α-detrinase which act as follows :-

Maltose $\xrightarrow{\text{Maltase}}$ Glucose + Glucose.

Isomaltose $\xrightarrow{\text{Isomaltase}}$ Glucose + Glucose.

Sucrose $\xrightarrow{\text{Sucrase}}$ Glucose + Fructose.

Lactose $\xrightarrow{\text{Lactase}}$ Glucose + Galactose

α-Dextrins $\xrightarrow{\alpha\text{-Dextrinase}}$ Glucose.

Lactose Intolerance :→ Lactose intolerance is the inability to digest significant amount of lactose, the predominant sugar of milk.

⇒ This inability results from a shortage of the enzyme lactase, which is normally produced by the cells that line the small intestine.

⇒ Lactase breaks down milk sugar into simpler forms that can then be absorbed into the blood stream.

⇒ When there is not enough lactase to digest the amount of lactose consumed, the results although not usually dangerous, may be very distressing.

⇒ Common symptoms include nausea, cramps, bloating, gas and diarrhoea, which begin about 30 minutes to 2 hours after eating or drinking foods containing lactose. The severity of symptoms varies depending on the amount of lactose each individual can tolerate.

⇒ Vertebrates do not produce any enzyme to digest cellulose. They depend on symbiotic digestion of cellulose by micro-organisms harboured in their digestive tracts.

⇒ These micro-organisms are found in the rumen and reticulum of the compound stomach of ruminants and in the caecum and appendix of non-ruminants.

(D) Digestion of proteins :→

⇒ Proteins are made up of amino acids, so proteins are broken down to amino acids during the process of digestion.

⇒ Enzymes that hydrolyse proteins are called proteases and peptidases. Many of these enzymes are secreted in their inactive forms called zymogens as their active forms would hydrolyse cellular and extra cellular proteins of organisms itself.

⇒ Inactive forms of enzymes are converted to their active forms at the sites of their actions :-

Digestion of Proteins:-

(A) Oral Cavity

Saliva does not contain any protein digesting enzyme!- So digestion of proteins does not occur in the oral cavity. However, saliva can denature the uncooked natural proteins such as that present in raw egg, unboiled milk or uncooked germinating seeds.

(B) Stomach:-

The gastric glands of the stomach secrete gastric juice. It contains HCl, proenzymes!- pepsinogen and prorennin.

⇒ Hydrochloric acid maintains a strongly acidic pH of about 2-3.7 in the stomach. HCl kills bacteria and other harmful organisms that may be present alongwith food.

⇒ HCl converts pepsinogen and prorennin into pepsin and rennin respectively.

⇒ Once pepsin is formed it changes pepsinogen into pepsin. Such an activation is called autocatalytic reaction.

⇒ Pepsin and rennin are absent in invertebrates.

⇒ Gastric juice is thoroughly mixed with food until it becomes a semifluid mass called chyme.

⇒ Various reactions are summarized below!-

⇒ Pepsinogen (Proenzyme) $\xrightarrow{HCl}$ Pepsin

⇒ Prorennin $\xrightarrow{HCl}$ Rennin

⇒ Casein $\xrightarrow{Rennin}$ Paracasein.

⇒ Paracasein + Ca ⟶ Calcium paracaseinate (Curd)

⇒ Calcium paracaseinate $\xrightarrow{Pepsin}$ peptones

⇒ Proteins $\xrightarrow{Pepsin}$ peptones.

⇒ Rennin is found in the gastric juice of human beings during infancy and in calf. In adults gastric juice is devoid of rennin. Rennin converts milk proteins casein into paracasein, leading to milk coagulation.

Function of HCl:-

1) It kills harmful bacteria.
2) It provides acidic medium in the stomach for gastric digestion.
3) It changes pepsinogen into pepsin and prorennin into rennin.
4) It softens the food and dissolves the cement materials between the cells of the food in order to make them readily available for enzyme action.
5) It stops the action of salivary enzyme.
6) It is believed to control the opening and closing of pyloric opening of stomach.
7) It denatures proteins.

(C) Small Intestine:-

(i) Action of pancreatic juice:- Pancreatic juice contains trypsinogen, chymotrypsinogen and procarboxypeptidase.

⇒ In the presence of enterokinase (a protease of intestinal juice) inactive trypsinogen is converted to active trypsin.

⇒ Trypsin then activates chymotrypsinogen and procarboxypeptidase into chymotrypsin and carboxypeptidase respectively.

⇒ This enables simultaneous action of all pancreatic proteases for a rapid digestion of proteins. The bile provides alkaline medium for various reactions. All these reactions are summarised as follows:-

⇒ Trypsinogen (proenzyme) $\xrightarrow{Enterokinase}$ Trypsin.

⇒ Chymotrypsinogen $\xrightarrow{Trypsin}$ Chymotrypsin

⇒ Procarboxypeptidase $\xrightarrow{Trypsin}$ Carboxypeptidase

⇒ Peptones —Trypsin→ Large peptides

⇒ Elastin —Elastase→ Large peptides

⇒ Peptones —Chymotrypsin→ Large peptides

⇒ Large peptides —Carboxypeptidases→ Dipeptides + Amino acids.

⇒ Trypsin acts best at an alkaline pH provided in the small intestine by the bicarbonates of pancreatic and intestinal juices and bile.

⇒ Trypsin hydrolyses proteins into peptides, but it has no action on keratin and milk protein casein.

⇒ In carnivorous predatory animals drinking blood of their prey, trypsin hydrolyses fibrinogen of blood into fibrin, leading to blood coagulation.

⇒ Chymotrypsin is an important milk coagulating enzyme and hydrolyses casein to paracasein. Paracasein is then coagulated to calcium paracaseinate.

⇒ Carboxypeptidases hydrolyse polypeptides to simple peptides by the successive removal of amino acid containing free carboxyl group at the end of the polypeptide chain.

(ii) Action of intestinal juice :→

⇒ Intestinal juice (Succus entericus) contains enterokinase (also called enteropeptidase), aminopeptidases and dipeptidases.

⇒ Enterokinase converts trypsinogen of pancreatic juice into trypsin. Actions of other enzymes are summarized below :-

Peptides —Aminopeptidases→ Dipeptides + Amino acids.

Dipeptides —Dipeptidases→ Amino acids.

⇒ The intestinal peptidases act best at pH 7.0-8.0.

⇒ They do not act on native proteins but only complete the hydrolysis started by other proteolytic enzymes.

⇒ Aminopeptidases hydrolyse polypeptides to amino acids and dipeptides by removing the amino acid containing the free amino group from the polypeptide, hence progressively shortening the polypeptide chain into dipeptides.

⇒ When polypeptide finally reaches the dipeptide stage it is hydrolysed by the activity of dipeptidase.

Digestion of fats :→

⇒ Fats and oils of the ingested food are triglycerides. They are digested by lipases. Their digestion starts in the stomach and is nearly completed in the small intestine.

(i) Saliva :- It contains almost no lipase, nor any fat-emulsifying agent occurs in the oral cavity.

(ii) Stomach :→ Stomach also lacks fat-emulsifying agent. However, gastric juice contains gastric lipase, which converts some fat into monoglycerides and fatty acids.

⇒ The reaction is negligible as the enzyme is sensitive to free acid and is soon destroyed by HCl.

(iii) Small intestine :→

In the small intestine, food meets three secretions :- bile, pancreatic juice and intestinal juice, all alkaline in nature.

Bile :→ It contains no enzyme and thus has no chemical action on food. Its salts namely Sodium glycocholate and Sodium taurocholate reduce the surface tension of large fat droplets and break them into many small ones. The process is called emulsification as it produces a fine emulsion of fats in the aqueous intestinal contents.

⇒ The small fat droplets present larger surface area to lipase, this increases lipase action on fats.

Triglycerides —Bile salts→ Emulsified Triglycerides

Pancreatic juice :- It contains pancreatic lipase, which is the principal fat-digesting enzyme. It hydrolyses fats in 3 stages :-

⇒ In the first stage (I) lipase separates one fatty acid molecule, changing the emulsified triglyceride into a diglyceride.

⇒ In the second stage (II) the diglyceride is broken down into another fatty acid molecule and a monoglyceride.

⇒ In the third stage (III), the monoglyceride is hydrolysed to another fatty acid molecule and a glycerol molecule.

⇒ Thus a complete hydrolysis of a fat molecule gives three fatty acid molecules and one glycerol molecule. However normally the digestion of fats remains incomplete in the intestine.

⇒ Hydrolysis of fats is a slow process and a few hours available for the action of lipase in the intestine are not enough for the completion of fat hydrolysis.

⇒ Thus, the end products of fat hydrolysis are fatty acid, glycerol, monoglycerides, diglycerides and even triglycerides.

⇒ Lipase is activated by the bile.

Triglyceride
↓ Lipase
1,2-Diglyceride + Fatty acid ..... I.
↓ Lipase
2 Monoglyceride + Fatty acid
↓ Isomerisation } ..... II.
1- Monoglyceride
↓
Glycerol + Fatty acid ..... III.

Intestinal Juice :-

⇒ Intestinal glands secrete intestinal lipase. This enzyme occurs mainly in the intestinal epithelial cells and only a small amount is released in the intestinal juice.

The lipase found in the intestinal juice hydrolyses some triglycerides, diglycerides and monoglycerides to fatty acids and glycerol like the pancreatic lipase.

⇒ The intestinal lipase present in the intestinal epithelial cells hydrolyses the absorbed triglycerides and diglycerides to monoglycerides and fatty acids.

⇒ Fatty acids, glycerol and monoglycerides are the end products of fat digestion.

⇒ Chyle is a white or pale yellow fluid taken up by the lacteals (lymph capillaries) from the intestine during digestion. It mainly consists of absorbed fat.

Digestion of nucleic acids :-

⇒ Nucleic acids are digested in the small intestine. The enzymes which digest nucleic acids are present in the pancreatic juice and intestinal juice.

(I) Pancreatic Juice :- It contains enzymes; DNAase and RNAase which act as follows :-

DNA —DNAase→ Deoxyribonucleotides
RNA —RNAase→ Ribonucleotides

(II) Intestinal Juice :- It contains enzymes nucleotidases and nucleosidases which act as follows :-

Nucleotides (Deoxyribonucleotides or Ribonucleotides) —Nucleotidases→ Nucleosides (Deoxyribonucleosides or Ribonucleosides) + Inorganic phosphate

Nucleosides (Deoxyribonucleosides or Ribonucleosides) —Nucleosidases→ Nitrogenous bases (Purines/pyrimidines) + Pentose Sugar (Deoxyribose / Ribose)

Neural And Hormonal Control of Digestion :→

A) Neural Control of digestion :→

The gastrointestinal tract is innervated by intrinsic nerves as well as by extrinsic nerves.

⇒ The intrinsic neural system also called the enteric neural system consists of (i) the Meissner's plexus situated in the submucosa and (ii) the Auerbach's plexus in the muscular layer.

⇒ The enteric neural system controls most of the gastrointestinal functions like secretion.

⇒ The extrinsic innervation of the gut consists of parasympathetic and sympathetic nerves which can modify the activity of the intrinsic neural system in response to reflex activity initiated from the GIT itself or from other parts of the body.

⇒ The sight, smell and presence of food in the gastrointestinal tract act as a stimuli for the secretion of saliva. This happens by the stimulation of Vagus nerve. Feeling of hunger as a particular time when regularly food is taken, is an example of Conditional reflex.

B) Hormonal Control of digestive Secretion :→

following hormones regulate the digestive secretion :—

(I) **Gastrin** :→ This hormone is secreted by gastrin cells (=G-cells) in the pyloric region of the stomach. It stimulates gastric glands to secrete and release the gastric juice. It also stimulates gastric mobility.

(II) **Enterogastrone** :→ (= Gastric Inhibitory peptide - GIP) :- It is secreted by the duodenal epithelium. It inhibits gastric secretion and motality. It slows gastric contractions, hence it is also called gastric inhibitory peptide.

(III) **Secretin** :→ It was the first hormone to be discovered by scientists. It is secreted by the epithelium of duodenum and jejunum. It releases bicarbonates in the pancreatic juice. It increases secretion of bile and it decreases gastric secretion.

(IV) **Cholecystokinin pancreozymin (CCK-PZ)** :→ Cholecystokinin is derived from three roots :— Chol means bile, Cyst meaning bladder and kinin meaning to remove.

⇒ The word pancreozymin is derived from pancreas and zymin, which means enzyme producer.

⇒ This hormone is secreted by the epithelium of entire small intestine. It stimulates the gall bladder to release bile and pancreas to secrete and release digestive enzymes in the pancreatic juice.

(V) **Duocrinin** :→ It is secreted by the duodenal epithelium and stimulates the Brunner's gland to release mucus and enzyme into the intestinal juice.

(VI) **Enterocrinin** :→ It is secreted by the epithelium of entire small intestine. It stimulates the crypts of Lieberkuhn to release enzymes into the intestinal juice.

(VII) **Vasoactive Intestinal Peptide (VIP)** :→ It is secreted by the epithelium of entire small intestine. It dilates peripheral blood vessels of the gut. It also inhibits gastric acid secretion.

(VIII) **Villikinin** :→ It is secreted by the epithelium of entire small intestine. It accelerates movement of villi.

Motilin is known to control churning movements of stomach and also stimulates secretion of pepsinogen in the stomach.

Somatostatin inhibits release of gastrin while Secretin has inhibitory effect on release of gastric juice.

Absorption of Nutrients :→ It is the process by which nutrients produced after digestion are circulated throughout the body by blood and lymph and supplied to all body cells according to their requirements.

⇒ Practically all absorption takes place in the small intestine, the presence of villi on the inner surface of the small intestine and the presence of microvilli on the free surface of the small intestinal epithelial cells enhances the absorptive capacity of the small intestine.

Absorption of Carbohydrates :→ All carbohydrates essentially are absorbed in the form of monosaccharides directly into the blood stream.

⇒ Blood carries these monosaccharides to the liver, where they are converted to glycogen and stored in this form.

⇒ Glucose and galactose are absorbed by active transport.

⇒ Fructose and mannose are absorbed through facilitated diffusion that is by the help of the carrier molecule but again it is along the concentration gradient (higher concentration to low concentration). The diffusion is more rapid but all the contents cannot be absorbed.

⇒ Undigested disaccharides are not absorbed. Lactose is less easily digested than maltose and sucrose and hence may find its way into the lower regions of the small intestine before digestion takes place.

Absorption of amino acids :→ Proteins are absorbed as amino acids directly into the blood stream.

⇒ Blood carries these amino acids to the tissues where they become part of the metabolic pool from which body proteins are synthesized.

⇒ Amino acids are absorbed by active transport coupled with active sodium transport. The energy for the transport is supplied by a sodium co-transport mechanism. They also enter the blood stream.

⇒ The end products of fats are a mixture of monoglycerides, fatty acids and glycerol.

⇒ Glycerol is water soluble so it is directly absorbed by the mucosal cells of intestine.

⇒ The long chain fatty acids and monoglycerides are insoluble in water.

⇒ In the intestinal lumen, fatty acids, monoglycerides and the bile salts aggregate to form water-soluble molecules called mixed micelles each being 0.03 to 4 nm in diameter.

⇒ Each mixed micelles has the bile salts in the outer part whereas the hydrophobic fatty acids and cholesterol molecules form the core of micelle.

⇒ These micelles are taken by the intestinal mucosal cells generally by the process of pinocytosis. Inside the mucosal cells fatty acids and monoglycerides react to form triglycerides.

⇒ The neutral fat so formed is surrounded by a coat of β-lipoprotein to form water soluble fine globules called chylomicrons each about 1 μ in diameter. Chylomicrons are milky in colour and are released in the lymph capillaries called lacteals from where they are carried into the thoracic duct and then into systemic circulation.

⇒ Short-chain (less than 14 carbon atoms) fatty acids are directly absorbed into the portal circulation.

⇒ The bile salts are also released in the portal blood and are carried to the liver. Liver extracts the bile salts and uses them in bile formation and then again sent to the intestine. In this way about 90% of bile salts are reabsorbed in ileum. This is called enterohepatic circulation of bile salts.

Absorption of nutrients through the Small Intestine.

	Process Involved	Name of nutrient
1)	Active Process	Glucose, galactose, Na^+ and amino acids, Ca^{++}, K^+, Mg^{++}, Fe^{++}, PO_4^{3-}
2)	Facilitated diffusion	Fructose and mannose.
3)	Diffusion	Short-chain fatty acids, glycerol, water, Cl^-, vitamin B Complex, vitamin C and vitamin P.

Absorption of water :→

⇒ The absorption of water by small intestine occurs by osmosis from the lumen of small intestine through epithelial cells and into the blood capillaries in the villi.

⇒ The absorption of water from the small intestine is associated with the absorption of electrolytes and digested food in order to maintain an osmotic balance with the blood.

Absorption of Salts :→ Sodium is able to move in and out of epithelial cells by diffusion. It can also move into mucosal cells by active transport. This process is coupled to the movement of glucose as mentioned earlier.

⇒ Several other ions including Ca^{++}, K^+, Mg^{++}, Fe^{++} and PO_4^{3-} are absorbed by active transport. Calcium absorption is enhanced by Vitamin D and parathormone (hormone secreted by parathyroid glands).

⇒ Cl^- ions can be absorbed by diffusion or active transport. Salts are also absorbed into blood capillaries.

Absorptions of water soluble vitamins :→

⇒ Most of water soluble vitamins such as the vitamin B complex, vitamin C and vitamin P are absorbed by diffusion into the blood capillaries.

⇒ But reabsorption of vitamin B_{12} requires combination with Castle's intrinsic factor produced by the stomach for its absorption.

⇒ Dietary vitamin B_{12} is released from ingested proteins in the stomach through the action of pepsin and acid.

⇒ It is rapidly bound by one of two vitamin B_{12} binding proteins that are present in gastric juice at acidic pH. These binding proteins have a greater affinity for the vitamin than does intrinsic factor.

⇒ In the small intestine pancreatic proteases digest the binding proteins releasing vitamin B_{12} which then becomes bound to intrinsic factor.

⇒ Finally there are receptors for intrinsic factor on the ileal mucosa which bind the complex allowing vitamin B_{12} to be absorbed into portal blood.

Absorption of fat soluble vitamins :→

⇒ Vitamin A is absorbed from the intestine and its absorption is facilitated by bile salts.

⇒ Vitamin D is absorbed with food fats and concentrates rapidly in liver. Inhibition of normal fat absorption results in diminished absorption of ingested vitamin D.

⇒ Absorption of vitamin E occurs through intestine which is promoted by bile salts.

⇒ Absorption of vitamin K also occurs in the intestine and requires bile salts. It is not stored in the body.

⇒ The amino acids, monosaccharides, short-chain fatty acids, minerals, water soluble vitamins, and water are absorbed into the blood.

⇒ Fatty acids, glycerols, glycerides, and fat soluble vitamins are absorbed into the lymph.

Assimilation of food :→ Assimilation means the incorporation of the absorbed food materials into the tissue cells as their integral and homogeneous component.

⇒ The various food molecules taken up by the cells are transformed as amino acid, monosaccharides and fats.

Amino acids :→ Amino acids reach the liver by way of hepatic portal vein.

⇒ The surplus amino acids gets deaminated in the liver by separation of amino group (NH_2). The amino group combines with Co_2 to form urea $Co(NH_1)_2$, which is excreted in the form of urine.

⇒ The rest of the amino acids molecules after deamination are converted into sugar or fat for use as source of energy.

⇒ Other amino acids are released by the liver to the cells of the body. Here they are transformed into the characteristic proteins of human body by intracellular enzymes.

⇒ Some of these proteins finally change into living material, the protoplasm for repair and growth, and some act as enzymes to catalyze chemical reactions.

⇒ Proteins are not stored in the body.

Monosaccharides :→ Glucose, fructose and galactose also reach the liver by way of hepatic portal vein.

⇒ Here fructose and galactose are converted into glucose.

⇒ Excess of glucose is converted into glycogen in the liver (glyco-genesis) and stored for supply at the time of need, and the rest is released to the body cells.

⇒ Some glucose is also stored in the muscles as glycogen it is used as fuel in the muscles themselves and not released to other cells.

⇒ Some glucose is changed into fats that are stored in the liver and muscles.

Fats :→ The absorbed fats changed into characteristic fats of human body by rearrangements of fatty acids.

⇒ Some fats are stored in the liver, bones, muscles, mesenteries, and adipose tissue, where as some enter into the composition of cell organelles, especially cell and nuclear membranes.

⇒ Fats are used as fuel also. For this they are split into fatty acids and glycerol.

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⇒ Fats are also changed into glycogen in the liver cells.

⇒ The fat is constantly exchanged between the blood stream and adipose tissue, every molecule of fat in adipose tissue is replaced about every three weeks.

⇒ Fat can also give rise to glucose.

Egestion :→ After the absorption of digested products in ileum, undigested food that reaches the large intestine contains a large amount of water.

⇒ The wall of intestine absorb water and any remaining inorganic nutrients like Ca^{++} and Fe^{++}.

⇒ As the water is absorbed, the semi-solids that remain are called faeces. Faeces can remain in the large intestine (colon) for a long time before being passed out to rectum for egestion. Faeces contain number of substances mentioned below :→

⇒ Undigested food which mainly consists of cellulose and other plant fibres.

⇒ Dead bacteria Intestine harbours many symbiotic bacteria which synthesize amino acids and some vitamins like vitamin K.

⇒ Mucus and dead mucosal cells from the gut wall :-

⇒ The gut lining is constantly shed off or wears off and is replaced by new cells.

⇒ Bile pigements and its derivatives give colour to faeces.

⇒ Smell of faeces is due to bacterial decay of food producing indole, skatol, thiols and hydrogen sulfide gases.

Disorders of Digestive System :-

1) **Heart burn** :- It is also called **reflux oesophagitis** is a discomfort or pain caused by the stomach contents travelling from the stomach up into the gullet (lower part of oesophagus).

⇒ Heartburn has nothing to do with the heart. It is a digestive problem, which is usually related to meals and posture and can often be relieved by remedies for indigestion.

⇒ The main symptoms are :- burning sensation in the center of the chest and belching.

⇒ Heartburn is caused by a faulty muscle in the stomach. There is "flap" at the top of the stomach that stops food from travelling back up into the oesophagus.

⇒ Sometimes the flap doesn't work properly and stomach acid escapes from the stomach, when the acid escapes heartburn occurs.