3 DIGESTIVE, CIRCULATORY AND LYMPHATIC SYSTEM

B12CH3

Outcomes: To be able to:

- discuss the role of the digestive system and outline the nutritional benefits of eating a balanced diet of locally available food;
- appreciate the roles of the circulatory and the lymphatic systems in the process of transporting nutrients and the defense mechanism of the body respectively.

Learning Objectives

At the end of this unit, you will be able to:

- define digestion, state the processes and list the organs that are involved;
- state the functions of enzyme in the process of digestion;
- explain nutrition, the classes of food and their specific importance to the body;
- list the components of blood and describe their functions and the process of blood clotting;
- discuss the heart, the blood and blood vessels;
- discuss the lymphatic system and its functions and composition of lymph;
- describe the structure and functions of lymph nodes;
- outline and give the function of other lymphoid organs (tonsils, spleen, thymus).

3.1. DIGESTIVE SYSTEM

Digestion is important. Our body needs nutrients from food and drink to work properly and to be healthy. Our digestive system breaks nutrients into parts small enough for our body to absorb. These nutrients help our body to give energy, grow and cell repair.

3.1.1. Nutrition

All living organisms require energy to operate the metabolic reactions that sustain life, and they need raw materials to build up most of their own body molecules. The materials which provide the two primary requirements of life, namely, energy and raw materials, are called **nutrients**. A substance which is taken to supply the necessary nutrients to the body is termed **food**, or **diet**. The sum total of the processes by which the living organisms obtain food and utilize it for use in various biological activities such as growth, maintenance and for meeting their energy needs is termed as **nutrition**.

Steps in the processes of Nutrition

Nutrition occurs in following steps:

I. Digestion: It involves breaking down of the complex organic food materials such as carbohydrates, proteins, lipids, nucleic acids into simpler, smaller, soluble molecules.

Digestion involves mechanical as well as chemical changes in the food taken. Mechanical alteration is brought about by teeth, and muscular contraction of stomach and intestinal walls. Breaking food into smaller pieces increases the surface area exposed to the enzymes of digestive juices. Chemical changes involve cleaving of complex, insoluble macromolecules into simpler, soluble subunits, and are brought about by the action of enzymes. Absorbable foods do not require such a change, being already fit for absorption. The nonabsorbable foods have to undergo a good deal of alteration so that they become ready for absorption. The subunits in the macromolecules of these foods are held together by anhydro bonds, i.e., bonds formed by the removal of water. Digestion of these macromolecules involves hydrolysis, in which the anhydro bonds are broken by the addition of water with the help of enzymes. These enzymes are called **hydrolases**. There are specific hydrolases for splitting starches, lipids, proteins and nucleic acids into their subunits. Thse are respectively called **carbohydrases**, **lipases**, **proteases (peptidases)** and **nucleases**.

$$\text{Starches} \xrightarrow{\text{Carbohydrates}} \text{Glucose}$$

$$\text{Proteins} \xrightarrow{\text{Proteases}} \text{Amino acids}$$

$$\text{Fats} \xrightarrow{\text{Lipases}} \text{Fatty Acids + Glycerol}$$

$$\text{Nucleic Acids} \xrightarrow{\text{Nucleases}} \text{Nitrogenous bases + pentose sugars + inorganic phosphates}$$

II. Absorption and Assimilation: Absorption involves passing of digested food components thorough the wall of small intestine into the blood or lymph. These absorbed food molecules are then circulated to different constituent cells of the body where they are absorbed. **Assimilation** involves use of absorbed simple food components in the synthesis of complex component in different body cells.

3.1.2. Classes of Food and its Importance

Different nutrients have different functions. Food can be categorized under three broad groups according to the function of the nutrient it provides. These groups are: energy-giving foods, body-building foods and protective foods. Carbohydrates and fats are energy-giving foods. Proteins are body-building foods. Vitamins and minerals are protective foods. They perform certain essential functions within the body.

Let us now study the various classes of food and its importance.

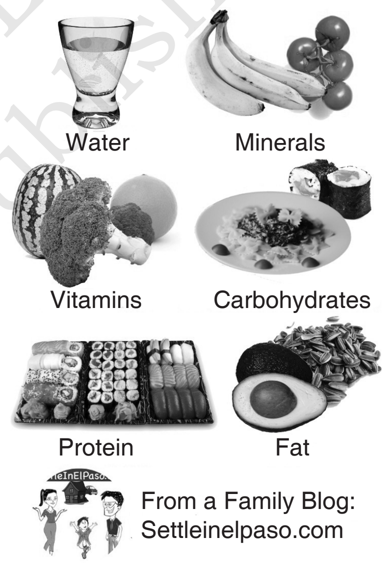


Fig. 3.1. Classes of food

Carbohydrates

Carbohydrates are the main source of ready energy. Wheat, rice and maize are the three main cereal crops with plenty of carbohydrates in the form of starch. There are two types of carbohydrate—sugars and cellulose.

- **Sugars:** The common sugar we eat is sucrose. The sugar found in milk is lactose.
- **Starch:** Starch when digested, we get simple sugars. It can be obtained from the seeds, roots or stems of plants. Starch is present in such food items as wheat, rice, maize, potato, sweet potato, arrowroot, tapioca and banana.

Cellulose is a carbohydrate that cannot be used as a nutrient by us because we cannot digest it. It is regarded as a dietary fibre, or roughage. Fruits and vegetables are rich sources of cellulose.

Importance:

- Carbohydrates are the cheapest source of energy. One gram of carbohydrate yields 4.2 kilocalories of energy on respiration.
- Simple sugars are used for the liberation of energy.
- For energy production our cells prefer to use carbohydrates over fats.

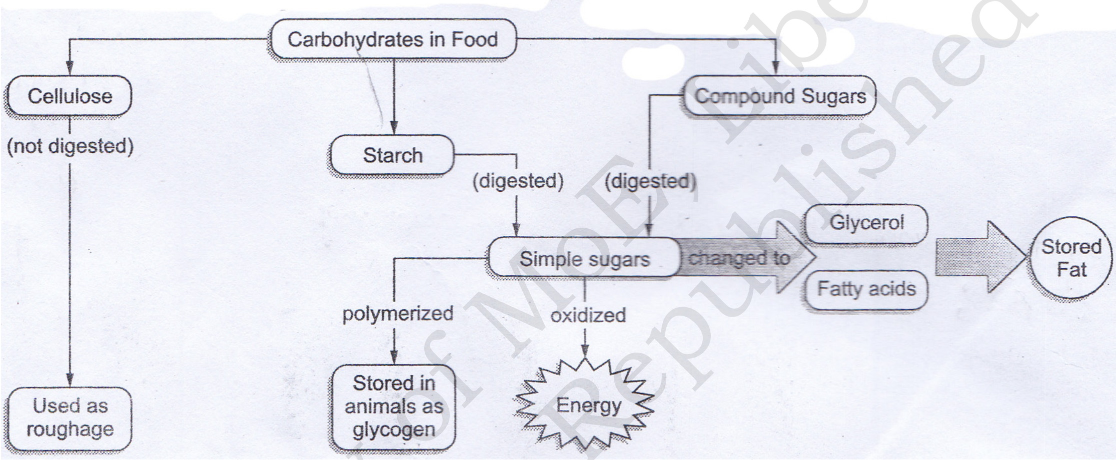


Fig. 3.2. Digestion and utilization of carbohydrates in our body

Fats

When fats are oxidized in the body they produce energy. The energy obtained is more than twice as much as that obtained from the same amount of carbohydrate. One gram of fat gives about 9.3 kcal of energy.

Importance

- Fats provide energy.
- Fats are used to build membranes of cells and organelles such as those of the Golgi complex and mitochondria.
- Excess fats get accumulated underneath the skin. Because of their location beneath the skin, they are called ***subcutaneous fat***. This fat acts as an insulator.
- Fat around organs such as the kidneys, ovaries and eyes protect them.
- In the blood, they dissolve vitamins A, D, E and K, and transport them from the intestine to different parts of the body.

Sources of fats: We get animal fat from butter, ghee, cheese, milk, egg yolk (yellow), fish liver (e.g., cod-liver oil), oily fish, and red meat such as mutton, beef and pork. Nuts (groundnut, walnut, etc.) and all cooking oils (coconut, sunflower, mustard, cotton seed, olive) are sources of vegetable fat.

Proteins

Proteins are formed from chemical units called amino acids. Proteins in our food are digested and broken up into the constituent amino acids. These amino acids are absorbed in the small intestine and transported by the blood to different parts of the body.

In general, the body requires 1 gram of protein for every kilogram of body weight. This means a 50-kg woman needs 50 g of protein every day.

Sources of proteins: Proteins can be obtained from plant as well as animal sources. Peas, groundnuts, beans, whole cereals (wheat, maize) and pulses are the best plant sources. Animal proteins can be had from meat, fish, poultry, egg white, milk and milk products.

Importance

- Proteins that act as catalysts for the biochemical reactions in the body are called enzymes. For example, the digestion of food, which is a series of chemical reactions, is speeded up by enzymes such as ptyalin (in saliva), pepsin (in the stomach), trypsin and lipase (in the small intestine).
- All movements in our body such as blinking and movement of the arm or legs involve the contraction and relaxation of muscles. Proteins that cause contraction arm relaxation of muscles are called contractile proteins. Actin and myosin are contractile proteins.
- Proteins that influence the working of cells and organs are called hormones. For example, insulin and glucagon are hormones that control blood-glucose level.
- Structural proteins play a part in building the membranes of cells. They form various structures of the body such as hair (keratin) and the lens of the eye.

Minerals

We need many metals and nonmetals for the various reactions taking place in our body. These are collectively called minerals. Just seven minerals comprise 60–80% of all the minerals needed by the body. These are calcium, magnesium, sodium, potassium, phosphorus, sulphur and chlorine. The remaining minerals include iron, iodine, copper, zinc, manganese, cobalt, molybdenum, selenium, chromium and fluorine.

Importance

- Sodium, potassium and calcium ions help in the transmission of nerve impulses.
- Sodium, potassium and calcium play an important role in the contraction of muscles.
- Calcium and phosphorus are needed to help form bones and teeth.
- Calcium is required for the clotting of blood.
- Phosphorus is present in every cell and plays a crucial role in the transfer of energy.
- Iron needed for the formation of haemoglobin.

Vitamins

Vitamins are a group of about fifteen organic compounds present in minute quantities in natural foodstuff. A 600-gram meal contains less than 1 g of vitamins, but these substances are essential for normal growth and maintenance of life. And they must come from food because except for vitamin D, we are unable to synthesize them in our body. Vitamins are needed only in small quantities. They do not provide energy. Nor do they form body structures. But they are essential for the regulation of body functions.

Vitamins are divided into two main groups: fat-soluble and water-soluble. Vitamins A, D, E, and K are fat-soluble. Vitamin C, and the B group of vitamins are **water-soluble**. A number of water-soluble vitamins are traditionally grouped as the B group of vitamins based on their somewhat similar properties and functions in the body. They constitute vitamin B complex. Vitamin B complex includes vitamins B_1, B_2, B_3, B_6, B_{12}, pantothenic acid, folic acid and biotin.

Importance

- Vitamin C help the body fight infections.
- There are bacteria in the intestine that synthesize vitamins for us. If their ability decrease, for some reason, we have to take more vitamins in our food, or have tablets or capsules.
- Some medicines reduce the ability of the intestine to absorb vitamins. Then too we need to take more than the usual quantity of vitamins.

Water

Water is the most abundant substance in the body. It constitutes 65% by weight of protoplasm and 92% by weight of blood plasma. The water we drink meets most of the water requirement of the body. Some comes from other beverages like tea, coffee, milk and fruit juices, some from food and some is formed in the body during respiration.

Importance of water in the body

- It is by far the best solvent and provides the medium in which most reactions in the body take place.
- In the excretion of waste (*e.g.*, urea) too, water acts as the solvent.
- Water regulates temperature by sweating and evaporation.

Roughage

It is the dietary fibre made up of cellulose. Salad, vegetables and fruits are sources of roughage Cellulose is not digested, but help in the movement of food and faecal matter along the alimentary canal. Corn and whole broken wheat are good source of roughage.

Importance

- Lack of roughage causes constipation.

Activity 1

Using web resources, search foods, that are locally available in your area. What do you like to eat most? What nutrients are present in those foods? With the help of this chapter, find out answers and discuss in class.

Do it Yourself

1. __________ are main source of ready energy.
2. We get __________ fat from butter, cheese, milk etc.
3. Proteins are formed from chemical units called __________ acids.
4. Chromium and fluorine are __________ .
5. Vitamins. A, D, E and K are __________ soluble.

3.1.3. Balanced diet and Local food in Liberia

A balanced diet one that provides all the nutrients required by the body in correct amount. Liberian cuisine is mostly made up of rice, cassava, plantain, yam, tropical fruits and vegetables (potatoes, greens, cassava leaf, okra, cabbage) as well as fish, meat and more.

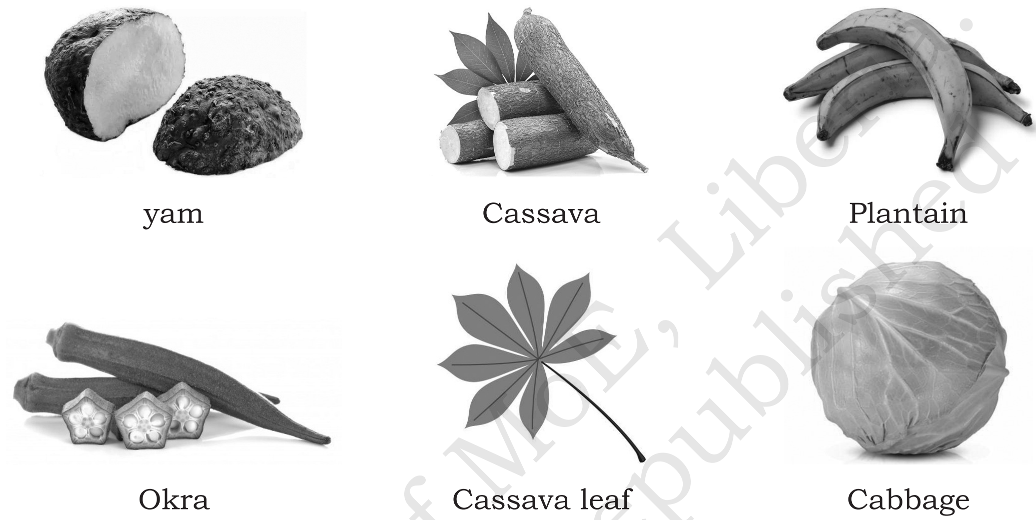


Fig. 3.3. Local food in Liberia

Sufficient consumption of fruits and vegetables is generally linked with a lowered risk of chronic lifestyle diseases, digestive problems, mental health problems, eye problems, height blood pressure and body weight management. It is recommended for adults to eat at least five servings of fruits and vegetables per day.

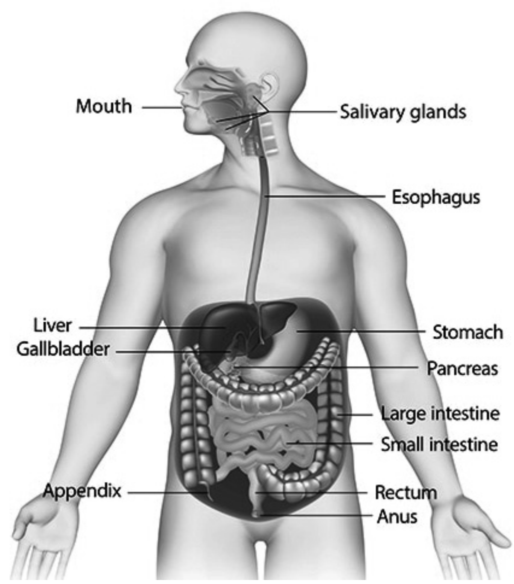


Fig. 3.4. Human digestive system

3.2. ALIMENTARY CANAL

Alimentary canal is also known as gut or digestive tract. In humans it is 8 to 9 metres long. The alimentary canal is a continuous canal which has many parts such as mouth, oesophagus, stomach, small intestine, large intestine, rectum and anus.

3.2.1. Mouth

The mouth is an opening which is protected by upper and lower lips (labia). The lips are covered with skin on the outer side and lined with mucous membrane on the inner side.

The mouth leads the food into the buccal cavity or oral cavity. The buccal cavity contains teeth, tongue and salivary glands. The teeth cuts the food into small pieces, chews and grinds it. The salivary glands secrete a watery juice called saliva.

Function

- The tongue helps in mixing the saliva with the food. Saliva is a digestive juice, which helps to digest the starch present in the food partially.
- The slightly digested food is swallowed by the tongue and goes down into the oesophagus (or food pipe).

3.2.2. Oesophagus

The oesophagus is about 25 cm long, muscular tube which runs downwards behind the trachea and heart, and passes through the diaphragm into the abdomen. The oesophagus consists of three parts—cervical part in the neck, thoracic part in the thorax and abdominal part in the abdomen. In the abdomen, the oesophagus bends sharply and opens into the stomach. This bend is one of the devices to check the back flow of the stomach contents into the oesophagus.

Function

The oesophagus serves to convey the food by peristalsis from the pharynx to the stomach.

3.2.3. Stomach

It is the wide, J-shaped distensible, muscular sac placed obliquely on the left side in the upper part of the abdomen just below the diaphragm. It is about 30 cm long and 15 cm wide.

The fold of peritoneum attaches stomach to the posterior abdominal wall. The stomach has four parts—cardiac part, fundus, body and pyloric part.

(i) **Cardiac Part:** It is so called because it is present near the heart. The oesophagus opens into it. This opening is called cardiac aperture. A ring of muscle called oesophageal sphincter or cardiac spincter guards the cardiac aperture. It checks the regurgitation (passage of food back into the buccal cavity) of the food.

(ii) **Fundus:** It is a small dome shaped part which 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 or Antrum:** It is the distal narrow part of the stomach. It consists of a wider pyloric antrum and a narrow pyloric canal. The latter leads into small intestine by pyloric aperture or pylorus.

Functions

The stomach performs four main functions :

- storage of food,
- churning and breaking up of food,
- partial digestion of food (proteins and fats),
- regulation of the flow of food into the small intestine,
- it also secretes a glycoprotein called **castle's intrinsic** gastric factor, necessary for the absorption of vitamin B_{12} in the intestine and
- it also secretes the hormone gastrin. The partially digested food then goes from the stomach into the small intestine.

3.2.4. Small Intestine

It is a small narrow tube, and in the longest part of the alimentary canal. In adult human, the small intestine is about 6.25 metres long. It comprises three parts—duodenum, jejunum and ileum.

(i) Duodenum: It is the shortest and widest part of the small intestine that follows the stomach. It is somewhat C-shaped. It receives the hepatopancreatic ampulla (also called ampulla of vater) of the hepatopancreatic duct formed by the union of bile duct and pancreatic duct.

(ii) Jejunum: It is the middle part of the small intestine that follows the duodenum. It is about 2.5 metres long. Its wall is thick and more vascular.

(iii) Ileum: It is the lower part of the small intestine and is about 3.5 metres long. Its wall is thin and less vascular.

Both the jejunum and ileum are greatly coiled and are suspended by mesentery. The jejunum and ileum largely fill the abdominal cavity below the liver and stomach.

Functions

- The small intestine completes the digestion of food.
- It absorbs the nutrients from the digested food into the blood and lymph.

Large Intestine

The small intestine leads into a much shorter **large intestine** or **colon**. Large intestine is about 1.5 metres long and is divisible into three parts—caecum, colon and rectum.

(i) Caecum and Vermiform Appendix: At the juncture where small intestine opens into colon, there is present a small blind sac-like structure called caecum. It plays no role in nutrient absorption and is a vestigial organ.

(ii) Colon: The caecum leads to the colon, which gives sacculated appearance due to a series of constrictions. The colon has three longitudinal bands called taeniae coli and a number of small pouches called haustra.

(iii) Rectum: The sigmoid colon opens into the rectum. It is 15–20 cm long and terminates into a 2.5 cm long anal canal. The opening of anal canal is called anus.

Functions

- The main functions of large intestine are the absorption of water; formation, temporary storage and elimination of faeces; and secretion of mucus for lubrication of mucosa.
- It also absorbs vitamin K and vitamin B complex produced by the colon bacteria present in it.

3.2.5. Accessory Organs

Some accessory digestive organs like salivary glands, pancreas, liver and gall bladder (biliary system) are also connected to the alimentary canal by a series of ducts.

Exocrine glands are glands of external secretion. These are those that secrete substance on the body surface through a duct. Salivary glands, pancreatic glands etc are some of the exocrine glands.

A. Salivary Glands

Any cell or organ that discharges a secretion into the oral cavity is called salivary gland. Humans have three pairs of salivary glands—parotid, sublingual and submaxillary or submandibular (Fig. 3.5).

(i) **Parotid Glands:** These are the largest glands which lie near the ears. The ducts of parotid glands called **Stenson's ducts** open into the oral cavity near the upper second molars.

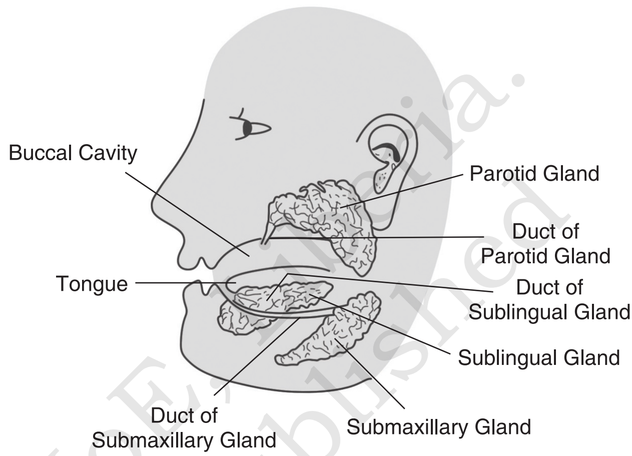


Fig. 3.5. Human Salivary glands

(ii) **Sublingual Glands:** These are the smallest salivary glands which are located beneath the tongue. The sublingual ducts also called ducts of Rivinus open into the floor of the oral cavity.

(iii) **Submaxillary (also called submandibular) Glands:** These are medium sized salivary glands which are located at the angles of the lower jaw.

The salivary glands secrete a viscous fluid called saliva. About 1–1.5 litres of saliva is secreted per day. Saliva is slightly acidic (pH 6.8). It is a mixture of water and electrolytes (Na^+, K^+, Cl^-, HCO_3^-), derived from blood plasma, mucus and serous fluids (watery constituent of saliva), and salivary amylase or ptylin (enzyme) and lysozyme (antibacterial agent) secreted by the main salivary glands.

Functions of Saliva

- It moistens and lubricates the buccal mucosa, tongue and lips, thus making speech possible.
- It helps in the process of mastication of food and converting it into a bolus suitable for swallowing.
- Bicarbonate ions of saliva neutrilise the acids in food.

- The thiocyanate ions and lysozyme present in saliva act as antimicrobial agent and prevent infection.
- Enzyme ptyalin (salivary amylase) helps in digestion of starch.

B. Pancreas

The pancreas is an elongated greyish-pink gland, located posterior to the stomach in the abdominal cavity. It is about 12 to 15 cm long and 2.5 wide and weighs about 60 grams. The pancreas comprises of three parts—head, body and tail (Fig. 3.6). The head lies in the curve of the duodenum, the body behind the stomach and tail meets the spleen lying in front of the left kidney.

The pancreas is both an endocrine and an exocrine glands.

(i) Exocrine Part: The exocrine tissue of the pancreas consists of rounded lobules (acini) that secrete an alkaline pancreatic juice with pH 8.8. About a litre of pancreatic juice is secreted each day. The pancreatic juice is carried into the duodenum through the main pancreatic duct and the accessory pancreatic duct. The pancreatic juice contains sodium bicarbonate, three proenzymes—trypsinogen, chymotrypsin and procarboxypeptidase and a number of enzymes such as pancreatic α-amylase, pancreatic lipase, elastase, DNAase and RNAase. The pancreatic juice helps in the digestion of all types of foods—starch, proteins, fats and nucleic acids. Its sodium bicarbonate neutrilizes the acidity of chyme caused by HCl.

(ii) Endocrine Part: The endocrine part of the pancreas consists of groups of islets of Langerhans. The latter are interspersed at random among the lobules. The human pancreas has about one million islets. They are most numerous in the tail part of the pancreas. Each islet of Langerhans consists of four types of cells—alpha cells, beta cells, delta cells and

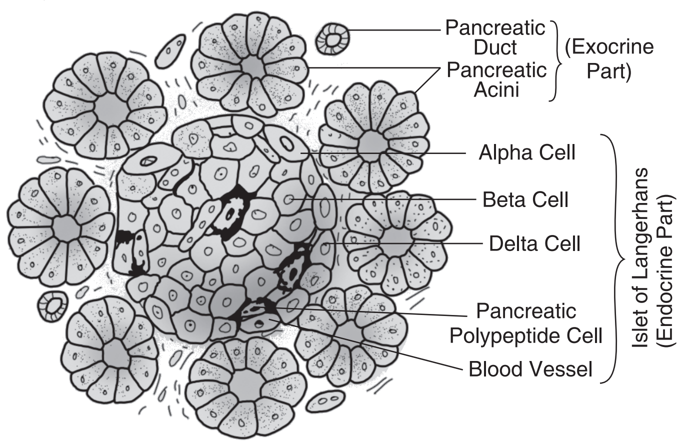


Fig. 3.6. Section of pancreas

pancreatic polypeptide cells (F. cells) (Fig. 16.14). They secrete different types of hormones which are poured into the circulating blood.

Functions

- Alpha cells secrete glucagon hormone which converts glycogen into glucose (glycogenolysis) in the liver. It is, therefore, also known as hyperglycemic or diabetogenic hormone.
- Beta cells produce insulin hormone which converts glucose into glycogen (glycogenesis) in the liver and muscles.
- Delta cells secrete somatostatin hormone, which, inhibits the secretion of glucagon by α cells and to a lesser extent secretion of insulin by β cells.
- Pancreatic polypeptide cells secrete **pancreatic polypeptide** (PP) which inhibits the release of pancreatic juice.

C. Teeth

Most of the mammals including man have diphyodont (two sets of teeth milk or deciduous and permanent), thecodont (teeth are embedded in the sockets of jaw bones – maxillae and mandible) and heterodont teeth (different types of teeth). There are present four types of teeth—incisors, canines, premolars and molars (Fig. 3.7).

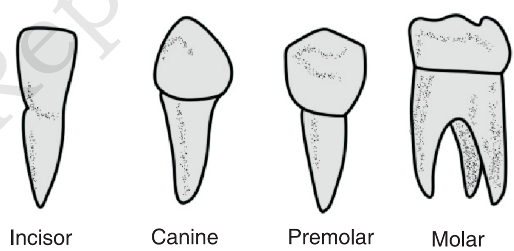


Fig. 3.7. Types of teeth

The **incisors** also called cutting teeth, have sharp, chisel-like cutting edges and occur at the anterior ends of the jaws. They are used for cutting, chopping and gnawing. The **canines** lie immediately behind the incisors. They are more pointed and used for ripping or shredding.

The **premolars** and **molars** are also called the **grinding teeth** or **cheek teeth**. They have broad and grooved tops, and are located further back in the jaw. They are used for shearing, crushing and grinding. Third molars in human beings are called **wisdom teeth**. The latter are called vestigial in humans.

Structure. A tooth consists of three regions—crown, neck and root. The crown is the exposed part. The neck is surrounded by a soft, fleshy skin called gum or gingiva. The root is embedded in a socket of the jaw bone. The incisors and canine have a single root, upper premolars have two roots, lower premolars have one root, upper molars have three roots, and lower molars have two roots.

The crown remains capped with hard and shining **enamel**, formed principally of calcium phosphate. Enamel is the hardest substance in the body and relatively resistant to decay. Both crown and root are composed of hard bone-like substance called **dentine**, which encloses the **pulp cavity**. The latter contains soft, gelatinous connective tissue called **pulp**. It has nerve and blood supplies that enters *via* **pulp canal** at the base (Figs. 3.8). The pulp cavity is lined by dentine forming cells, the **odontoblast**. The root is fixed in the alveolus of the jaw bone by **cementum** or **periodontal membrane**.

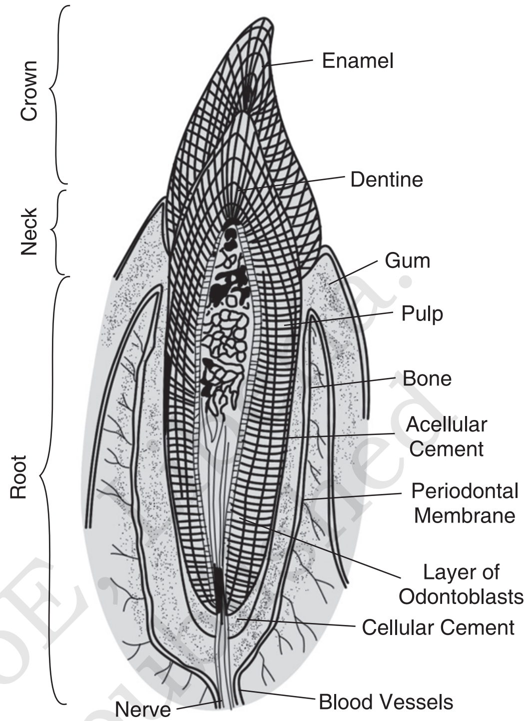


Fig. 3.8. V.S. Human tooth

D. Tongue

It is a voluntary muscular and glandular structure attached to the floor of mouth by a fold called lingual frenulum. Tongue occupies the floor of the mouth. The upper surface of the tongue remains divided into anterior oral part and posterior pharyngeal part by an inverted V-shaped furrow called sulcus terminalis. The apex of the sulcus terminalis projects backward and is marked by a small median pit called foramen-caecum.

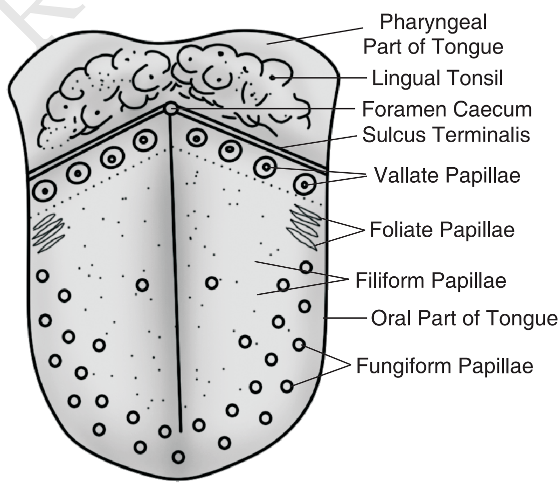


Fig. 3.9. Upper surface of human tongue

Lingual Papillae: The upper surface of the tongue bears small projections called lingual papillae. These are of four types:

(i) **Vallate** ***or*** **circumvalate papillae** are the largest papillae and are arranged in an inverted V-shaped row towards the base of the tongue. They are 8 to 12 in number. Each of which surrounded by a circular groove and contains up to *100 taste buds (= gustatory receptors).*

(ii) **Filiform papillae** are the smallest and most numerous, occur mainly near the centre. They contain tactile (touch) receptors, only.

(iii) **Fungi-form papillae** are rounded and are most numerous near the tip of the tongue. Each filiform papilla contains about five taste buds.

(iv) **Foliate papillae** are not developed in human tongue, but are present in other mammals at the sides of the base of the tongue.

Human tongue has four taste areas — anterior part (sweet taste), posterior part (bitter taste), sides (sour taste) and a small part behind the anterior end (salt taste). The areas of sweet and salt tastes can overlap.

Functions of Tongue

- It acts as an accessory digestive organ.
- It helps in chewing by sending the food under the grinding teeth.
- It helps in swallowing the food.
- It acts as a brush to clean the teeth.
- It also plays a role in speech and forming words along with lips teeth and hard palate.

3.2.6. Liver

The liver is the largest gland of the body, weighing 1.4–1.8 kg in males and 1.2–1.4 kg in females. It lies in the upper right side of the abdominal cavity just below the diaphragm, and is attached to the latter by a median vertical fold of peritoneum. It is dark red and spongy. The liver consists of two main lobes—large **right lobe** and much smaller, **left lobe** (Fig. 3.10). The two lobes are separated by a membrane—**falciform ligament**, 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** on the posterior surface. Liver consists of small structural and functional units called **hepatic lobules** containing hepatic cells (hepatocytes) arranged radially around a central vein. The mammalian liver also contains phagocytic cells called **Kupffer cells**. They eat bacteria and worn-out blood corpuscles. The liver is capable of regenerate rapidly.

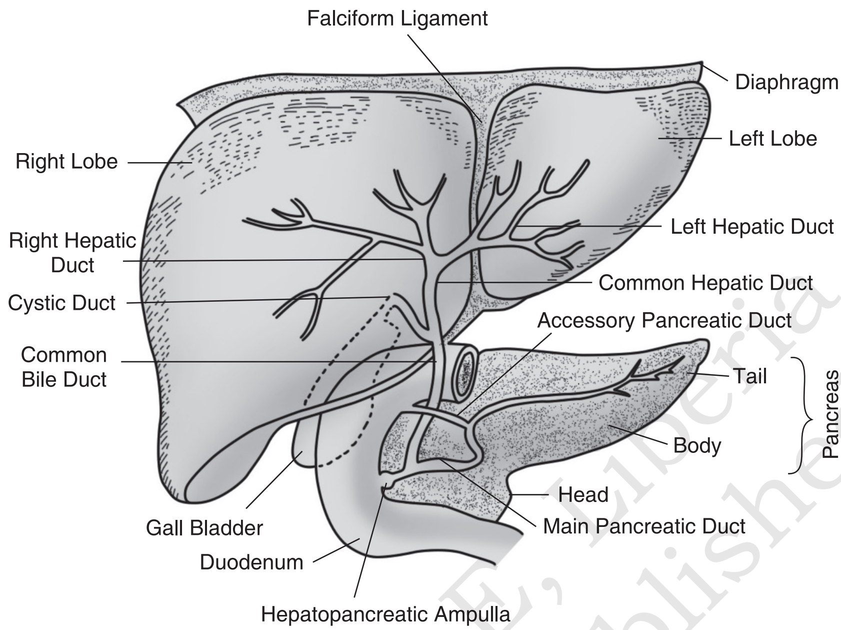


Fig. 3.10. Liver and pancreas with associated structures.

Functions of Liver

- Bile is the main exocrine secretion of liver. The bile salts help in the digestion of fats in the small intestine by bringing about their **emulsification** (conversion of large fat droplets into small ones).
- Liver brings about deamination of amino acids which results in the formation of ammonia which is converted into urea.
- Liver is involved in the elimination of certain wastes.
  (i) Liver synthesizes urea from ammonia and carbon dioxide, which is eliminated through excretory system.
  (ii) The pigments (**bilirubin** yellow and **biliverdin** green) and certain other waste products such as cholesterol, metal ions and breakdown products of haemoglobin reach the duodenum through bile and pass out with faeces.
- Liver converts toxic substances into harmless substances, *e.g.*, *prussic acid*, formed in all body cells during metabolism is rendered harmless in the liver cells.
- Liver produces angiotensinogen (a protein) which helps kidneys in osmoregulation (maintenance of body fluid).
- Liver helps in maintaining the optimum body temperature by generating enough heat due to its high metabolic activities.
- Bile increases peristalsis of the intestine.
- It contains no enzyme but activates enzyme lipase.

Activity 2

Make a chart of human digestive system. Label the following organs in this chart using different coloured pencil.

(a) Oesophagus (b) Stomach
(c) Small intestines (d) Large intestines

Do it Yourself

1. Which organ connects the mouth to the stomach?
(a) Liver (b) Oesophagus
(c) Large intestine (d) stomach

2. This is the lower part of the small intestine.
(a) Duodenum (b) Jejunum
(c) Ileum (d) None of these

3. These are the largest glands which lie near the ears.
(a) Parotid (b) Sublingual
(c) Submaxillary (d) All of the above

4. __________ moistens and lubricates the buccal mucosa.
(a) Saliva (b) Teeth
(c) Tongue (c) None of these

5. These cells produce insulin hormone.
(a) Alpha (b) Beta
(c) Delta (d) pancreatic

3.2.7. Absorption through villi and hepatic portal vein

The process of digestion simply alters the ingested food into its constituents that are soluble and diffusible substances producing a milky fluid called chyle. These digested food substances must be passed on the tissues before they can perform essential cell functions. The process by which the end products of digestion pass through the intestinal mucosa into the blood or lymph is called **absorption**.

Villi

Site of Absorption: Absorption of substances takes place in different parts of the alimentary canal like mouth, stomach, small intestine and large intestine. However, maximum absorption occurs in the small intestine through villi.

Nutrients to be Absorbed: The nutrients which are to be absorbed include monosaccharides (glucose, fructose, etc), amino acids, fatty acids, glycerol, salts (electrolytes), vitamins and water.

1. **Absorption of Monosaccharides:** Small amount of monosaccharides like gucose is absorbed by simple diffusion. However, maximum absorption of monosaccharides such as glucose and galactose is carried out by active transport. Active transport occurs against the concentration gradient and hence requires energy. Sodium pump of the cell membrane helps in the active uptake of the monosaccharides.
   Fructose is absorbed with the help of the carrier ions like Na^+. This mechanism is called facilitated transport.
2. **Absorption of Amino Acids:** Amino acids are absorbed by active transport and some by facilitated transport. They also enter the blood stream.
3. **Absorption of Fatty Acids and Glycerol (= Absorption of Fats) and Fat Soluble Vitamins.** Fatty acids and glycerol being insoluble in water, cannot be absorbed into the blood directly. They are first incorporated into small, spherical, water soluble droplets called **micelles**, with the help of the bile salts and phospholipids in the intestinal lumen.

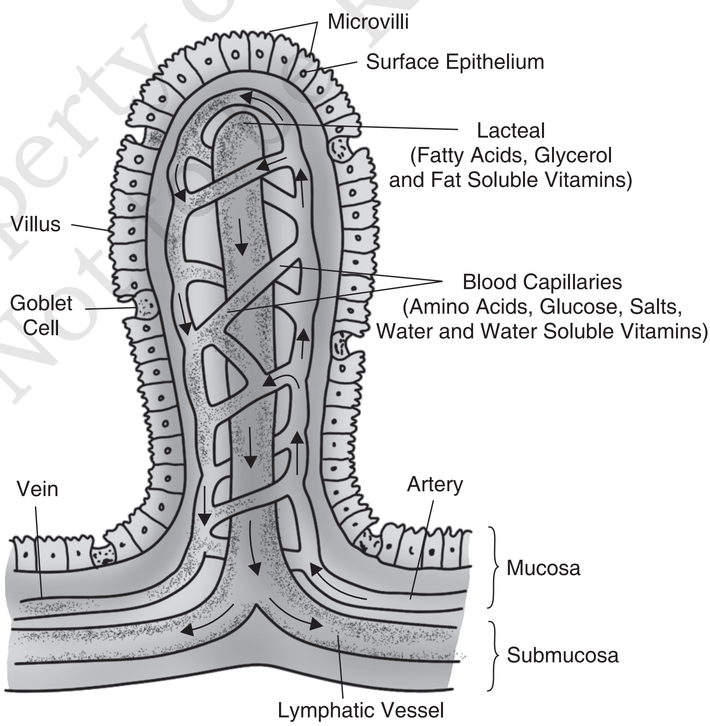


Fig. 3.11. Villus showing absorption of nutrients.

The micelles move into the intestinal mucosa, where, they are reformed into very small protein coated fat globules called the **chylomicrons**. The latter are transported into the lymph vessels (**lacteals**) in the villi. These lymph vessels ultimately release the absorbed substances into the blood stream.

4. **Absoprtion of Water Soluble Vitamins:** Most of water soluble vitamins like vitamin B complex, vitamin C, vitamin H and vitamin M are absorbed by diffusion into the blood capillaries.
5. **Absorption of Salts (Electrolytes):** Sodium is absorbed into the mucosal cells by diffusion as well as by active transport. Chloride ions are also absorbed by diffusion or active transport. Several other ions including calcium, potassium, magnesium, ion and phosphate are absorbed by active transport. Salts are also absorbed into the blood capillaries.
6. **Absorption of Water:** Water is absorbed by osmosis. This process occurs so long as the solute concentration (and the consequent osmotic pressure) is higher in the blood than in the intestinal contents. Absorption of any solute raises the osmotic pressure of the blood and brings about absorption of an equivalent amount of water. Water is absorbed partly in the small intestine and mostly in the large intestine.

Hepatic Portal Vein

It is a blood vessel that carries blood from the gastro intestinal tract, gall bladder, pancreas, and spleen to the liver. This blood contains nutrients and toxins extracted from digestives contents. Approximately 75% of total liver blood flow in through the portal vein. Hepatic portal vein transports absorbed food from the small intestines to the liver.

Activity 3

Open your mouth in front of mirror. Count how many teeth you have? With the help of teachers try to identify. You can do same process with your friends. Compare your teeth with your friends and discuss in the class.

Do it Yourself

1. These vessels release the absorbed substances into the blood stream.

2. Amino acids are absorbed by this transport.
3. This transports absorbed food from the small intestines to the liver.
4. In which part of the body does absorption take place during digestion process?
5. Water is absorbed by which process?

INFOBOX

Liver is the largest gland and second largest organ of human body. It can weigh up to 1.3 to 1.6 kg for a human adult and is a reddish brown in colour.

3.2.8 Functions of Digestive Enzymes in the Process of Digestion

Humans perform extracellular digestion with the help of digestive enzymes released from the secretory cells of the digestive system.

Digestion is a process in which polymers of carbohydrates, fats, proteins and nucleic acids are broken down into monomers by the addition of water with the help of enzymes. These enzymes are called hydrolases (general term for digestive enzymes).

Digestion in Oral (Buccal) Cavity: In the oral cavity, food is mixed with saliva secreted by the salivary glands. Saliva is a mixture of water, electrolytes (Na^+, K^+, Cl^-, HCO_3^-), derived from the blood plasma, mucus and serous fluids, salivary α-amylase or ptylin (enzyme) and lysozyme (an antibacterial agent).

The enzymatic hydrolysis (digestion) of food is initiated in the oral cavity by the action of starch digesting enzyme salivary amylase (ptylin) present in the saliva. The salivary amylase converts starch into maltose, isomaltose and small dextrins called α-dextrins.

$$\text{Starch} \xrightarrow{\text{Salivary amylase}} \text{Maltose} + \text{Isomaltose} + \alpha\text{-Dextrins}$$

The digestion of starch continues as the bolus passes down through the oesophagus into the stomach till the medium becomes fairly acidic in the stomach.

Digestion in the Stomach. In the stomach, the food is exposed to the action of **gastric juice**, which is a mixture of **hydrochloric acid**, proenzymes – **pepsinogen, prorennin** (only in infants), **lipase** and **mucus**. HCl converts pepsinogen and prorennin into pepsin and rennin respectively. Once pepsin is formed it changes pepsinogen into pepsin.

Pepsin and rennin are absent in invertebrates. The mucus present in the gastric juice lubricates and protects the epithelial surface from excoriation of HCl and digestion by enzymes.

The chemical reactions which occur in the stomach are given below:

$$\underset{\text{(Proenzyme)}}{\text{Pepsinogen}} \xrightarrow{\text{HCl}} \text{Pepsin}$$

$$\text{Proteins} \xrightarrow{\text{Pepsin}} \text{Proteoses, peptones and lage peptides}$$

$$\underset{\text{(Proenzyme)}}{\text{Prorennin}} \xrightarrow{\text{HCl}} \text{Rennin}$$

$$\underset{\text{(Milk protein)}}{\text{Casein}} \xrightarrow{\text{Rennin}} \text{Paracasein}$$

$$\text{Paracasein + Ca} \longrightarrow \text{Calcium paracaseinate (curd)}$$

$$\text{Calcium paracaseinate} \xrightarrow{\text{Pepsin}} \text{Peptones}$$

Partially digested broth of food (chyme), then leaves the stomach through its pyloric end and enters the duodenum.

Digestion in the Small Intestine. The duodenum receives digestive enzymes and bicarbonates from the pancreas in the form of **pancreatic juice** and **bile** from the liver **via** gall bladder. The pancreatic juice contains protein digesting enzymes—**trypsin**, **chymotrypsin** and **carboxypeptidase**, starch digesting enzyme—**pancreatic** α-**amylase** and fat digesting enzyme—**lipase**. All these enzymes enter the duodenum **via** pancreatic duct. Trypsin, chymotrypsin and carboxypeptidase are proenzymes (zymogens), and are secreted in their inactive forms as **trypsinogen**, **chymotrypsinogen** and **procarboxypeptidase** respectively. Trypsinogen is activated by enterokinase secreted by the intestinal mucosa, whereas chymotrypsinogen and procarboxypeptidase are activated by **trypsin**.

Digestion of most of the nutrients takes place in the duodenum under the action of various enzymes. The actions of major enzymes in the digestion of chyme are summarised below:

1. Action of Pancreatic Juice

(i) ***Action on Proteins***

$$\underset{\text{(Proenzyme)}}{\text{Trypsinogen}} \xrightarrow[\text{of intestinal juice}]{\text{Enterokinase}} \text{Trypsin}$$

Chymotrypsinogen $\xrightarrow{\text{Trypsin}}$ Chymotrypsin
(Proenzyme)

Procarboxypeptidase $\xrightarrow{\text{Trypsin}}$ Carboxypeptidase
(Proenzyme)

Proteins $\xrightarrow{\text{Trypsin}}$ Large Peptides

Proteins $\xrightarrow{\text{Chymotrypsim}}$ Large Peptides

Elastin $\xrightarrow{\text{Elastase}}$ Large Peptides

Large Peptides $\xrightarrow{\text{Carboxypeptidases}}$ Dipeptide + Amino acids

(ii) ***Action on Starch***

Starch $\xrightarrow[\alpha\text{-Amylase}]{\text{Pancreatic}}$ Maltose + Isomaltose + α-Dextrin

(iii) ***Action on Fats***

Pancreatic lipase is the principal enzyme for the digestion of fat. In addition, an intestinal lipase is also helpful in the digestion of fat. The pancreatic lipase converts emulsified fat (triglyceride fats), first into diglycerides and then into monoglycerides, releasing a fatty acid at each step. Lipase is activated by the bile.

Fat $\xrightarrow{\text{Bile}}$ Emulsified fat

Emulsified fat $\xrightarrow{\text{Pancreatic lipase}}$ Fatty acid + Diglyceride

Diglyceride $\xrightarrow{\text{Pancreatic lipase}}$ Fatty acid + Monoglyceride

Monoglyceride $\xrightarrow{\text{Pancreatic lipase}}$ Fatty acid + Glycerol

(iv) ***Action on Nucleic Acids***

Pancreatic juice contains two nucleases — *deoxyribonuclease* (*DNAase*) and *ribonuclease* (*RNAase*), which act as follows :

DNA $\xrightarrow{\text{DNAase}}$ Deoxyribonucleotides

RNA $\xrightarrow{\text{RNAase}}$ Ribonucleotides

2. Action of Intestinal Juice

Intestinal juice (succus entericus) contain protein digesting enzymes—*enterokinase* (also called "*activator enzyme*"), *aminopeptidases* and *dipeptidases*. Enterokinase converts trypsinogen of pancreatic juice into trypsin. It also contains carbohydrates digesting enzymes—*maltase*, *isomaltase*, *sucrase* (*invertase*), *lactase* and α-*dextrinase*; lipid digesting enzymes—*intestinal lipase*, and nucleotide digesting enzymes— *nucleotidases* and *nucleosidases*. The actions of these enzymes are summarized below:

(i) *Action on Peptidases*

Large Peptides $\xrightarrow{\text{Aminope ptidases}}$ Dipeptides + Amino acids

Dipeptides $\xrightarrow{\text{Dipeptidases}}$ Amino acids

(ii) Action on Carbohydrases

Maltose $\xrightarrow{\text{Maltase}}$ 2 Glucose

Isomaltose $\xrightarrow{\text{Isomaltase}}$ 2 Glucose

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

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

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

(iii) *Action on Fats*

Intestinal lipase converts fats (left after the action of pancreatic lipase) into monoglycerides and fatty acids. Finally, all fats are converted into fatty acids, glycerol and monoglycerides.

Monoglycerides $\xrightarrow{\text{Intestinal lipase}}$ Fatty acid + Glycerol

(iv) Action on Nucleotides

Nucleotides (Deoxyribonucleotides/ Ribonucleotides) $\xrightarrow{\text{Nucleotidases}}$ Nucleosides (Deoxyribonucleosides/ Ribonucleosides) + Inorganic phosphate

Nucleosides (Deoxyribonucleosides/Ribonucleosides) $\xrightarrow{\text{Nucleotidases}}$ Nitrogenous bases (Purine/Pyrimidine) + Pentose sugar (Deoxyribose/Ribose)

3.2.9. Effects of Malnutrition on Growth and Development and on the Immune System

Malnutrition is a condition caused by not getting enough diet or right kind of diet. The term 'malnutrition' covers problems of both undernutrition and overnutrition. In case of **undernutrition**, the intake of food is too insufficient to meet the needs of metabolic energy. Consequently, the individual shall have to make up the shortfall by metabolising some molecules of its own body. Excess intake of food and nutrients is called **overnutrition.**

Insufficiency of nutrients also cause effect on immune system. Loss of immune system cause many diseases which are summarised below.

Protein Energy Malnutrition (PEM): Generally, growing children suffer from **protein energy malnutrition** because they need more proteins for their growth and development. Protein energy malnutrition leads to two types of diseases — Kwashiorkor and Marasmus (Fig. 3.12).

1. Kwashiorkor

This disease was first reported from Africa but now quite common in underdeveloped countries like Africa, Asia, South America and Central America.

Causes.

It is a disease caused due to severe protein deficiency. It occurs in children in the age group of 1–5 years particularly belonging to poor families. Main causes of ***PEM*** are:

(i) Diet mainly contains fats and carbohydrates.
(ii) Early termination of breast feeding by the mother.
(iii) Late introduction of supplementary protein food.
(iv) Unplanned spacing of the children.

Symptoms

(i) Children stop growing. Their bellies become swollen and hair colour fades.
(ii) Disease resistance of such children is lowered.
(iii) Children develop *dysentery* or *diarrhoea.*
(iv) Children suffering during first year of life also suffer from *mental retardation.*
(v) Other usual symptoms are *oedema, anaemia, fatty liver, swelling of body parts* and *slendered legs.*

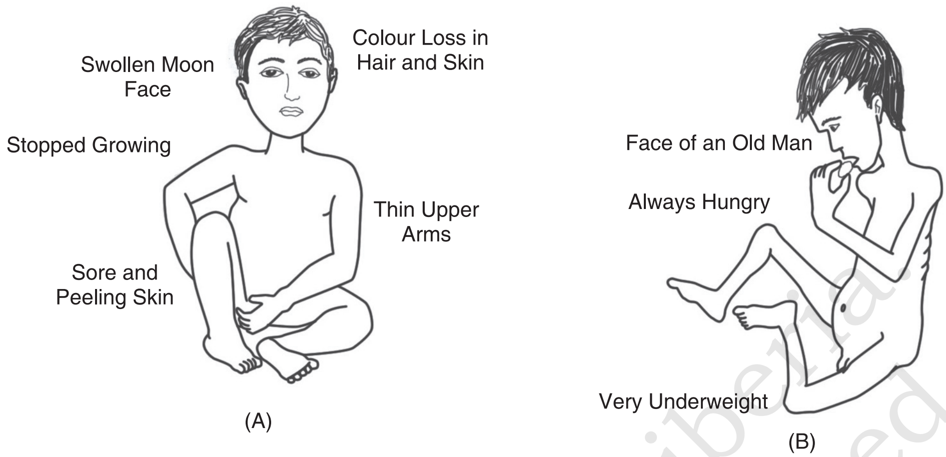


Fig. 3.12. Patients of PEM. A. Kwashiorkor; B. Marasmus.

2. Marasmus

It usually affects infants below the age of one year.

Causes

(i) It is a type of **PEM** which occurs due to prolonged protein deficiency and total deficiency of food calories.

(ii) Early replacement of mother's milk to the diet deficient in proteins and calories.

(iii) Unplanned spacing between the children.

Symptoms

(i) Children suffering from this disease show *mental retardation* of irreversible nature.

(ii) The body becomes lean and weak.

Disorders Due to Overnutrition: The excess nutrients are stored as increased body mass. Such a situation is called overnutrition. Some common type of disorder caused by over nutrition are described below:

1. **Obesity:** It is the most common form of overnutrition, which is caused by excessive intake of highcalorie nutrients such as sugar, honey and saturated fats. Obese people are more prone to diabetes, osteoarthritis, hypertension and heart ailments. Obese women are more prone to infertility.

Activity 4

Make a survey in your area and other areas also. Visit to those people who are suffering from many diseases due to malnutrition. Count number of people who have disorders due to malnutrition and overnutrition and write down in your notebook. Try to help them to explain about balanced diet. Make a chart to aware people.

Do it Yourself

1. Kwashiorkor is caused by deficiency of __________.
2. Marasmus usually affects __________ below the age of one year.
3. __________ is common form of obesity.
4. __________ suffering from marasmus do not suffer from oedema.
5. Obese people are more prone to __________.

3.3. CIRCULATORY SYSTEM

Human circulatory system also called the blood vascular system consists of a muscular heart, a network of closed branching blood vessels and the blood.

3.3.1. Human Heart

The human heart is mesodermally derived organ located between the lungs in thoracic cavity. It is a hollow, fibromuscular organ which is somewhat conical or pyramidal in shape with upper broad part, the base and lower narrow, the apex. Its weight varies in males from 280–340 g (average 300 g) and in females from 230–280 g (average 250 g).

Externally, human heart consists of four chambers—two relatively small upper chambers called **atria** and two larger lower chambers called **ventricles**. The left and right atria are separated externally by a shallow vertical **interatrial groove**. A transverse groove is present between the atria and ventricles, called **coronary sulcus**. Two grooves are also present on the ventricle. These are called the **anterior interventricular sulcus** and **posterior interventricular sulcus**. These sulci have coronary arteries through which the heart receives blood.

The right and left atria receive blood from different body parts. The right atrium receives deoxygenated blood from all parts of the body, except the lungs, through the superior and inferior vena cava. Pulmonary veins bring oxygenated blood to the left atrium from the lungs. The right and left atria pour their blood into the right and left ventricles, respectively. From the right ventricle arises a pulmonary trunk, which soon bifurcates to form right and left pulmonary arteries, which supply deoxygenated blood to the lungs of the respective side. The left ventricle gives rise to an ascending aorta, through which the oxygenated blood is supplied to the coronary arteries and the systemic circulation of the body.

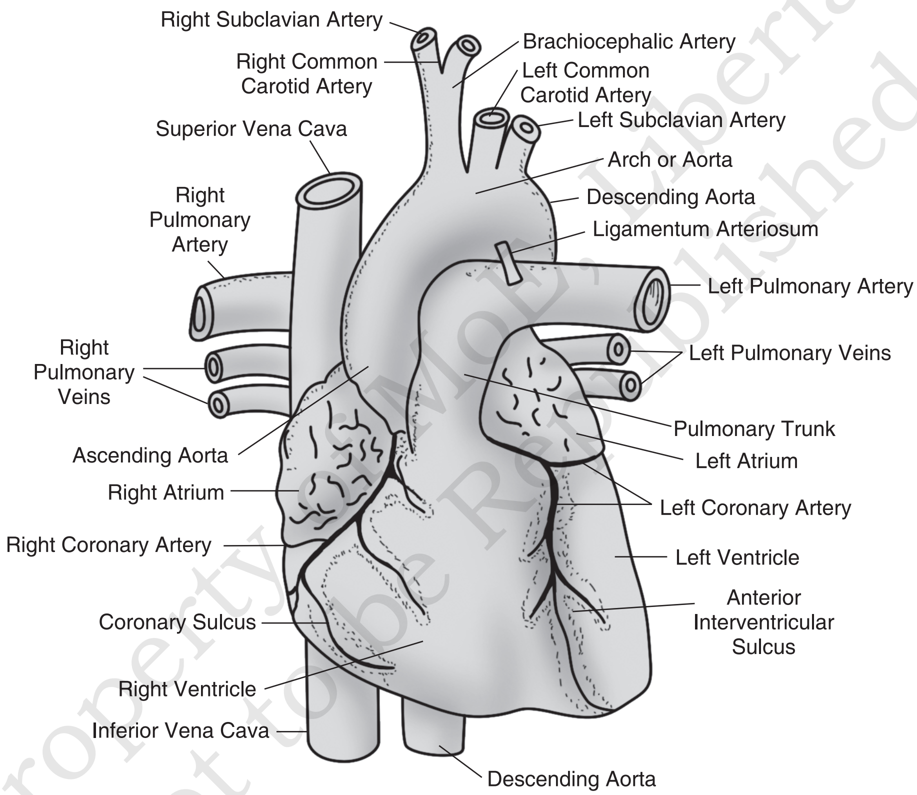


Fig. 3.13. Human heart in front view.

Internally, the four chambers of the heart are separated by septa and valves (Fig. 3.13). The right atrium receives the openings of superior vena cava, inferior vena cava and coronary sinus. The opening of inferior vena cava is guarded by **Eustachian valve**. The opening of coronary sinus has **coronary** or **Thebasian valve**. The left atrium receives four openings of pulmonary veins. The two ventricles are separated by interventricular septum.

Cardiac Valves. The **atrioventricular** (AV) **valves** separate the atria and ventricles. The right AV valve lies between the right atrium and right ventricle. It is called **tricuspid valve** because it consists of three flaps or cusps. The left AV valve is present between left atrium and left ventricle. It consists of two cusps and is called **bicuspid** or **mitral valve**.

The major arteries, which leave the heart (*i.e.*, pulmonary trunk arising from the right ventricle and aorta leaving the left ventricle) have **semilunar valves** (three half moon shaped pockets) to prevent the back flow of blood into the ventricles.

3.3.2. Blood Vessels

The blood flows strictly through a fixed route through the arteries and veins. **Arteries** carry blood from the heart to different body parts. **Veins** bring blood from different body parts to the heart. Basically, each artery and vein consists of three layers or coats.

1. **Tunica intima:** It is the innermost coat which is made up of an **elastic membrane** made up of elastic tissue of yellow fibres and **squamous endothelium** lining the lumen.
2. **Tunica media:** It is a middle coat which is formed of elastic connective tissue and smooth muscle fibres. It is thicker in artery.
3. **Tunica externa:** It is the outermost coat formed of connective tissues.

The veins have valves to prevent backward flow of blood (Fig. 3.14). In the organs both arteries and veins divide to form **arterioles** and **venules** respectively. The arterioles and venules further divide into the thin walled vessels called **capillaries**. The wall of capillaries is made up of endothelium only. The nutrients, hormones, gases, etc. can diffuse into the tissue cells through the wall of capillaries and vice versa.

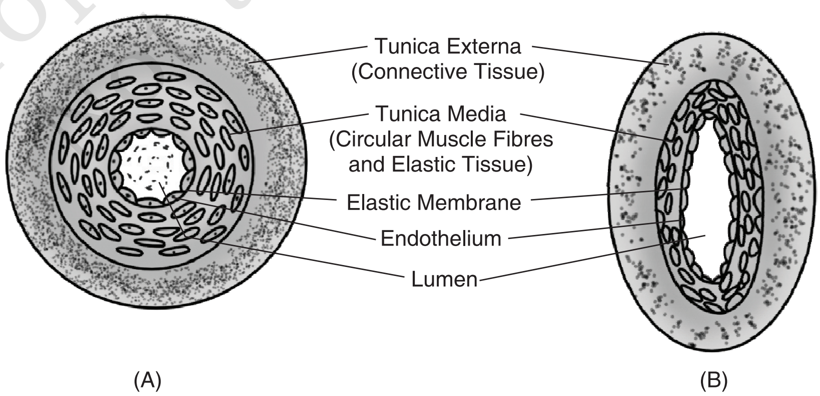


Fig. 3.14. A. T.S. artery; B.T.S. vein

3.3.3. Components of Blood

A. Plasma

Plasma is a straw coloured, viscous fluid constituting nearly 55 per cent of the blood. It contains about 91–92 per cent water and 8 per cent solids. The solids include plasma proteins, nutrients (such as glucose, amino acids, fatty acids, phospholipids, cholesterol, fats, nucleosides and mineral salts), hormones, enzymes, antibodies, heparin, dissolved gases (such as oxygen, carbon dioxide) and waste products (such as urea, uric acid and creatinine). Plasma without the clotting factors is called **serum**.

Functions

- Transport
- Prevention of blood loss,
- Maintenance of blood pH
- Uniform distribution of heat all over the body, and
- Conducting heat to skin for dissipation.
- Body immunity
- Retention of fluid in blood

B. Blood cells

The Blood cells are of two types—erythrocytes or red blood cells (RBCs) and leucocytes or white blood cells (WBCs). Nearly 45 per cent volume of blood consists of formed elements.

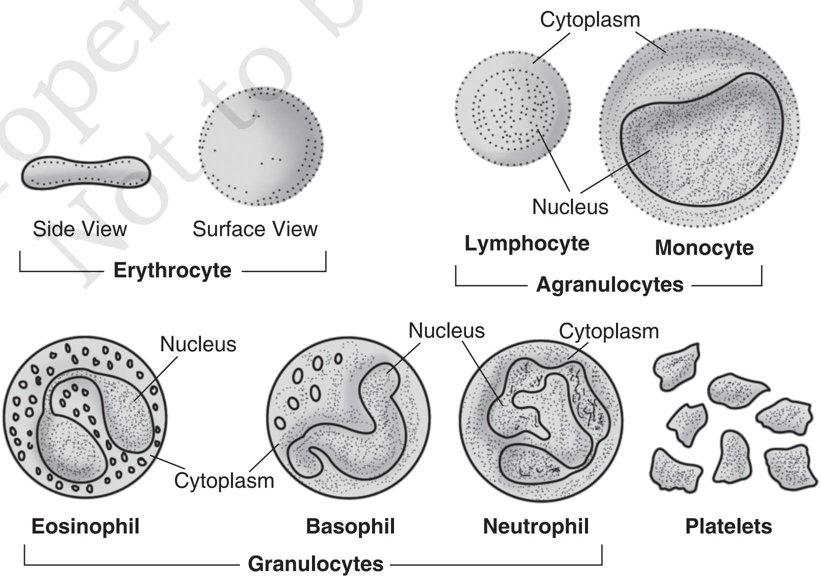


Fig. 3.15. Human blood corpuscles

1. **Erythrocytes (Red Blood Corpuscles or RBCs):** They are the most abundant of all types of cells in the blood. Red blood corpuscles are biconcave and circular in shape. Human erythrocytes are 7–8 μm in diameter and 1–2 μm thick near the rim.

   The total number of RBCs per microlitre (1 μm l = 1 mm^3) of blood is termed as the **total count of RBCs**. A healthy adult man has, on an average 5 millions to 5.5 millions of RBCs mm^{-3} of blood. The total count of RBCs is more in man than in a woman. It is due to the fact that women undergo menstruation. The decrease in RBC count causes oxygen shortage in the blood, which stimulates the release of the hormone, **erythropoietin** from the kidney cells into the blood. Erythropoietin stimulates the bone marrow to increase the production of RBCs.

   The RBCs contain a red coloured, iron containing complex protein called **haemoglobin**, hence the colour and name of these cells. 100 mL of blood of a normal man contains about 15 g of haemoglobin and of normal woman an average of 13 g haemoglobin. Thus, the quantity of haemoglobin is less in women as they undergo menstruation.

Functions

- Haemoglobin of RBCs plays a significant role in transport of respiratory gases (*i.e.*, oxygen and carbon dioxide).
- Haemoglobin is an excellent acid-base buffer which is largely responsible for maintaining the pH of blood. Acidity of blood results haemoglobin to carry less oxygen.

2. **Leucocytes (White Blood Corpuscles or WBCs):** The leucocytes are the most active and motile constituents of blood as well as lymph. They are colourless due to the lack of haemoglobin. They are nucleated and rounded or irregular in shape.

   The leucocytes are relatively lesser in number. The number of leucocytes per microlitre of blood is called the **Total Leucocyte Count** (TLC). This varies from 6000 to 8000 mm^{-3} (per cubic millimetre) of blood in adult humans.

   Types. The leucocyets are of two main types—Granulocytes and Agranulocytes.

   (i) Granulocytes: They contain granules and irregularly lobed nucleus in the cytoplasm. Based on their staining property, the granulocytes are divided into three types:

(a) ***Eosinophils.*** They are characterised by a bilobed nucleus. They help in dissolving blood clot.

(b) ***Basophils.*** They have two to three lobed nucleus. They are the least (0.5–1.0 per cent) among WBCs.

(c) ***Neutrophils.*** They have two to seven lobed nucleus. Neutrophils do not take colour when exposed to acidic, as well as basic dyes.

(ii) Agranulocytes: They lack granules in their cytoplasm. Agranulocytes are of two types:

(a) ***Lymphocytes.*** They are smaller in size with large rounded nucleus. They produce serum globulins (antibodies) to destroy microbes and their toxins, reject graft and kill tumour cells. They also help in healing injuries. Lymphocytes occurs in two major types—B lymphocytes (B cells) and T lymphocytes (T cells). Both are responsible for immune responses of the body.

(b) ***Monocytes.*** They are the **largest** of all types of WBCs and somewhat amoeboid in shape. They have kidney shaped nucleus.

Leucocytes are generally short lived.

3. Thrombocytes (Blood Platelets): They are flat and non-nucleated fragments of the cells rather than true cells. They contain a few cell organelles and secretory granules in the cytoplasm. They have a group of basophilic granules in the centre which give the appearance of a nucleus. Thrombocytes are fewer than the RBCs and more than the WBCs in number. There are about 1,500,00–3,500,00 platelets mm^{-3} of the blood.

Platelets can release a variety of substances called **platelet factors** (*e.g.*, thromboplastin) most of which are involved in the coagulation of blood.

Activity 5

Find out how the amazing muscles that make up your heart work to keep you blood pumping every day. Make a pump using a jar, a balloon and two straws to get an idea of how your hear pumps blood.

Do it Yourself

1. Human heart consists of ________ chambers.
2. ________ carry blood from the heart to different body parts.
3. Nearly 45 percent of volume of ________ consists of formed elements.
4. ________ are the most abundant of all types of cells in the blood.
5. ________ plays a important role in transport of respiratory gases in RBCs.

INFOBOX

An electrical system controls the rhythm of your heart. It is called the cardiac conduction system.

Process of Blood Clotting

When an injury is caused, the wound does not continue to bleed for a long time. Usually the blood stops flowing after sometimes by a natural device called blood coagulation or blood clotting. This is a mechanism to prevent excessive loss of blood from the body. The process of coagulation can be described in three major steps:

(i) At the site of an injury, the blood platelets disintegrate and release a phospholipid, called **platelet factor**-3 (platelet thromboplastin). Injured tissue also releases a lipoprotein factor called **thromboplastin**. These two factors combine with calcium ions (Ca^{2+}) and certain proteins of blood plasma to form an enzyme called **prothrombinase**.

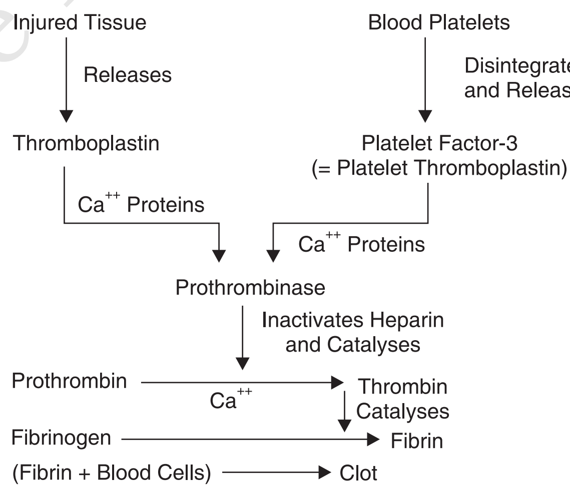


Fig. 3.16. The process of blood clotting.

(ii) In presence of calcium, the prothrombinase inactivates heparin (or **antiprothrombin-anticoagulant**). Prothrombinase also catalyses the conversion of **prothrombin** (an inactive plasma protein) into an active protein called *thrombin* and some small **peptide fragments**.

(iii) Thrombin acts as enzyme and first causes depolymerization of **fibrinogen** (a soluble plasma protein) into its monomers. Later thrombin stimulates repolymerization of these monomers into long insoluble fibre-like polymers called **fibrin**. The thin long and solid fibres of fibrin form a dense network upon the wound and trap blood corpuscles and platelets to form a **clot**. The clot seals the wound and checks the bleeding. A clot is formed at the wound in about 2–8 minutes after injury. Soon after, the clot starts contracting (clot retraction) and a pale yellow fluid called **serum**, starts oozing out from it. This serum is blood plasma minus the corpuscles and fibrinogens.

3.3.4. Types of Circulations

The movement of blood follows double circulation (systemic and pulmonary circulation and circulation through special regions.

1. Double Circulation

(i) Systemic Circulation : It involves the flow of oxygenated blood from the left ventricle to all parts of the body and deoxygenated blood from various body parts to the right atrium. It is also called **systemic circulation**. The systemic circulation starts from the left ventricle of the heart, passes to the aorta, to the arteries originating from it and to all their branches, thence to the arterioles, capillaries, venules and the veins of the whole body and finally to the two vena cavae which enter the right atrium. The systemic circulation carries oxygen and nutrients to body tissues and removes carbon dioxide and other wastes from the tissues.

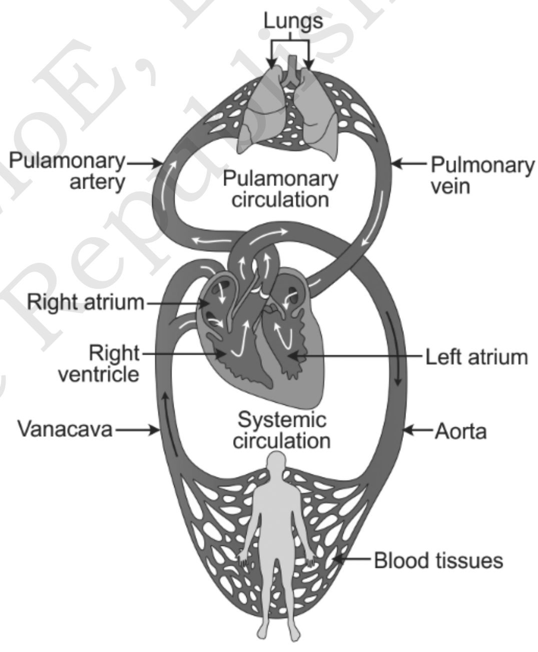


Fig. 3.17. Double circulation

(ii) Pulmonary Circulation: The flow of deoxygenated blood from the right ventricle to the lungs and the return of oxygenated blood from the lungs to the left atrium is called the **pulmonary circulation**. The pulmonary trunk arises from the right ventricle and then divides into the **right pulmonary artery** and **left pulmonary artery** which supply deoxygenated blood to the right and left lungs respectively. Two pulmonary veins from each lung transport the oxygenated blood to the left atrium. The systemic circulation and pulmonary circulation constitute the **double circulation**.

3.4. BLOOD TYPES

Blood groups are different types of ***erythrocyte phenotypes*** or ***allotypes*** found in human beings due to the presence of genetically controlled antigens and antibodies. Human beings have more than 30 types of antigens on the surface of blood cells. They give rise to different types of blood groups. Two such grouping—the ABO and Rh are widely used all over the world.

3.4.1. ABO Blood Grouping

ABO grouping is based on the presence or absence of two surface antigens (chemicals that can induce immune response) on the RBCs namely A and B. Similarly, the plasma of different individuals contains two natural antibodies (proteins produced in response to antigens). People with blood group A have the A antigen on the surface of their RBCs, and antibodies against antigen B in their plasma. Persons with blood group B have B antigen on their RBC's and antibodies against antigen A in their plasma. Individuals with AB blood group have both antigen A and antigen B on their RBCs, and no antibodies for either of the antigens in their plasma. Type O individuals are without A and B antigens on their RBCs, but have antibodies against these antigens in their plasma. The distribution of antigens and antibodies in the four groups of blood, A, B, AB and O are given in Table 3.1.

Table 3.1. Blood Groups and Donor Compatibility

Blood Group	Antigen on RBCs	Antibodies in Plasma	Donor's Group (can get blood from)	Recipient's Group (can give blood to)
A	A	anti B	A, O	A, AB
B	B	anti A	B, O	B, AB
AB	A, B	None	A, B, AB, O	AB
O	None	anti A, B	O	A, B, AB, O

During blood transfusion, any blood can not be used. The blood of a donor has to be carefully matched with the blood of a recipient before any blood transfusion to avoid severe problems of clumping (production of clots that clog capillaries). The group O blood can be donated to persons with any other blood group. Therefore, the individuals with blood group O are called '**universal donors**'. Persons with AB group can accept blood from persons with any group of blood. Therefore, such persons are called **'universal recipients'**.

3.4.2. Rh (Rhesus) Blood Groups

Landsteiner and Weiner (1940) discovered another protein on the surface of red blood corpuscles of rhesus monkey and many human beings. They called it as **Rh factor** or **Rh-antigen**. Depending on the race, 80 to 99 per cent of humans possess this factor and are **Rh positive (Rh^+)**. Others who do not have this factor are known as **Rh negative (Rh^-)**. The formation of Rh protein is controlled by a dominant gene, which may be designated as R. Thus, RR (homozygous dominant) and Rr (heterozygous) individuals are Rh positive, and rr (homozygous recessive) individuals are Rh negative. Phenotypically, Rh positive and Rh negative individuals are normal. The problem arises when an Rh –ve person, is exposed to Rh +ve blood during blood transfusion or pregnancy.

(i) Incompatibility During Blood TransfusionL The first transfusion of Rh^+ blood to the person with Rh^- blood causes no harm. However, the recipient starts preparing antibodies (anti-Rh factor) against Rh antigen in his/her blood. If the recipient person receives Rh^+ blood second time, the anti Rh factor present in his/her blood attack and destroy red blood corpuscles of the received blood.

3.4.3. Functions of Blood

Blood has following functions in the body:

- Blood transports O_2 from the respiratory organs to the tissues and CO_2 from the tissues to the respiratory organs.
- Blood transports the digested food from the alimentary canal to the different body cells.
- Hormones are carried by blood from the endocrine glands to the target organ.
- Blood transports excretory matter to the kidneys or other excretory organs.
- Some leucocytes are phagocytic in nature, and certain leucocytes produce antitoxins to neutralize the toxins released by the foreign germs.
- Blood maintains the body temperature to a constant level after distributing heat within the body.
- The clotting factors present in the blood prevent loss of blood from the site of injury by the formation of clot.
- Blood maintains necessary supplies for the repair of damaged tissue. Eosinophils and basophils help in the healing of wounds.

3.5. EFFECTS OF SUBSTANCE (DRUGS AND ALCOHOL) ON THE DIGESTIVE, CIRCULATORY AND LYMPHATIC SYSTEMS

- Alcohol and drug use can be harmful to your health and get out of hand for some people. Modest use of alcohol can help your heart health in some circumstances, but it can also lead to long-term effects that are harmful and reduce your ability to fight off HIV. Different drugs have different effects on the body, and they can affect your judgement, mental health, and physical health differently.
- Drinking too much alcohol can damage your liver, and immune system. Chronic drinkers with HIV may be at greater risk for disease progression than those who drink very little or not at all.
- Methamphetamines can lead to liver, and impaired blood circulation, significant , weight loss and tooth decay.
- Drugs like cocaine and heroin can seriously damage your circulatory systems.

- Methamphetamines and cocaine can negatively affect your immune system, making it easier for your body to get an infection.
- Alcohol increases your heart rate and expands your blood vessels, making more blood flow to the skin (which causes you to feel warm), however, this heat passes out through the skin, causing body temperature to fall after it has risen.
- Alcohol is first broken down in the stomach, promoting an increase in digestive juices. Alcohol also irritates the small intestine and colon where it is further broken down and absorbed, and it also can affect the normal speed that food moves through them, which may result in abdominal pain, bloating, and diarrhea.
- Alcohol—most of it, in fact—is metabolized in the liver, which filters circulating blood and removes and destroys toxic substances, including alcohol. The liver can handle a certain amount of alcohol, but as a person continues to drink, it can become stressed to the point of causing permanent damage
- Alcohol causes the pancreas to produce toxic substances that can eventually lead to pancreatitis, a dangerous inflammation and swelling of the blood vessels in the pancreas that prevents proper digestion.

3.6. LYMPHATIC SYSTEM

Lymphatic system consists of lymph, lymphatic vessels, lymphatic nodes and lymphocytes.

3.6.1. Lymph

Lymph is a colourless mobile connective tissue present in the lymphatic system. When the blood passes through the capillaries in tissues, some water along with many small water soluble substances and some leucocytes (WBCs) move out into the spaces

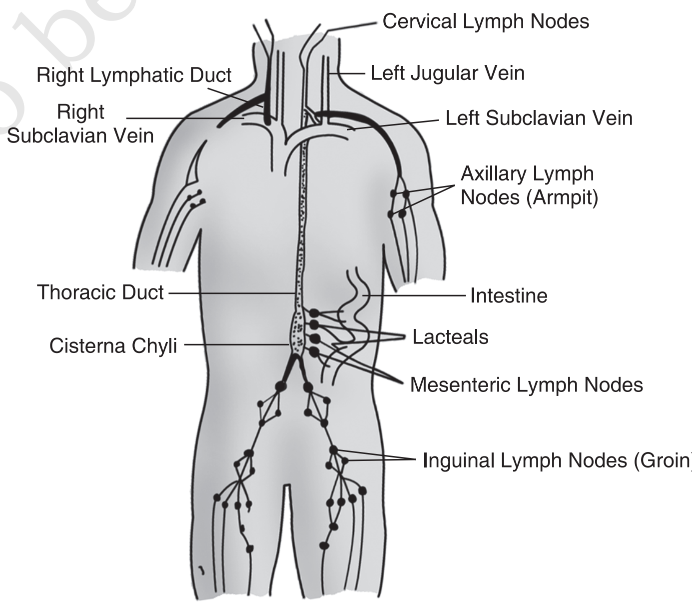


Fig. 3.18. Human Lymphatic System.

between the cells of tissues leaving the larger proteins and erythrocytes (RBCs) in the blood vessels. This fluid released out is called the interstitial fluid or tissue fluid. It has the same mineral distribution as that in plasma. An elaborate network of vessels called lymphatic system collects this fluid and drain it back to the major veins.

The fluid present in the lymphatic system is called the lymph.

Composition of lymph

Lymph consists of **lymph plasma** (fluid) and **lymph corpuscles** (cells). The lymph is similar to that of blood but has fewer blood proteins, less calcium and phosphorus and high glucose concentration. The proteins are mainly globin proteins, which are actually antibodies. Other components of the lymph plasma are very much like that of blood plasma *i.e.*, organic, inorganic substances, water, etc. The lymph corpuscles are floating amoeboid cells, the leucocytes (WBCs), which are mostly lymphocytes.

Functions of Lymph

- Lymph acts as 'middle man' which helps in exchange of nutrients and gases between the blood and the cells.
- Lymph is also an important carrier for hormones.
- Fats are absorbed through lymph in the lacteals present in the intestinal villi.
- It destroys the invading microorganisms and foreign particles in the lymph nodes.
- Body cells are kept moist by the lymph.

3.6.2. Lymphatic Vessels

The lymphatic capillaries unite to form larger lymphatic vessels. The latter resembles the veins in structure, but have thinner walls and more numerous valves. The smaller lymphatic vessels write to form larger vessels, which in turn unite to form two main lymphatic vessels or trunks called the **thoracic duct** and **right lymphatic duct**.

— **Thoracic duct** receives lymph from the entire body except the right side of the head, neck, the thorax and the right arm.

— **Right lymphatic duct** receives lymph from the right side of the head, neck and thorax and the right arm. It opens into the right subclavian vein.

3.6.3. Lymphatic Nodes.

These are small oval or bean shaped structures located at intervals in the course of lymphatic vessels. They are abundant in specific regions such as the grains, armpits and neck. Lymphatic nodes contain lymphocytes, plasma cells and fixed macrophages.

Functions

- Both B lymphocytes and T lymphocytes are produced here.
- Macrophages of lymph nodes remove bacteria, foreign material and cell debris from the lymph.
- B lymphocytes are transformed into plasma cells that produce antibodies against invading antigens, while T lymphocytes attack the pathogen and other foreign bodies.

3.6.4. Lymphocytes

They are smaller in size with large rounded nucleus. They possess scant pale blue cytoplasm. They have a proportion of about 20–25 per cent. They produce serum globulins (antibodies) to destroy microbes and their toxins, reject graft and kill tumour cells. They also help in healing injuries. Lymphocytes occurs in two major types—B lymphocytes (B cells) and T lymphocytes (T cells). Both are responsible for immune responses of the body.

3.6.5. Function of other lymphoid organs

The organ which secrete lymph are called lymphoid organs. These are spleen, thymus and tonsils.

A. Spleen

The spleen is the largest component of the lymphatic system.

Structure: The spleen is a large (7–10 cm. in diameter), bean-shaped, vascular, dark-red organ located in the abdomen just below the diaphragm at the tail of the pancreas behind the stomach. The spleen in composed of **red pulp** (reticular tissue rich in RBCs) having small patches of **white pulp** (lymphatic nodules) scattered in it.

Function

Spleen serves many functions:

- The worn-out red blood corpuscles are phagocytized by the free and fixed macrophages present in the spleen.

- When the animal is at rest and needs less oxygen due to slow metabolism, some red corpuscles are withdrawn from circulation and stored in the spleen During active life, when the animal requires more oxygen, also in case of haemorrhage (blood loss in injury), the stored red corpuscles are released into the blood stream.
- The plasma cells present in the spleen produce antibodies, the protective proteins that provide immunity.
- In the embryo, the spleen produces new red blood corpuscles.

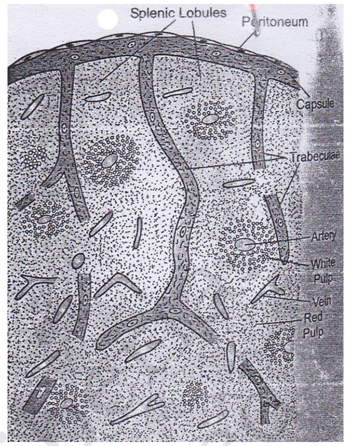


Fig. 3.19. A part of T.S. Spleen

- The macrophages of the spleen engulf and destroy the foreign germs and other substances entering the blood.

B. Thymus

Thymus is also a lymphatic organ. It lies in the upper chest near the neck. It is prominent in children but begins to degenerate in early childhood. It "educates" the lymphocytes in the foetus to distinguish body cells (self) from foreign cells (nonself).

C. Tonsils

Tonsils too are lymphatic tissues. They are located in the throat. They do not filter lymph. They are thought to protect against infection.

Lymphoid tissue is also found in Peyer's patches and vermiform appendix.

Lab work

1. **Test for carbohydrates**

   (a) Test for the Presence of Starch: To detect the presence of starch in potato or wheat flour, place a small quantity of crushed raw potato or wheat flour in a test tube. Add some water in the test tube to form a solution. Now add a drop of a weak iodine solution. The colour of the solution in the test tube turns blue-back. This indicates the presence of starch.

Take a small portion of boiled egg-white in a test tube. Add a drop of weak iodine solution. You will find that the egg white has not turned blue. This indicates that egg white does not contain starch. Egg white contains albumin, which is a protein.

(b) **Test for the Presence of Sugar:** Take small pieces of banana, potato,unripe tamarind or lemon. Crush them and strain their juices. Take three test tubes. In each test tube add five to ten drops of the juice obtained from a particular source. To each of these test tubes add a few drops of Benedict's solution. This solution contains copper sulphates, sodium citrate and sodium carbonate. Place your test tubes in a water-bath, in which the water is boiling, for one minute. A green, yellow, orange or red precipitate indicates the presence of sugar. Experiment with other vegetables like bitter gourd, and with saliva and urine.

2. **Test for proteins**

Test for Proteins. Take pieces of hard-boiled egg-white in a test tube. Add a few drops of dilute nitric acid, just enough to cover the food material. Heat the test tube slightly. Then rinse off the acid with water, and add some ammonium hydroxide solution. The contents of the test tube will turn yellow when heated with nitric acid and orange when ammonium hydroxide is added. This indicates the presence of protein. Repeat your experiment with other food materials like peas and apple.

3. **Test for Fats**

Test for Fats in Different Food Items. Take a few groundnuts and crush them after wrapping them in a piece of clean white paper. Unwrap the paper and hold it up against the light. You will see oily patches on the paper. Mustard seeds, almond, coconut and walnut will also give the same result. When you do the same experiment with rice or wheat grains, you will not find oily patches.

ACTIVITY 6

Draw a neat diagram of lymphatic system showing lymph, lymphatic vessels and lymphatic nodes.

Do it Yourself

1. __________ is a colourless mobile connective tissue present in the lymphatic system.
2. Right lymphatic duct receives __________ from the right side of the head, neck and thorax.
3. Tunical externa is the outermost coat formed of connective tissues. (True/False)
4. Lymphatic nodes are small oval or bean shaped structures. (True/False)
5. Lymphatic system consists of blood, plasma and blood vessels. (True/False)

KEY GLOSSARY

- **Absorption:** Passing of diffusible food through small intestines into blood or lymph.
- **Digestion:** Convertion of non-diffusible food into diffusible food by the process of hydrolysis.
- **Heterodent:** Presence of different types of teeth in a mammal.
- **Lymph:** Transparent fluid derived from blood containing lymphocytes but low in protein.
- **PEM:** Deficiency of proteins as well as food calories.
- **Peristalsis:** Involuntary movements of gut wall which moves food backward.
- **Systemic circulation:** The flow of oxygenated blood from the left ventricle to all parts of the body (except lungs) and flow of deoxygenated blood from all parts of the body to the right atrium.

SUMMARY

- Digestion is important. Our body needs nutrients from food and drink to work properly and to be healthy.
- All living organisms require energy to operate the metabolic reactions that sustain life, and they need raw materials to build up most of their own body molecules.

- Digestion involves mechanical as well as chemical changes in the food taken.
- Different nutrients have different functions. Food can be categorized under three broad groups according to the function of the nutrient it provides.
- Vitamins are a group of about fifteen organic compounds present in minute quantities in natural foodstuff.
- A balanced diet one that provides all the nutrients required by the body.
- The mouth is an opening which is protected by upper and lower lips (labia).
- Some accessory digestive organs like salivary glands, pancreas, liver and gall bladder (biliary system) are also connected to the alimentary canal by a series of ducts.
- Any cell or organ that discharges a secretion into the oral cavity is called salivary gland.
- Most of the mammals including man have diphyodont (two sets of teeth milk or deciduous and permanent), thecodont (teeth are embedded in the sockets of jaw bones – maxillae and mandible) and heterodont teeth (different types of teeth).
- The liver is the largest gland of the body, weighing 1.4–1.8 kg in males and 1.2–1.4 kg in females.
- The process of digestion simply alters the ingested food into its constituents that are soluble and diffusible substances producing a milky fluid called chyle.
- Humans perform extracellular digestion with the help of digestive enzymes released from the secretory cells of the digestive system.
- Malnutrition is a condition caused by not getting enough diet or right kind of diet.
- The excess nutrients are stored as increased body mass. Such a situation is called overnutrition.
- The human heart is mesodermally derived organ located between the lungs in thoracic cavity. It is a hollow, fibromuscular organ which is somewhat conical or pyramidal in shape with upper broad part, the base and lower narrow, the apex.
- The blood flows strictly through a fixed route through the arteries and veins.

- The Blood cells are of two types— erythrocytes or red blood cells (RBCs) and leucocytes or white blood cells (WBCs).
- When an injury is caused, the wound does not continue to bleed for a long time. Usually the blood stops flowing after sometimes by a natural device called blood coagulation or blood clotting.
- The movement of blood follows double circulation (systemic and pulmonary circulation and circulation through special regions.
- Alcohol and drug use can be harmful to your health and get out of hand for some people.
- Lymphatic system consists of lymph, lymphatic vessels, lymphatic nodes and lymphocytes.
- Lymph is a colourless mobile connective tissue present in the lymphatic system.
- The lymphatic capillaries unite to form larger lymphatic vessels.

EXERCISES

A. Multiple choice questions.

1. It involves breaking down of the complex organ food materials such carbohydrates, fats, proteins etc.

(a) Digestion (b) Absorption
(c) Assimilation (d) Ingestion

2. For immediate energy production in cells one should take

(a) fats (b) vitamin C
(c) proteins (d) glucose

3. About 70% of our energy requirement should be met by

(a) carbohydrates (b) fats
(c) proteins (d) vitamins

4. The largest gland in human body is

(a) pancreas (b) liver
(c) pituitary (d) thyroid.

5. Muscular contractions of stomach are known as

(a) circulation (b) egestion
(c) peristalsis (d) absorption.

6. Ptyalin is secreted by
   (a) salivary glands   (b) prostate glands
   (c) stomach   (d) pancreas.

7. Which is not a function of HCl in stomach?
   (a) Softening fibrous food elements.
   (b) Promoting formation of pepsin.
   (c) Killing bacteria ingested with food and drinks.
   (d) Breaking down proteins into peptones.

8. The level of glucose in the blood is controlled by
   (a) duodenum   (b) gall bladder
   (c) ileum   (d) liver.

9. A secretion that digests both carbohydrates and proteins is
   (a) ptyalin   (b) pepsin
   (c) pancreatic juice   (d) saliva.

10. Select what is not true of intestinal villi among followings?
   (a) They possess microvilli.
   (b) They increase the surface area.
   (c) They are supplied with capillaries and the lacteal vessels.
   (d) They only participate in digestion of fats.

C. Match the Column A with Column B and choose the correct option.

Column A		Column II	
1.	Bilirubin and biliverdin	(a)	Parotid
2.	Hydrolysis of starch	(b)	Bile
3.	Digestion of fat	(c)	Lipases
4.	Salivary gland	(d)	Amylases

B. Fill in the Blanks.

1. PEM stands for _______ .

2. The tongue bears four types of papillae _______, ______, ______ .

3. _______ teeth grow twice.

4. Four kind of teeth are present in human dentition _______, _______, _______, _______ .

5. In man the paired salivary glands are termed as _______, _______, _______ .
6. The bile pigments are _______ and _______ .
7. Conversion of glycogen into glucose is known as _______ .
8. The cells found in the endocrine part of pancreas are (a) _______ (b) _______ (c) _______ .
9. Lipase converts _______ into _______ .
10. Pancreas secretes ______ from its exocrine part called as _____ .

D. Very short answer questions.

1. Why do we need food?
2. Name the steps in the process of digestion.
3. Name two types of carbohydrate.
4. What is the function of fats?
5. What is the role of roughage in our body?
6. Write the weight of liver in female body.
7. What is the function of lipases?
8. How is Kwashiorkor disease caused?
9. What is obesity?
10. Define overnutrition.

E. Short Answer Type Questions.

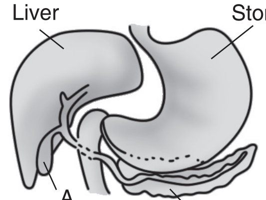
1. Describe the process of digestion.
2. What are the functions of carbohydrates.
3. Write the name of classes of food.
4. Write short notes on (a) Heart (b) Liver
5. Write two functions of liver

F. Long Answer Type Questions.

1. State the functions of digestive enzymes.
2. Describe absorption through the villi.
3. Describe the processes of nutrition.
4. What are the effects of malnutrition on growth and development?
5. Describe the effects of alcohol and drugs on the organs of circulatory and lymphatic system.
6. List the various blood groups.

G. Diagram based Questions.

1. Given here is a diagram showing location of liver and pancreas. Answer the following questions.



(i) Give the location of pancreas.

(ii) Name the largest gland of the human body.

(iii) Label part A and give its function.

2. Given here is the sketch of three children A, B and C, B is healthy child and A, C are abnormal children.

(i) Children A and C are suffering from which abnormality.

(ii) The bending pattern of legs of A and C represents two different terms. What are those ?

(iii) Write the cause of this abnormality.

(iv) Write the name of deficiency symptom in adults.

H. Draw and Label the structure heart.