Blood & circulation

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6th term 2
6. Human Organ systems

Introduction

Organ systems are formed by the association of organs which are organized from tissues. This kind of organization helps the organism to perform various activities more efficiently. A group of organs that work together to perform a particular function is known as an organ system. The Human body has eight major organ systems. They are

- Skeletal System
- Digestive System
- Circulatory System
- Endocrine System
- Muscular System
- Respiratory System
- Nervous System
- Excretory System

In this lesson, let us study more about the structure and function of these organ systems of our body.

Skeletal System

The skeletal system consists of bones, cartilages and joints. Bones provide a frame work for the body. Bones along with muscles help in movements such as walking, running, chewing and dancing etc.,

The adult human skeletal system consists of 206 bones and few cartilages, ligaments and tendons. Ligaments help in connecting bone to bone. Tendons connect bone to muscle. The two major divisions of the skeletal system are Axial skeleton and Appendicular skeleton.

Axial skeleton forms the upright axis of the body which includes

- Skull
- Vertebral column
- Rib cage

Appendicular skeleton consist of the bones of the limbs along with their pectoral and pelvic girdles.

Skull

The skull is made up of cranial bones and facial bones. It protects the brain and the structures of the face. The hyoid bone present at the base of the buccal cavity and the auditory ossicles (Malleus, Incus and Stapes) are also included in the skull. Lower jaw bone is the largest and strongest bone in the human face.

Vertebral Column

Vertebral column extends from the base of the skull. It protects the spinal cord. It is formed by a number of serially arranged small bones called vertebrae (singular : vertebra)

Rib cage

The rib cage is made up of 12 pairs of curved, flat rib bones. It protects the delicate vital organs such as heart and lungs.

Limbs

Man has two pairs of limbs namely upper limbs (fore limbs) and lower limbs (hindlimbs). Fore limbs are used for holding, writing etc., while hind limbs are used for walking, sitting etc.,

Skeletal System

Girdles

The fore limbs and hind limbs are attached to the axial skeleton with the help of pectoral and pelvic girdle respectively.

Muscular System

In the body, muscular system along with the skeletal and nervous system, is responsible for the body movements. Muscles can contract and therefore, help in moving other parts of the body. It maintains the posture and body position. There are three types of muscles namely

- Skeletal muscle
- Smooth muscle
- Cardiac muscle

How do muscles work?

Muscles of the body can only pull and they cannot push. Two muscles are required to move a bone at a joint. When one muscle contracts, the other muscle relaxes.

For example, to move 'the lower arm up and down two type of muscles called biceps and triceps are required. When we raise our lower hand, the biceps in front become short by contraction and the triceps at the back stretch to pull up the arm. When we lower our arm, the triceps at the back contract and biceps stretch to pull the arm down.

Skeletal Muscles

Skeletal muscles of our body are attached to the bones. They are called **Voluntary muscles** because they can be controlled by our will. Example: Muscles of arm

Smooth muscles

Smooth muscles are found in the walls of the digestive tract, urinary bladder, arteries and other internal organs. They are called **'Involuntary muscles'** because they are not controlled by our will.

Cardiac muscles

The walls of the heart is made up of cardiac muscles. They are capable of rhythmic, contraction continuously and involuntary in nature.

Digestive System

Digestive system consists of the alimentary canal and associated glands. This system is involved in the conversion of complex food substances into simple forms and absorption of digested food.

The digestive glands associated with the alimentary canal are salivary glands, liver, and pancreas. They secrete enzymes which help in the process of digestion of food in the digestive tract or alimentary canal.

The alimentary canal is about 9 meters long. Stomach is a major organ for digestion of food materials. Absorption of digested food occurs in the small intestine.

Parts of Alimentar canal	
1.	Mouth
2.	Buccal cavity
3.	Pharynx
4.	Oesophagus or Food pipe
5.	Stomach
6.	Small Intestine
7.	Large Intestine
8.	Anus

Associated glands for digestion	
1.	Salivary glands
2.	glands
3.	Liver
4.	Pancreas
5.	Intestinal glands

Respiratory System

Respiratory system is involved in exchange of respiratory gases and there by helps us to breathe. The human respiratory system consists of nostrils, nasal cavity, pharynx, larynx, trachea, bronchi and lungs. It helps in the movement of air in and out of the body. Exchange of O2 and CO2 occurs between air in the lung and blood. The entry of food into the wind pipe is prevented by a flap like structure called Epiglottis.

Lungs

Lungs are the main respiratory organ. They are located within the chest cavity. The trachea, commonly called windpipe, is a tube supported by cartilaginous rings that connects the pharynx and larynx to the lungs, allowing the passage of air. The trachea divides into right and left bronchi and enter into the lungs. They divide further and ends in small air sacs called alveoli. The lungs are covered by a double layered pleura. Diffusion of gases (O_2 and CO_2) occurs across the alveolar membrane

Each lung has about 300 million air sacs or alveoli. Yawning helps us to take in more amount of O_2 and to give out CO_2.

Circulatory system

The circulatory system is one of the important system consisting of heart, blood vessels and blood. It transports respiratory gases, nutrients, hormones and waste materials within the body. It protects the body from harmful pathogens and also regulates the body temperature.

Heart

Heart is located in the thoracic cavity between the two lungs. The heart is four chambered and is surrounded by a double layered membrane called **pericardium.** The heart pumps blood continuously throughout our life time.

Blood vessels

Three types of blood vessels are present in the body. They are **arteries, veins and capillaries**. They form a closed network through which the blood is circulated.

Blood

Blood is a fluid connective tissue of red colour containing plasma and blood cells. There are three types of blood cells namely, Red blood corpuscles (RBCs), White Blood corpuscles (WBCs) and Blood Platelets. RBCs are produced in the bone marrow.

Donate Blood
Hospitals have blood banks where blood can be temporarily stored before it is given to the patients in need. Every healthy person over 18 years of age can donate blood. So that, it can be given to persons in need during emergencies of accidents or operations. Blood donation saves their life.

Nervous System

Nervous system is well developed in human and is composed of neurons or nerve cells. This system includes brain, spinal cord, sensory organs and nerves. The two important functions of the nervous system along with the endocrine system are **conduction and co-ordination.**

Brain

The brain is a complex organ which is placed inside the cranium. It is protected by a three layered tissue coverings called meninges. Brain has three regions namely fore brain, mid brain and hind brain. It is the controlling centre of the body.

Brain is said to store as many as 100 million bits of information in a life time.

Spinal cord

It is the extension of medulla oblongata of the hind brain and is enclosed within the vertebral column. Spinal cord connects the brain to different part of the body through nerves.

The Functions of the Nervous System

1. Sensory Input

The conduction of signals from sensory receptors.

2. Integration

The interpretation of the sensory signals and the formulation of responses.

3. Motor output

The conduction of signals from the brain and spinal cord to effectors, such as muscle and gland cells.

Sense organs

Sense organs are like the windows to the outside world. There are five sense organs in our body such as eyes, ears, nose, tongue and skin. They make us aware of our surroundings. We are able to see, hear, smell, taste and feel, only through sense organs.

Eyes

Eyes help us to see things around us i.e., their colour, shape, size whether they are near or far, moving or at rest. The eyelids and eyelashes keep the eyes safe. The eye has three main parts namely cornea, iris and pupil.

Ears

Ears help to hear and differentiate sounds around us. The ears also help us in maintaining the balance of the body when we are walking,

running or climbing. The ear has three major parts, the outer ear, the middle ear and the inner ear. The outer ear in human beings is made up of an external flap called pinna.

Skin

Skin is the largest sense organ as it covers the whole body. The skin helps to feel the things around us by touching, that is whether they are hot or cold, smooth or rough, dry or wet, hard or soft. Skin covers the body and protects it from germs. It also keeps the body moist and regulates the body temperature.

Functions of the skin

1. Skin forms an effective barrier against infection by microbes and pathogens.

2. Skin helps us to synthesize vitamin D using sunlight.

Endocrine System

Endocrine system regulates various functions of the body and maintains the internal environment. Endocrine glands are present in the body, produce chemical substances called **hormones.**

Take Care of Your Sense organs

- Do not read in very bright or very dim light and also in moving vehicle.
- Avoid exposing eyes to screens of television, computer, laptop and cell phone for a long time.
- Do not rub your eyes harshly.
- Wash your eyes gently with clean water, two or three times a day.
- Ears should be protected from hard blows.
- One should never try to prick ears with toothpicks or hairpins, which are dangerous practices because it may puncture the ear drum and cause ear infection.
- One should bath at least once a day to keep skin clean and fresh.

Glands	Location
Pituitary gland	At the base of brain
Pineal Gland	At the base of brain
Thyroid Gland	Neck
Thymus Gland	Chest
Pancreas (Islets of Langerhans	Abdomen
Adrenal Gland	Above the kidney
Gonads	Pelvic cavity

Excretory System

The nitrogenous wastes are removed from the body by the excretory system. It is composed of kidneys, ureters, urinary bladder and urethra.

Kidneys

These are bean shaped structures present in the abdominal cavity. The functional units of the kidney are called **Nephrons** which filter the blood and form the urine.

Why do we drink water? Our body contains about 70% water. Some parts have more water like the grey matter of the brain (about 85%) and some less, like fat cell (about 15%).
We normally consume 1.5 to 3.5 litres of water every day in the form of food and water.

Points to Remember

- The skeletal system gives shape to the body and protects the soft internal organs.

- There are three types of muscles – skeletal muscle (voluntary), smooth muscle (involuntary) and cardiac muscle.
- Circulatory system constitutes the heart, blood vessels and blood.
- Diaphragm – A large flat muscle forming the floor at the chest cavity.
- Digestion is the process of breaking complex food into simple and soluble substances.
- Brain is protected by the skull. It has three parts – cerebrum, cerebellum and medulla oblongata.
- The sense organs are Eyes, Ears, Nose, Tongue and Skin.

10th lesson
Unit – 14 TRANSPORTATION IN PLANTS

Introduction

- Multicellular organisms possess millions of cells in their body. Every cell needs a constant supply of essential substances like nutrients and oxygen to maintain life and survival. Food is the only source of energy and every cell gets its energy by the breakdown of glucose. The cells utilise this energy and govern various vital activities of life.

- Have you ever wondered how water and nutrients absorbed by the root are transported to the leaves? How is the food prepared by the leaves carried to the other parts of the plant? Do you know how water reaches the top of tall plants inspite of not having a circulatory system like animals? Water absorbed by the roots have to reach entire plant and the food synthesised by the leaves have to be distributed to all the parts of the plant. To understand this we need to recall the anatomy of the plants. Water and mineral salts absorbed by the roots reach all parts of the plant through the xylem. The food synthesised by the leaves are translocated to all parts of the plant through the phloem. The bulk movement of substances through the vascular tissue is called Translocation.

- 'Transport' means to carry things from one place to another. Have you ever wondered how in animals the useful substances are transported to other cells and toxic substances are removed? In larger organisms transport of nutrients, salts, oxygen, hormones and waste products around the body are performed by the **'Circulatory system'**. The circulatory system consists of the circulating fluids, **the blood and lymph** and **the heart and blood vessels** which form the collecting and transporting system.

Means of Transport in Plants

- The transport of materials in and out of the cells is carried out by diff usion and active transport in plants.

Diffusion

- The movement of molecules in liquid and solids from a region of higher concentration to a region of their lower concentration without the utilization of energy is called **diffusion**. Th is is a passive process.

Active Transport

- Active transport utilizes energy to pump molecules against a concentration gradient. Active transport is carried out by membrane bound proteins. Th ese proteins use energy to carry substances across the cell membrane hence they are oft en referred to as **pumps**. Th ese pumps can transport substances from a low concentration to a high concentration (**'uphill' transport**).

Osmosis

- Osmosis is the **movement of solvent** or water molecules from the **region of higher concentration** to the region of lower concentration through a semi-permeable membrane. Th is process is carried out till an equilibrium is reached. Osmosis is the passive movement of water or any other solvent molecules.

Plasmolysis

- It occurs when water moves out of the cell and resulting in the shrinkage of cell membrane away from the cell wall.

Imbibition

- Imbibition is a type of diffusion in which a solid absorbs water and gets swelled up. eg. absorption of water by seeds and dry grapes. If it were not for imbibition, seedlings would not have been able to emerge out of the soil.

Root Hair-Water Absorbing Unit

- There are millions of root hairs on the tip of the root which absorb water and minerals by diffusion. Root hairs are thin walled, slender

extension of epidermal cell that increase the surface area of absorption.

Pathway of Water Absorbed by Roots

- Once the water enters the root hairs, the concentration of water molecules in the root hair cells become more than that of the cortex. Thus water from the root hair moves to the cortical cells by osmosis and then reaches the xylem. From there the water is transported to the stem and leaves.

Types of Movement of Water into the Root Cells

- Once water is absorbed by the root hairs, it can move deeper into root layers by two distinct pathways:

Apoplast pathway
Symplast pathway

Apoplast Pathway

- The **apoplastic** movement of water occurs exclusively through the intercellular spaces and the walls of the cells. Apoplastic movement does not involve crossing the cell membrane. This movement is dependent on the gradient.

Symplast Pathway

- In **symplastic** movement, the water travels through the cells i.e. their cytoplasm; intercellular movement is through the plasmodesmata. Water enter the cells through the cell membrane, hence the movement is relatively slower. Movement is again down a potential gradient.

Transpi.ration

- Transpiration is the evaporation of water in plants through stomata in the leaves. Stomata are open in the day and closed at night. The opening and closing of the stomata is due to the change in turgidity

of the guard cells. When water enters into the guard cells, they become turgid and the stoma open. When the guard cells lose water, it becomes flaccid and the stoma closes.

- Water evaporates from mesophyll cells of leaves through the open stomata, this lowers water concentration in mesophyll cells. As a result, more water is drawn into these cells from the xylem present in the veins through the process of osmosis. As water is lost from the leaves, pressure is created at the top to pull more water from the xylem to the mesophyll cells, this process is called **transpiration pull**. This extends up to the roots causing the roots to absorb more water from the soil to ensure continuous flow of water from the roots to the leaves.

- Transpiration is affected by several external factors such as temperature, light, humidity, and wind speed. Internal factors that affect transpiration include number and distribution of stomata, percentage of open stomata, water status of the plant, canopy structure etc.

Importance of Transpiration

- ❖ Creates transpirational pull for transport of water
- ❖ Supplies water for photosynthesis
- ❖ Transports minerals from soil to all parts of the plant
- ❖ Cools the surface of the leaves by evaporation.
- ❖ Keeps the cells turgid; hence, maintains their shape

Root Pressure

- As ion from the soil are actively transported into the vascular tissue of the root, water moves along and increases the pressure inside the xylem. This pressure is called root pressure and is responsible for pushing water to smaller height of the stem.

Uptake of Minerals

- Plants depend on minerals from soil for its nutritional requirements. All minerals cannot be passively absorbed by the roots. Two factors

account for this: (i) minerals are present in the soil as charged particles (ions) that cannot move across cell membranes and

- (ii) the concentration of minerals in the soil is usually lower than the concentration of minerals in the root. Therefore, most minerals enter the root by active absorption through the cytoplasm of epidermal cells. This needs energy in the form of ATP. Then it is transported to all parts by transpiration pull.

Translocation of Mineral Ions

- Minerals are remobilised from older dying leaves to younger leaves. This phenomenon can be seen in deciduous plants. Elements like phosphorus, sulphur, nitrogen and potassium are easily mobilised, while elements like calcium are not remobilised. Small amounts of material exchange takes place between xylem and phloem.

Phloem Transport

- The food synthesised by the leaves are transported by the phloem either to the area of requirement or stored. Phloem tissue is composed of sieve tubes which have sieve plates. Cytoplasmic strands pass through the pores in the sieve plates.

- Phloem transports food (sucrose) from a source to a sink. The source is part of the plant that synthesize food, i.e., the leaf, and sink, is the part that needs or stores the food. But, the source and sink may be reversed depending on the season, or the plant's need.

- Since the source-sink relationship is variable, the direction of movement in the phloem can be upwards or downwards, i.e., **bidirectional**. In contrast, the movement is always **unidirectional** in xylem i.e., upwards.

Translocation of Sugars

- The mechanism of translocation of sugars from source to sink is through pressure flow hypothesis Glucose prepared at source (by photosynthesis) is converted to sucrose. Sucrose moves into the

companion cells, then into the living phloem sieve tube cells by active transport. This process produces a hypertonic condition in the phloem. Water in the adjacent xylem moves into the phloem by osmosis. As osmotic pressure builds up, the phloem sap moves to areas of lower pressure. By active transport sucrose moves into the cells where it is utilised or stored. As sugars are removed, the osmotic pressure decreases and water moves out of the phloem.

Ascent of Sap and its Events – An Overview

- The upward movement of water and minerals from roots to different plant parts is called ascent of sap. A number of factors play a role in ascent of sap and it takes places in following

Root Pressure: Water from soil enters the root hairs due to osmosis. Root pressure is responsible for movement of water up to the base of the stem.

Capillary Action: Water or any liquid rises in a capillary tube because of physical forces, this phenomenon is called capillary action. In the same way, in stem water rises up to certain height because of capillary action.

Adhesion-cohesion of Water Molecules: Water molecules form a continuous column lowing steps
in the xylem because of forces of adhesion and cohesion among the molecules.

Cohesion: The force of attraction between molecules of water is called cohesion.

Adhesion: The force of attraction between molecules of different substances is called adhesion.Water molecules stick to a xylem because of force of adhesion.

Transpiration Pull: Transpiration through stomata creates vacuum which creates a suction. called transpiration pull. The transpiration pull sucks the water column from the xylem tubes and thus water is able to rise to great heights even in the tallest plants.

11th vol 1
Unit – 5
Digestion and Absorption

We all eat food. If you do not take breakfast in the morning how do you feel by noon? The food we eat provides energy and organic substances for growth and for replacement of worn and damaged tissues. It also regulates and coordinates the various activities that take place in our body. The components of our food are carbohydrates, proteins, lipids, vitamins, minerals, fibre and water. We obtain food from plant and animal sources. The food, we eat are macromolecules, and cannot directly enter into our cells. These have to be broken into smaller micromolecules in absorbable forms, for which we need a digestive system. Plants however are autotrophs and synthesize their food, hence they do not require a digestive system. The primary function of the digestive system in the animals is to bring the nutrients, water and electrolytes from the external environment into every cell in the body through the circulatory system.

Alimentary canal faces a conflict between the need of nutrient absorption and to keep our intestinal tract free from pathogenic bacteria and virus. About 7 litres of digestive juice are poured into the alimentary canal and are reabsorbed each day. If this does not happen the body gets rapidly dehydrated and may lead to reduction in the blood pressure.

Digestive system

The process of digestion involves intake of the food (Ingestion), breakdown of the food into micromolecules (Digestion), absorption of these molecules into the blood stream (Absorption), the absorbed substances becoming components of cells (Assimilation) and elimination of the undigested substances (Egestion). Digestive system includes the alimentary canal and associated digestive glands.

Structure of the alimentary canal

The alimentary canal is a continuous, muscular digestive tract that begins with an anterior opening, the mouth and opens out posteriorly through the anus. The alimentary canal consists of mouth, buccal cavity,

pharynx, oesophagus, stomach, intestine, rectum and anus. The mouth is concerned with the reception of food and leads to the buccal cavity or oral cavity.

Mechanical digestion is initiated in the buccal cavity by chewing with the help of teeth and tongue. Chemical digestion is through salivary enzymes secreted by the salivary glands.

Each tooth is embedded in a socket in the jaw bone; this type of attachment is called thecodont. Human beings and many mammals form two sets of teeth during their life time, a set of 20 temporary milk teeth (deciduous teeth) which gets replaced by a set of 32 permanent teeth (adult teeth). This type of dentition is called diphyodont. The permanent teeth are of four different types (heterodont), namely, Incisors (I) chisel like cutting teeth, Canines (C) dagger shaped tearing teeth, Pre molars (PM) for grinding, and Molars (M) for grinding and crushing. Arrangement of teeth in each half of the upper and lower jaw, in the order of I, C, PM and M can be represented by a dental formula, in human the dental formula is

$$\frac{2123}{2123} \times 2$$

Mineral salts like calcium and magnesium are deposited on the teeth and form a hard layer of 'tartar' or calculus called plaque. If the plaque formed on teeth is not removed regularly, it would spread down the tooth into the narrow gap between the gums and enamel and causes inflammation, called gingivitis, which leads to redness and bleeding of the gums and to bad smell. The hard chewing surface of the teeth is made of enamel and helps in mastication of food.

Tongue is a freely movable muscular organ attached at the posterior end by the frenulum to the floor of the buccal cavity and is free in the front. It acts as a universal tooth brush and helps in intake food, chew and mix food with saliva, to swallow food and also to speak. The upper surface of the tongue has small projections called papillae with taste buds.

The oral cavity leads into a short common passage for food and air called pharynx. The oesophagus and the trachea (wind pipe) open into the pharynx. Food passes into the oesophagus through a wide opening

called gullet at the back of the pharynx. A cartilaginous flap called epiglottis prevents the entry of food into the glottis (opening of trachea) during swallowing. Two masses of lymphoid tissue called tonsils are also located at the sides of the pharynx.

Oesophagus is a thin long muscular tube concerned with conduction of the food to a 'J' shaped stomach passing through the neck, thorax and diaphragm. A cardiac sphincter (gastro oesphageal sphincter) regulates the opening of oesophagus into the stomach. If the cardiac sphincter does not contract properly during the churning action of the stomach the gastric juice with acid may flow back into the oesophagus and cause heart burn, resulting in GERD (Gastero Oesophagus Reflex Disorder).

The stomach functions as the temporary storage organ for food and is located in the upper left portion of the abdominal cavity. It consists of three parts – a cardiac portion into which the oesophagus opens; a fundic portion and a pyloric portion that opens into the duodenum. The opening of the stomach into the duodenum is guarded by the pyloric sphincter. It periodically allows partially digested food to enter the duodenum and also prevents regurgitation of food. The inner wall of stomach has many folds called gastric rugae which unfolds to accommodate a large meal.

The small intestine assists in the final digestion and absorption of food. It is the longest part of the alimentary canal and has three regions, a 'U' shaped duodenum (25cm long), a long coiled middle portion jejunum (2.4m long) and a highly coiled ileum (3.5m long). The wall of the duodenum has Brunner's glands which secrete mucus and enzymes. Ileum is the longest part of the small intestine and opens into the caecum of the large intestine. The ileal mucosa has numerous vascular projections called villi which are involved in the process of absorption and the cells lining the villi produce numerous microscopic projections called microvilli giving a brush border appearance that increase the surface area enormously. Along with villi, the ileal mucosa also contain mucus secreting goblet cells and lymphoid tissue known as Peyer's patches which produce lymphocytes. The wall of the small intestine bears crypts between the base of villi called crypts of Leiberkuhn.

The large intestine consists of caecum, colon and rectum. The caecum is a small blind pouch like structure that opens into the colon and it possesses a narrow finger like tubular projection called vermiform appendix. Both caecum and vermiform appendix are large in herbivorous animal and act as an important site for cellulose digestion with the help of symbiotic bacteria. The colon is divided into four regions – an ascending, a transverse, a descending part and a sigmoid colon. The colon is lined by dilations called haustra (singular – haustrum). The "S" shaped sigmoid colon (pelvic colon) opens into the rectum. Rectum is concerned with temporary storage of faeces. The rectum open out through the anus. The anus is guarded by two anal sphincter muscles. The anal mucosa is folded into several vertical folds and contains arteries and veins called anal columns. Anal column may get enlarged and causes piles or haemorrhoids.

Histology of the Gut

The wall of the alimentary canal from oesophagus to rectum consists of four layers namely serosa, muscularis, sub-mucosa and mucosa. The serosa (visceral peritoneum) is the outermost layer and is made up of thin squamous epithelium with some connective tissues. Muscularis is made of smooth circular and longitudinal muscle fibres with a network of nerve cells and parasympathetic nerve fibres which controls peristalsis. The submucosal layer is formed of loose connective tissue containing nerves, blood, lymph vessels and the sympathetic nerve fibres that control the secretions of intestinal juice.

The innermost layer lining the lumen of the alimentary canal is the mucosa which secretes mucous.

Though the bile juice of liver has nodigestive enzyme but is very essential for proper digestion of food, especially of the fats. Discuss the following?

a. What is composition of bile?
b. How it helps in digestion of fats and other nutrients of food?
c. How it helps in absorption of fats?

Digestive glands

Digestive glands are exocrine glands which secrete biological catalysts called enzymes. The digestive glands associated with the alimentary canal are salivary glands, liver and pancreas. Stomach wall has gastric glands that secrete gastric juice and the intestinal mucosa secretes intestinal juice.

Salivary glands

There are three pairs of salivary glands in the mouth. They are the largest parotids gland in the cheeks, the sub-maxillary/ sub-mandibular in the lower jaw and the sublingual beneath the tongue. These glands have ducts such as Stenson's duct, Wharton's duct and Bartholin's duct or duct of Rivinis respectively. The salivary juice secreated by the salivary glands reaches the mouth through these ducts. The daily secretion of saliva from salivary glands ranges from 1000 to 1500mL.

Gastric glands

The wall of the stomach is lined by gastric glands. Chief cells or peptic cells or zymogen cells in the gastric glands secrete gastric enzymes and Goblet cells secrete mucus. The Parietal or oxyntic cells secrete HCl and an intrinsic factor responsible for the absorption of Vitamin B12 called Castle's intrinsic factor.

Liver

The liver, the largest gland in our body is situated in the upper right side of the abdominal cavity, just below the diaphragm. The liver consists of two major left and right lobes; and two minor lobes. These lobes are connected with diaphragm. Each lobe has many hepatic lobules (functional unit of liver) and is covered by a thin connective tissue sheath called the Glisson's capsule. Liver cells (hepatic cells) secrete bile which is stored and concentrated in a thin muscular sac called the gall bladder. Th e duct of gall bladder (cystic duct) along with the hepatic duct from the liver forms the common bile duct. The bile duct passes downwards and joins with the main pancreatic duct to form a common duct called hepato-pancreatic duct. The opening of the

hepato-pancreatic duct into the duodenum is guarded by a sphincter called the sphincter of Oddi. Liver has high power of regeneration and liver cells are replaced by new ones every 3-4 weeks.

Apart from bile secretion, the liver also performs several functions

1. Destroys aging and defective blood cells
2. Stores glucose in the form of glycogen or disperses glucose into the blood stream with the help of pancreatic hormones
3. Stores fat soluble vitamins and iron
4. Detoxifies toxic substances.
5. Involves in the synthesis of nonessential amino acids and urea.

Pancreas

The second largest gland in the digestive system is the Pancreas, which is a yellow coloured, compound elongated organ consisting of exocrine and endocrine cells. It is situated between the limbs of the 'U' shaped duodenum. The exocrine portion secretes pancreatic juice containing enzymes such as pancreatic amylase, trypsin and pancreatic lipase and the endocrine part called Islets of Langerhans secretes hormones such as insulin and glucagon. The pancreatic duct directly opens into the duodenum.

Digestion of food and role of digestive enzymes

The process of digestion converts the solid food into absorbable and assimilable forms. This is accomplished by mechanical and chemical processes.

Digestion in the buccal cavity

The smell, sight and taste as well as the mechanical stimulation of food in the mouth, triggers a reflex action which results in the secretion of saliva. The mechanical digestion starts in the mouth by grinding and chewing of food. It is called mastication. The saliva contain water, electrolytes (Na^+, K^+, Cl^-, HCO_3), salivary amylase (ptyalin), antibacterial agent lysozyme and a lubricating agent mucus (a glycoprotein). The mucus in saliva prepares the food for swallowing by moistening, softening, lubricating and adhering the masticated food into a bolus.

About 30 percent of polysaccharide, starch is hydrolyzed by the salivary amylase enzyme into disaccharides (maltose). The bolus is then passed into the pharynx and then into the oesophagus by swallowing or deglutition. The bolus further passes down through the oesophagus to the stomach by successive waves of muscular contraction called peristalsis. The gastro oesphageal sphincter controls the passage of food into the stomach.

Digestion in the stomach

Food remains in the stomach for 4 to 5 hours, the rhythmic peristaltic movement churns and mixes the food with gastric juice and make it into a creamy liquid called chyme. The gastric secretion is partly controlled by autonomic reflexes. The secretion of gastric juice begins when the food is in the mouth. The gastric juice contains HCl and proenzymes. The proenzyme pepsinogen, on exposure to HCl gets converted into the active enzyme pepsin which converts proteins into proteoses and peptones (peptides). The HCl provides an acidic medium (pH1.8) which is optimum for pepsin, kills bacteria and other harmful organisms and avoids putrifaction. The mucus and bicarbonates present in the gastric juice play an important role in lubrication and protection of the mucosal epithelium from the eroding nature of the highly acidic HCl. Another proteolytic enzyme found in gastric juice of infants is rennin helps in the digestion of milk protein, caseinogen to casein in the presence of calcium ions. This enzyme secretion gradually reduces with aging.

Digestion in the small intestine

The bile, pancreatic juice and intestinal juice are the secretions released into the small intestine. Movements generated by the muscularis layer of the small intestine helps in the thorough mixing of the food with various secretions in the intestine and thereby facilitate digestion.

The pancreatic juice contains enzymes such as trypsinogen, chymotrypsinogen, carboxypeptidases, pancreatic amalyses, pancreatic lipases and nucleases. Trypsinogen is activated by an enzyme, enterokinase, secreted by the intestinal mucosa into active trypsin,

which in turn activates the enzyme chymotrypsinogen in the pancreatic juice. The bile contains bile pigments (bilirubin and biliverdin) as the break down products of hemoglobin of dead RBCs, bile salts, cholesterol and phospholipids but has no enzymes. Bile helps in emulsification of fats. Bile salts reduce the surface tension of fat droplets and break them into small globules. Bile also activates lipases to digest lipids.

Proteins and partially digested proteins in the chyme on reaching the intestine are acted upon by the proteolytic enzymes of pancreatic juice. Trypsin hydrolyses proteins into polypeptides and peptones, while chymotrypsin hydrolyses peptide bonds associated with specific amino acids.

The pancreatic amylase converts glycogen and starch into maltose. Lipase acts on emulsified fat (triglycerides) and hydrolyses them into free fatty acid and monoglycerides. Monoglycerides are further hydrolysed to fatty acid and glycerol. Nucleases in the pancreatic juice break the nucleic acid into nucleotides and nucleosides.

The secretions of the Brunner's gland along with the secretions of the intestinal glands constitute the intestinal juice or succus entericus. The enzymes in the intestinal juice such as maltase, lactase, sucrase (invertase), dipeptidases, lipases, nucleosidases act on the breakdown products of bile and pancreatic digestion.

Maltose	Maltase →	glucose + glucose
Sucrose	sucrase →	glucose + fructose
Lactose	Lactase →	glucose + galactose
Dipeptides, Tripeptides	Peptidase →	amino acids
Nucleotides	Nucleotidase →	Nucleoside + Phosphoric acid
Nucleoside	Nucleosidase →	Sugar + Nitrogen base
Diglycerides and monoglycerides	Lipases →	Fatty acids + glycerol

The mucus along with the bicarbonate ions from the pancreas provides an alkaline medium (pH 7.8) for the enzymatic action. As a result of digestion, all macromolecules of food are converted into their corresponding monomeric units.

Carbohydrates ⟶ monosaccharides (glucose, fructose, galactose)

Proteins ⟶ amino acids

Lipids ⟶ fatty acids and glycerol

The simple substances thus formed are absorbed in the jejunum and ileum region of the small intestine. The undigested and unabsorbed substances are propelled into the large intestine. The activities of the gastro-intestinal tract are carried out by the neural and hormonal control for proper coordination of different parts. Gastric and intestinal secretions are stimulated by neural signals. Hormonal control of the secretion of digestive juices is carried out by local hormones produced by the gastric and intestinal mucosa.

Do you feel ill after drinking milk or after eating dairy products?

If so, you cannot digest disaccharide lactose in milk because, the intestinal enzyme lactase is either inactive or absent or present only in very small amounts. The undigested lactose remains in the gut in such persons with lactose intolerance and is broken down by bacteria, causing gas, bloating, stomach cramps and diarrhoea.

Absorption and assimilation of proteins, carbohydrates and fats

Absorption is a process by which the end product of digestion passes through the intestinal mucosa into the blood and lymph. The villi in the lumen of ileum are the absorbing units, consisting of a lacteal duct in the middle surrounded by fine network of blood capillaries. The process of absorption involves active, passive and facilitated transport. Small amounts of glucose, amino acids and electrolytes like chloride ions are generally absorbed by simple diffusion. The passage of these substances into the blood depends upon concentration gradients. However, some of the substances like fructose are absorbed with the help of the carrier ions like Na+. This mechanism is called facilitated transport.

Nutrients like amino acids, glucose and electrolytes like Na+ are absorbed into the blood against the concentration gradient by active transport. The insoluble substances like fatty acids, glycerol and fat soluble vitamins are first incorporated into small, spherical water soluble droplets called micelles and are absorbed into the intestinal mucosa where they are re-synthesized into protein coated fat globules called chylomicrons which are then transported into the lacteals within the intestinal villi and eventually empty into lymphatic duct. The lymphatic ducts ultimately release the absorbed substances into the blood stream. While the fatty acids are absorbed by the lymph duct, other materials are absorbed either actively or passively by the capillaries of the villi. Water soluble vitamins are absorbed by simple diffusion or active transport. Transport of water depends upon the osmotic gradient.

Absorption of substances in the alimentary canal takes place in mouth, stomach, small intestine and large intestine. However maximum absorption takes place in the small intestine. Absorption of simple sugars, alcohol and medicines takes place in the stomach. Certain drugs are absorbed by blood capillaries in the lower side of the tongue and mucosa of mouth. Large intestine is also involved in absorption of more amounts of water, vitamins, some minerals and certain drugs.

Absorbed substances are transported through blood and lymph to the liver through the hepatic portal system. From the liver, nutrients are transported to all other regions of the body for utilization. All the body tissues utilize the absorbed substance for their activities and incorporate into their protoplasm, this process is called assimilation.

Egestion

The digestive waste and unabsorbed substances in the ileum enter into the large intestine and it mostly contains fibre called roughage. The roughage is utilized by symbiotic bacteria in the large intestine for the production of substances like vitamin K and other metabolites. All these substances are absorbed in the colon along with water. The waste is then solidified into faecal matter in the rectum. The faecal matter initiates a neural reflex causing an urge or desire for its removal. The egestion of

faeces through the anal opening is called defaecation. It is a voluntary process and is carried out by a peristaltic movement.

Nutrients, Vitamins and Minerals

Food comprises of macronutrients and micronutrients. The nutrients required in larger quantities are called macronutrients, whereas those required in small quantities are called micronutrients. Essential nutrients cannot be synthesized by the body; they have to be included in the diet. Macronutrients are lipids, carbohydrates, proteins and the micronutrients are vitamins and minerals. Water plays an important role in the metabolic processes and prevents dehydration of the body.

Intake of too much of food or lesser amount of food than the basic requirement is called malnutrition. A diet which can provide all the metabolic requirements of the body in a right proportion is called balanced diet. That means it should contain carbohydrates and fats for energy yielding, proteins for growth and replacement; and vitamins, minerals and water for physiological regulation.

Vitamins:

Vitamins are naturally occurring organic substances regularly needed in minute quantities for maintaining normal health as metabolic regulators. The identified vitamins are classified as fat soluble (A,D,E and K) and vitamin B and vitamin C are water soluble. Vitamin A, D, E and K, if consumed beyond required level may cause defects, commonly referred to as hypervitaminosis.

Minerals:

These are the inorganic chemical elements, i.e., Ca, Fe, I, K, Mg, Na, P, S, etc needed for regulation of various physiological functions. These can be classified into major minerals (Na, P, K, Ca, Mg, S, Cl) and others are trace minerals such as Fe, Cu, Zn, Co, Mn, I, and fluorine. Sodium ions are more abundant than any other cation in the body fluids.

N.I. Lunin discovered vitamins but the name vitamin was given by Dr. Funk (1912). The first vitamin isolated was B1 by Dr.Funk. The first vitamin produced by fermentation process using, Acetobacter bacteria is Vitamin C.

Fat soluble vitamins		
Vitamins	**Functions**	**Symptoms of Deficiency**
A (Retinol)/ Antixerophthalmic vitamin	Plays a vital role in visual perception. Maintenance and growth of epithelial tissue.	Night blindness (Nyctalopia), Xerophthalmia (drying of eyeballs), Bitot's spot in the cornea, Dermatosis (dry and scaly skin) and Keratomalacia Atrophy of lacrymal glands and reduction in tear secretion
D (Calciferol)/ Antirachitic vitamin	Promotes intestinal absorption of calcium and phosphorus. Formation of teeth and bones.	Rickets in children (softness and deformities of bones and bow legs and pigeon chest) and Osteomalacia in adults (weak and fragile bones, bent, deformed pelvis).
E (Tocopherol) / Antisterility vitamin	Antioxidant It keeps the skin healthy by reduces the process of ageing.	Sterility in animals, Ruptured red blood cells
K Anti haemorrahagic vitamin.	1. Required for the synthesis of prothrombin in the liver.	Defect in blood clotting called Haemorrhagic manifestations.

Water soluble vitamins		
Vitamins	**Functions**	**Symptoms of Deficiency**
B_1 (Thiamine)	Involved in	Beriberi: affects

	carbohydrate metabolism. Act as a coenzyme	muscular, nervous and cardiovascular system
B_2 (Riboflavin)	Acts as coenzyme in oxidation and reduction reactions	Inflammation, soreness and fissures in the corners of the mouth, lips and tongue. Loss of appetite. Skin and eye disorder.
B_3 (Pantothenic acid)	Acts as coenzyme A and is essential for the metabolism of fats and carbohydrates	Gastrointestinal disorders, anaemia, Burning feet syndrome, etc.
B_4 (choline)	Precursor for acetylcholine	Fatty liver
B_5 (Niacin / Nicotinic acid)	Derivatives of coenzyme	Pellagra (4D Syndrome) characterised by dermatitis, diarrhoea and dementia (mental deterioration) and death.
B_6 (Pyridoxine)	Haemoglobin formation, brain, heart and liver activities	Dermatitis, convulsions, muscular twitching and anaemia
B_7 (Biotin) / Vit.H	Acts as a coenzyme in synthesis of fat, glycogen and amino acids	Dermaititis
B_9 (Folic acid)	It acts as a co-enzyme for synthesis of nucleic acid and essential for growth and formation of RBC	Megaloblastic anaemia (large, immature, nucleated RBC in blood)
B_{12} (Cobalamine)	Promotes DNA	Pernicious anaemia

	synthesis. Necessary for maturation of RBC and formation of myelin Sheath	(immature nucleated RBC without haemoglobin). Causes nervous disorder.
C (Ascorbic acid)	Acts as an antioxidant. Strengthens the immune system. Necessary for healthy gums and teeth.	Scurvy (Sailor's disease) characterized by spongy and bleeding gums, falling of teeth, fragile bones, delayed wound healing etc. - Infantile scurvy)

Food adulterants cause harmful effects in the form of headaches, palpitations, allergies, cancers and in addition reduces the quality of food. Common adulterants are addition of citric acid to lemon juice, papaya seeds to pepper, melamine to milk, vanillin for natural vanillin, red dyes to chillis, lead chromate and lead tetraoxide to turmeric powder, etc.,

Caloric value of carbohydrates, proteins and fats

We obtain 50% energy from carbohydrates 35% from fats and 15% from proteins. We require about 400 to 500 gm of carbohydrates, 60 to 70 gm of fats and 65 to 75 gm of proteins per day. Balanced diet of each individual will vary according to their age, gender, level of physical activity and others conditions such as pregnancy and lactation. Carbohydrates are sugar and starch. These are the major source of cellular fuel which provides energy. The caloric value of carbohydrate is 4.1 calories per gram and its physiological fuel value is 4 Kcal per gram.

Lipids are fats and derivatives of fats, are also the best reserved food stored in our body which is used for production of energy. Fat has a caloric value of 9.45 Kcal and a physiological fuel value of 9 Kcal per gram.

Many research findings have proven that usage of chemical preservatives and artificial enhancers lead to highly harmful effects. It includes heart

ailments, hypertension, infertility, gastrointestinal disorders, early puberty in girls, weakening of bones, damage in organs like kidney and liver, chronic obstructive pulmonary diseases, headache, allergies, asthma, skin rashes and even cancer. Remember that nothing will beat and overtake the taste and safety of homemade foods. "East or west home preparation is the best."

Proteins are source of amino acids required for growth and repair of body cells. They are stored in the body only to a certain extent; large quantities are excreted as nitrogenous waste. The caloric value and physiological fuel value of one gram of protein are 5.65 Kcal and 4 Kcal respectively. According to ICMR (Indian Council of Medical Research and WHO (World Health Organization), the daily requirement of protein for an average Indian is 1gm per 1 kg body weight.

Nutritional and digestive disorders

Intestinal tract is more prone to bacterial, viral and parasitic worm infections. This infection may cause inflammation of the inner lining of colon called colitis. The most common symptoms of colitis are rectal bleeding, abdominal cramps, and diarrhoea.

Protein energy malnutrition: (PEM)

Growing children require more amount of protein for their growth and development. Protein deficient diet during early stage of children may lead to protein energy malnutrition such as Marasmus and Kwashiorkor. Symptoms are dry skin, pot-belly, oedema in the legs and face, stunted growth, changes in hair colour, weakness and irritability. Marasmus is an acute form of protein malnutrition. This condition is due to a diet with inadequate carbohydrate and protein. Such children are suffer from diarrhoea, body becomes lean and weak (emaciated) with reduced fat and muscle tissue with thin and folded skin.

Indigestion: It is a digestive disorder in which the food is not properly digested leading to a feeling of fullness of stomach. It may be due to inadequate enzyme secretion, anxiety, food poisoning, over eating, and spicy food.

Constipation: In this condition, the faeces are retained within the rectum because of irregular bowel movement due to poor intake of fibre in the diet and lack of physical activities.

Vomiting: It is reverse peristalsis. Harmful substances and contaminated food from stomach are ejected through the mouth. This action is controlled by the vomit centre located in the medulla oblongata. A feeling of nausea precedes vomiting.

Jaundice: It is the condition in which liver is affected and the defective liver fails to break down haemoglobin and to remove bile pigments from the blood. Deposition of these pigments changes the colour of eye and skin yellow. Sometimes, jaundice is caused due to hepatitis viral infections.

Liver cirrhosis: Chronic disease of liver results in degeneration and destruction of liver cells resulting in abnormal blood vessel and bile duct leading to the formation of fibrosis. It is also called deserted liver or scarred liver. It is caused due to infection, consumption of poison, malnutrition and alcoholism.

Gall Stones: Any alteration in the composition of the bile can cause the formation of stones in the gall bladder. The stones are mostly formed of crystallized cholesterol in the bile. The gall stone causes obstruction in the cystic duct, hepatic duct and also hepato-pancreatic duct causing pain, jaundice and pancreatitis.

Appendicitis: It is the inflammation of the vermiform appendix, leading to severe abdominal pain. The treatment involves the removal of appendix by surgery. If treatment is delayed the appendix may rupture and results in infection of the abdomen, called peritonitis.

Hiatus hernia (Diaphragmatic hernia): It is a structural abnormality in which superior part of the stomach protrudes slightly above the diaphragm. The exact cause of hiatus hernias is not known. In some people, injury or other damage may weaken muscle tissue, by applying too much pressure (repeatedly) on the muscles around the stomach while coughing, vomiting, and straining during bowel movement and lifting heavy object. Heart burn is also common in those with a hiatus

hernia. In this condition, stomach contents travel back into the oesophagus or even into oral cavity and causes pain in the centre of the chest due to the eroding nature of acidity.

Diarrhoea: It is the most common gastrointestinal disorder worldwide. It is sometimes caused by bacteria or viral infections through food or water. When the colon is infected, the lining of the intestine is damaged by the pathogens, thereby the colon is unable to absorb fluid. The abnormal frequency of bowel movement and increased liquidity of the faecal discharge is known as diarrhoea. Unless the condition is treated, dehydration can occur. Treatment is known as oral hydration therapy. This involves drinking plenty of fluids – sipping small amounts of water at a time to rehydrate the body.

Peptic ulcer: It refers to an eroded area of the tissue lining (mucosa) in the stomach or duodenum. Duodenal ulcer occurs in people in the age group of 25 - 45 years. Gastric ulcer is more common in persons above the age of 50 years. Ulcer is mostly due to infections caused by the bacterium Helicobacter pylori. It may also be caused due to uncontrolled usage of aspirin or certain antiinflammatory drugs. Ulcer may also be caused due to smoking, alcohol, caffeine and psychological stress.

Obesity: It is caused due to the storage of excess of body fat in adipose tissue. It may induce hypertension, atherosclerotic heart disease and diabetes. Obesity may be genetic or due to excess intake of food, endocrine and metabolic disorders. Degree of obesity is assessed by body mass index (BMI). A normal BMI range for adult is 19- 25; above 25 is considered as obese. BMI is calculated as body weight in Kg, divided by the square of body height in meters. For example, a 50 Kg person with a height of 160 cms would have a BMI of 19.5.

That is BMI = $50/1.6^2 = 19.5$

Nobel Prize for the year 2005 was awarded to Robin Warren and Barry Marshall for the discovery of Helicobacter pylori which causes peptic ulcer.

Alimentary canal faces a conflict between the need of nutrient absorption and to keep our intestinal tract free from pathogenic bacteria

and virus. About 7 litres of digestive juice are poured into the alimentary canal and are reabsorbed each day. If this does not happen the body gets rapidly dehydrated and may lead to reduction in the blood pressure.

Unit – 6
Respiration

We inhale and exhale air. Why is breathing so important for life? What happens when we breathe? Why energy is required for the body to perform various life processes? Where does the energy come from? We eat food for energy. Though the above raised questions look disconnected, we should know that the process of breathing is connected to the process of release of energy from food. Oxygen is utilized by the organisms to breakdown the biomolecules like glucose and to derive energy. During this breakdown carbondioxide, which is a harmful gas is also released. It is very obvious that oxygen has to be provided to cells continuously and the CO2 to be released immediately by the cells. So the need of a respiratory system is essential for life.

We have discussed in the previous chapter how food provides energy for growth and repair of tissues. As mentioned earlier along with food, oxygen is necessary for breakdown of glucose to energy. In this chapter we shall discuss the respiratory organs of human, the mechanism of breathing, exchange and transport of gases and a few respiratory disorders.

The term respiration refers to the exchange of oxygen and carbondioxide between environment and cells of our body where organic nutrients are broken down enzymatically to release energy.

Respiratory functions

The five primary functions of the respiratory system are –

i. To exchange O2 and CO2 between the atmosphere and the blood.
ii. To maintain homeostatic regulation of body pH.
iii. To protect us from inhaled pathogens and pollutants.
iv. To maintain the vocal cords for normal communication (vocalization).
v. To remove the heat produced during cellular respiration through breathing.

Respiratory organs in various organisms.

Different animals have different organs for exchange of gases, depending upon their habitats and levels of organization. The amount of dissolved oxygen is very low in water compared to the amount of oxygen in the air. So the rate of breathing in aquatic organisms is much faster than land animals.

In animals like sponges, coelenterates and flatworms exchange of gases takes place through the body surface by simple diffusion. Earthworms use their moist skin, whereas insects have tracheal tubes. Gills are used as respiratory organs in most of the aquatic Arthropods and Molluscs. Among verterbrates, fishes use gills whereas amphibians, reptiles, birds and mammals have well vascularized lungs. Frogs spend most of their time in water and also use their moist skin for respiration along with lungs.

Human Respiratory System

The respiratory system includes the external nostrils, nasal cavity, the pharynx, the larynx, the trachea, the bronchi and bronchioles and the lungs which contain the alveoli. The parts starting from the external nostrils up to the terminal bronchioles constitute the conducting zone, whereas the alveoli and the ducts are called the respiratory zone. The parts of the conducting zone, humidifies and warms the incoming air.

In human beings, air enters the upper respiratory tract through the external nostrils. The air passing through the nostrils is filtered by fine hairs and mucus lining the passage. The external nostrils lead to the nasal chamber which opens into the nasopharynx which opens through the glottis of the larynx region into the trachea. The ciliated epithelial cells lining the trachea, bronchi and bronchioles secrete mucus. Mucus membrane lining the airway contains goblet cells which secrete mucus, a slimy material rich in glycoprotein. Microorganisms and dust particles attach in the mucus films and are carried upwards to pass down the gullet during normal swallowing. During swallowing a thin elastic flap called epiglottis prevents the food from entering into the larynx and avoids choking of food.

The trachea is semiflexible tube supported by multiple cartilaginous rings which extends up to the midthoracic cavity and at the level of the 5th thoracic vertebra where it divides into right and left primary bronchi, one bronchus to each lung. Within the lungs the bronchi divides repeatedly into secondary and tertiary bronchi and further divides into terminal bronchioles and respiratory bronchioles.

Bronchi have 'C' shaped curved cartilage plates to ensure that the air passage does not collapse or burst as the air pressure changes during breathing. The bronchioles are without cartilaginous rings and have rigidity that prevent them from collapsing but are surrounded by smooth muscle which contracts or relaxes to adjust the diameter of these airways.

The fine respiratory bronchioles terminate into highly vascularised thin walled pouch like air sacs called alveoli meant for gaseous exchange. The diffusion membrane of alveolus is made up of three layers – the thin squamous epithelial cells of the alveoli, the endothelium of the alveolar capillaries and the basement substance found in between them. The thin squamous epithelial cells of the alveoli are composed of Type I and Type II cells. Type I cells are very thin so that gases can diffuse rapidly through them. Type II cells are thicker, synthesize and secrete a substance called Surfactant.

The lungs are light spongy tissues enclosed in the thoracic cavity surrounded by an airtight space. The thoracic cavity is bound dorsally by the vertebral column and ventrally by the sternum, laterally by the ribs and on the lower side by the dome shaped diaphragm.

The lungs are covered by double walled pleural membrane containing a several layers of elastic connective tissues and capillaries, which encloses the pleural fluid. Pleural fluid reduces friction when the lungs expand and contract.

Characteristic features of respiratory surface:

- surface area must be very large and richly supplied with blood vessels
- should be extremely thin and kept moist

- should be in direct contact with the environment
- should be permeable to respiratory gases

The steps involved in respiration are

i. The exchange of air between the atmosphere and the lungs.
ii. The exchange of O2 and CO2 between the lungs and the blood.
iii. Transport of O2 and CO2 by the blood.
iv. Exchange of gases between the blood and the cells.
v. Uptake of O2 by the cells for various activities and the release of CO2.

SURFACTANTS are the thin non–cellular films made of protein and phospholipids covering the alveolar membrane. The surfactant lowers the surface tension in the alveoli and prevents the lungs from collapsing. It also prevents pulmonary oedema. Premature Babies have low levels of surfactant in the alveoli may develop the new born respiratory distress syndrome (NRDS) because the synthesis of surfactants begins only after the 25th week of gestation.

Mechanism of breathing

The movement of air between the atmosphere and the lungs is known as ventilation or breathing. Inspiration and expiration are the two phases of breathing. Inspiration is the movement of atmospheric air into the lungs and expiration is the movement of alveolar air that diffuse out of the lungs.

Lungs do not contain muscle fibres but expands and contracts by the movement of the ribs and diaphragm. The diaphragm is a sheet of tissue which separates the thorax from the abdomen. In a relaxed state, the diaphragm is domed shaped.

Ribs are moved by the intercostal muscles. External and internal intercostal muscles found between the ribs and the diaphragm helps in creating pressure gradients. Inspiration occurs if the pressure inside the lungs (intrapulmonary pressure) is less than the atmospheric pressure likewise expiration takes place when the pressure within the lungs is higher than the atmospheric pressure.

Inspiration	Expiration
Respiratory centre initiates the stimuli during inspiration ↓ Impulses are carried to the inspiratory muscles through nerves. ↓ Diaphragm and inspiratory muscles contract. ↓ The thoracic volume increases as the chest wall expands. ↓ The intra pulmonary pressure is reduced. ↓ The alveolar pressure decreases than the atmospheric pressure ↓ Air flows into the alveoli until the alveolar pressure equalizes the atmospheric pressure and the alveoli get inflated.	Respiratory centre terminates the stimuli during expiration. ↓ The diaphragm and inspiratory muscles relax. ↓ Chest wall contracts and the thoracic volume gets reduced. ↓ The intra pulmonary pressure is reduced. ↓ The alveolar pressure increases than the atmospheric pressure. ↓ Air is sent out due to the contraction of alveoli. ↓ Air flows out of the alveoli until the alveolar pressure equalizes the atmospheric pressure and the alveoli get deflated.

Inspiraton is initiated by the contraction of the diaphragm muscles and external intercostal muscles, which pulls the ribs and sternum upwards and outwards and increases the volume of the thoracic chamber in the dorso–ventral axis, forcing the lungs to expand the pulmonary volume. The increase in pulmonary volume and decrease in the intrapulmonary pressure forces the fresh air from outside to enter

the air passages into the lungs to equalize the pressure. This process is called inspiration.

Relaxation of the diaphragm allows the diaphragm and sternum to return to its dome shape and the internal intercostal muscles contract, pulling the ribs downward reducing the thoracic volume and pulmonary volume. This results in an increase in the intrapulmonary pressure slightly above the atmospheric pressure causing the expulsion of air from the lungs. This process is called expiration.

On an average, a healthy human breathes 12–16 times/minute. An instrument called Spirometer is used to measure the volume of air involved in breathing movements for clinical assessment of a person's pulmonary function.

Respiratory volumes and capacities

The volume of air present in various phases of respiration is denoted as

Respiratory volumes:

- Tidal Volume (TV) Tidal volume is the amount of air inspired or expired with each normal breath. It is approximately 500 mL., i.e. a normal human adult can inspire or expire approximately 6000 to 8000mL of air per minute. During vigorous exercise, the tidal volume is about 4–10 times higher.

- Inspiratory Reserve volume (IRV) Additional volume of air a person can inspire by forceful inspiration is called Inspiratory Reserve Volume. The normal value is 2500–3000 mL.

- Expiratory Reserve volume (ERV) Additional volume of air a person can forcefully exhale by forceful expiration is called Expiratory Reserve Volume. The normal value is 1000–1100 mL.

- Residual Volume (RV) The volume of air remaining in the lungs after a forceful expiration. It is approximately 1100–1200 mL.

Respiratory capacities:

- Vital capacity (VC) the maximum volume of air that can be moved out during a single breath following a maximal inspiration. A person first inspires maximally then expires maximally. VC=ERV+TV+IRV

- Inspiratory capacity (IC) The total volume of air a person can inhale after normal expiration. It includes tidal volume and inspiratory reserve volume. IC=TV+IRV

- Expiratory capacity (EC) The total volume of air a person can exhale after normal inspiration. It includes tidal volume and expiratory reserve volume. EC=TV+ERV

- Total Lung Capacity (TLC) The total volume of air which the lungs can accommodate after forced inspiration is called Total Lung Capacity. This includes the vital capacity and the residual volume. It is approximately 6000mL. TLC=VC+RV

- Minute Respiratory Volume The amount of air that moves into the respiratory passage per minute is called minute respiratory volume. Normal TV = 500mL; Normal respiratory rate = 12 times/minute Therefore, minute respiratory volume = 6 Liters/minute (for a normal healthy man).

Why do some people snore? – Breathing with a hoarse sound during sleep is caused by the vibration of the soft palate. Snoring is caused by a partially closed upper air way (nose and throat) which becomes too narrow for enough air to travel through the lungs. This makes the surrounding tissues to vibrate and produces the snoring sound.

Healthy lungs contain large amounts of elastic connective tissue around the alveoli, containing elastin, which makes the lung tissue elastic. People with emphysema and bronchitis have difficulty in exhaling because the enzyme elastase destroys the elastin around the alveoli and reduces the elasticity of the lungs.

Dead space

Some of the inspired air never reaches the gas exchange areas but fills the respiratory passages where exchange of gases does not occur. This air is called dead space.

Dead space is not involved in gaseous exchange. It amounts to approximately 150mL.

Exchange of gases

The primary site for the exchange of gases is the alveoli. The uptake of O2 and the release of CO2 occur between the blood and tissues by simple diffusion driven by partial pressure gradient of O2 and CO2. Partial pressure is the pressure contributed by an individual gas in a mixture of gases. It is represented as pO2 for oxygen and pCO2 for carbon–dioxide. Due to pressure gradients, O2 from the alveoli enters into the blood and reaches the tissues. CO2 enters into the blood from the tissues and reaches alveoli for elimination. As the solubility of CO2 is 20–25 times higher than that of O2, the partial pressure of CO2 is much higher than that of O2 (Tab.6.1 and Figure 6.6).

Respiratory pigments
Haemoglobin

Haemoglobin belongs to the class of conjugated protein. The iron containing pigment portion haem constitutes only 4% and the rest colourless protein of the histone class globin. Haemoglobin has a molecular weight of 68,000 and contains four atoms of iron, each of which can combine with a molecule of oxygen.

Methaemoglobin

If the iron component of the haem moieties is in the ferric state, than the normal ferrous state, it is called methaemoglobin. Methaemoglobin does not bind O2. Normally RBC contains less than 1% methaemoglobin.

Respiratory gases	Partial pressure mm Hg				
	Atmospheric air	Alveoli	Deoxygenated Blood	Oxygenated blood	Tissues
O_2	159	104	40	95	40
CO_2	0.3	40	45	40	45

Transport of gases

Transport of oxygen

Molecular oxygen is carried in blood in two ways: bound to haemoglobin within the red blood cells and dissolved in plasma. Oxygen is poorly soluble in water, so only 3% of the oxygen is transported in the dissolved form. 97% of oxygen binds with haemoglobin in a reversible manner to form oxyhaemoglobin (HbO_2). The rate at which haemoglobin binds with O_2 is regulated by the partial pressure of O_2. Each haemoglobin carries maximum of four molecules of oxygen. In the alveoli high pO_2, low pCO_2, low temperature and less H+ concentration, favours the formation of oxyhaemoglobin, whereas in the tissues low pO2, high pCO_2, high H+ and high temperature favours the dissociation of oxygen from oxyhaemoglobin.

A sigmoid curve (S–shaped) is obtained when percentage saturation of haemoglobin with oxygen is plotted against pO_2. This curve is called oxygen haemoglobin dissociation curve. This S–shaped curve has a steep slope for pO_2 values between 10 and 50mmHg and then flattens between 70 and 100 mm Hg.

Under normal physiological conditions, every 100mL of oxygenated blood can deliver about 5mL of O_2 to the tissues.

Transport of Carbon–dioxide

Blood transports CO_2 from the tissue cells to the lungs in three ways

i. Dissolved in plasma About 7 – 10% of CO_2 is transported in a dissolved form in the plasma.

ii. Bound to haemoglobin About 20 – 25% of dissolved CO2 is bound and carried in the RBCs as carbaminohaemoglobin (Hb CO2) CO2 + Hb $\rightleftharpoons$ Hb CO2

iii. As bicarbonate ions in plasma about 70% of CO2 is transported as bicarbonate ions.

This is influenced by pCO2 and the degree of haemoglobin oxygenation. RBCs contain a high concentration of the enzyme, carbonic anhydras, Whereas small amounts of carbonic anhydrase is present in the plasma.

At the tissues the pCO2 is high due to catabolism and diffuses into the blood to form HCO3 – and H+ ions. When CO2 diffuses into the RBCs, it combines with water forming carbonic acid (H2CO3) catalyzed by carbonic anhydrase. Carbonic acid is unstable and dissociates into hydrogen and bicarbonate ions.

Carbonic anhydrase facilitates the reaction in both directions.

$$CO_2 + H_2O \underset{\text{carbonic anhydrase}}{\rightleftharpoons} H_2CO_3 \underset{\text{carbonic anhydrase}}{\rightleftharpoons} HCO_3^- + H^+$$

The HCO_3– moves quickly from the RBCs into the plasma, where it is carried to the lungs. At the alveolar site where pCO_2 is low, the reaction is reversed leading to the formation of CO_2 and water. Thus CO_2 trapped as HCO_3– at the tissue level it is transported to the alveoli and released out as CO_2. Every 100mL of deoxygenated blood delivers 4mL of CO_2 to the alveoli for elimination.

Bohr effect and Haldane effect

Increase in PCO2 and decrease in pH decrease the affinity of haemoglobin for oxygen and shifts the oxyhaemoglobin dissociation curve to the right and facilitates unloading of oxygen from hemoglobin in the tissue. This effect of pCO2 and pH on the oxyhaemoglobin dissociation curve is called the Bohr small effect.

The Haldane effect, on the other hand describes how oxygen concentrations determines hemoglobin's affinity for carbon dioxide. The amount of carbon dioxide transported in blood is remarkably affected by the degree oxygenation of the blood. The lower the partial pressure of O_2 lower is the affinity of haemoglobin saturation with oxygen hence more CO_2 is carried in the blood. This phenomenon is called Haldane effect. This effects CO_2 exchanges in both the tissues and lungs.

In the lungs the process is reversed as the blood moves through the pulmonary capillaries, its PCO_2 declines from 45mm Hg to 40mm Hg. For this to occur carbondioxide is freed from HCO_3- ions and Cl- ions moves in to the plasma and reenters the RBC and binds with H+ to form carbonic acid which dissociates in to CO_2 and water. This CO_2 diffuses along its partial gradient from the blood to the alveoli.

Regulation of Respiration

A specialised respiratory centre present in the medulla oblongata of the hind brain called respiratory rhythm centre is responsible for this regulation. Pneumotaxic centre present in pons varoli region of the brain moderates the function of the respiratory rhythm centre to ensure normal breathing. The chemosensitive area found close to the rhythm centre is highly sensitive to CO_2 and H^+. And H^+ are eliminated out by respiratory process. Receptors associated with the aortic arch and carotid artery send necessary signals to the rhythm centre for remedial action. The role of O_2 is insignificant in the regulation of respiratory rhythm.

Particulate matter PM 2.5 in the air is increasing day by day which causes respiratory illness. Central Pollution Control Board (CPCB) reports that the quality of air is not good due to soot and smoke. So some cities in India are using CNG (Compressed Natural Gas) as fuel.

Problems in Oxygen transport

When a person travels quickly from sea level to elevations above 8000ft, where the atmospheric pressure and partial pressure of oxygen are lowered, the individual responds with symptoms of acute mountain sickness (AMS)–headache, shortness of breath, nausea and dizziness due

to poor binding of O2 with haemoglobin. When the person moves on a long–term basis to mountains from sea level is body begins to make respiratory and haematopoietic adjustments. To overcome this situation kidneys accelerate production of the hormone erythropoietin, which stimulates the bone marrow to produce more RBCs.

Allergy is caused by allergens. When we enter a polluted area, immediately we start sneezing and coughing. The allergens in that place affect our respiratory tracts and the responses to the allergens start within minutes. Allergens provoke an inflammatory response. A common manifestation of allergy is Asthma.

When a person descends deep into the sea, the pressure in the surrounding water increases which causes the lungs to decrease in volume. This decrease in volume increases the partial pressure of the gases within the lungs. This effect can be beneficial, because it tends to drive additional oxygen into the circulation, but this benefit also has a risk, the increased pressure can also drive nitrogen gas into the circulation. This increase in blood nitrogen content can lead to a condition called nitrogen narcosis. When the diver ascends to the surface too quickly a condition called 'bends' or decompression sickness occurs and nitrogen comes out of solution while still in the blood forming bubbles. Small bubbles in the blood are not harmful, but large bubbles can lodge in small capillaries, blocking blood flow or can press on nerve endings. Decompression sickness is associated with pain in joints and muscles and neurological problems including stroke. The risk of nitrogen narcosis and bends is common in scuba divers.

During carbon–dioxide poisoning, the demand for oxygen increases. As the O_2 level in the blood decreases it leads to suffocation and the skin turns bluish black.

Disorders of the Respiratory system

Respiratory system is highly affected by environmental, occupational, personal and social factors. These factors may be responsible for a number of respiratory disorders. Some of the disorders are discussed here.

Asthma – It is characterized by narrowing and inflammation of bronchi and bronchioles and difficulty in breathing. Common allergens for asthma are dust, drugs, pollen grains, certain food items like fish, prawn and certain fruits etc.

Emphysema– Emphysema is chronic breathlessness caused by gradual breakdown of the thin walls of the alveoli decreasing the total surface area of a gaseous exchange. i.e., widening of the alveoli is called emphysema. The major cause for this disease is cigarette smoking, which reduces the respiratory surface of the alveolar walls.

Bronchitis– The bronchi when it gets inflated due to pollution smoke and cigarette smoking, causes bronchitis. The symptoms are cough, shortness of breath and sputum in the lungs.

Pneumonia– Inflammation of the lungs due to infection caused by bacteria or virus is called pneumonia. The common symptoms are sputum production, nasal congestion, shortness of breath, sore throat etc.

Tuberculosis– Tuberculosis is caused by Mycobacterium tuberculae. This infection mainly occurs in the lungs and bones. Collection of fluid between the lungs and the chest wall is the main complication of this disease.

Occupational respiratory disorders– The disorders due to one's occupation of working in industries like grinding or stone breaking, construction sites, cotton industries, etc. Dust produced affects the respiratory tracts.

Long exposure can give rise to inflammation leading to fibrosis.

Silicosis and asbestosis are occupational respiratory diseases resulting from inhalation of particle of silica from sand grinding and asbestos into the respiratory tract. Workers, working in such industries must wear protective masks.

Effects of Smoking

Today due to curiosity, excitement or adventure youngsters start to smoke and later get addicted to smoking. Research says about 80% of the lung cancer is due to cigarette smoking.

Smoking is inhaling the smoke from burning tobacco. There are thousands of known chemicals which includes nicotine, tar, carbon monoxide, ammonia, sulphur– dioxide and even small quantities of arsenic. Carbon monoxide and nicotine damage the cardiovascular system and tar damages the gaseous exchange system. Nicotine is the chemical that causes addiction and is a stimulant which makes the heart beat faster and the narrowing of blood vessels results in raised blood pressure and coronary heart diseases. Presence of carbon monoxide reduces oxygen supply. Lung cancer, cancer of the mouth and larynx is more common in smokers than non–smokers. Smoking also causes cancer of the stomach, pancreas and bladder and lowers sperm count in men. Smoking can cause lung diseases by damaging the airways and alveoli and results in emphysema and chronic bronchitis. These two diseases along with asthma are often referred as Chronic Obstructive Pulmonary Disease (COPD). When a person smokes, nearly 85% of the smoke released is inhaled by the smoker himself and others in the vicinity, called passive smokers, are also affected. Guidance or counselling should be done in such users to withdraw this habit.

Unit – 7
Body Fluids and Circulation

Animals particularly larger animals like mammals, are more active. They depend on locomotion to find food which is an energy consuming process. Nervous system is required to coordinate activities by sending nerve impulses that involves energy. All living cells have to be supplied with nutrients, oxygen and other substances and have to remove CO2 and waste products from them. It is therefore essential to have efficient mechanisms for transport of these substances to and from the cells. Different groups of animals have evolved different methods of transport. Very small organisms like the sponges and coelenterates lack a circulatory system. Water from their surroundings enters their body cavity to facilitate the cells to exchange substances by diffusion. More complex organisms use special fluids and well organized transport systems within their body to transport such materials by bulk flow or connective transport with pumps. The phenomenon of bulk flow is fundamental to many physiological processes like respiration, digestion and excretion. The bulk flow of fluids can transport substances to long distances faster than by diffusion. The human circulatory system can circulate a millilitre of blood from the heart to feet and back again within 60 sec, rather than 60 years which may be needed if it were by diffusion.

Within our body the oxygen and carbon dioxide are exchanged in the lungs and tissues whereas nutrients from the digestive system are carried to the liver and the wastes from the tissues are carried by the blood and finally removed by the kidneys. The hormones are transported to their target organs. Circulatory system helps to maintain the homeostasis of the body fluids and body temperature (heat exchange).

The homeostatic regulation of the cardio vascular system maintains blood flow, or perfusion, to the heart and brain. In vasovagal syncope (fainting), signals from the nervous system cause a sudden decrease in blood pressure, and the individual faints from lack of oxygen to the brain.

In this chapter you will learn how the heart and blood vessels work together most of the time to prevent such problems.

Body fluids

The body fluid consists of water and substances dissolved in them. There are two types of body fluids, the intracellular fluid present inside the cells and the extracellular fluid present outside the cells. The three types of extracellular fluids are the interstitial fluid or tissue fluid (surrounds the cell), the plasma (fluid component of the blood) and lymph. The blood flowing into the capillary from an arteriole has a high hydrostatic pressure. This pressure is brought about by the pumping action of the blood and it tends to force water and small molecules out through the permeable walls of the capillary into the tissue fluid.

The volume of fluid which leaves the capillary to form tissue fluid is the result of two pressure (hydrostatic pressure and Oncotic pressure). At the anterior end of the capillary bed, the water potential is lesser than hydrostatic pressure inside the capillary bed which is enough to push fluid into the tissues. The tissue fluid has low concentration of protien than that of plasma. At the venous end of the capillary bed, the water potential is greater than the hydrostatic pressure and the fluid from the tissues flows into the capillary and water is drawn back into the blood, taking with it waste products produced by the cells.

Composition of Blood

Blood is the most common body fluid that transports substances from one part of the body to the other. Blood is a connective tissue consisting of plasma (fluid matrix) and formed elements. The plasma constitutes 55% of the total blood volume. The remaining 45% is the formed elements that consist of blood cells. The average blood volume is about 5000ml (5L) in an adult weighing 70 Kg.

Plasma

Plasma mainly consists of water (80-92%) in which the plasma proteins, inorganic constituents (0.9%), organic constituents (0.1%) and respiratory gases are dissolved. The four main types of plasma proteins synthesized in the liver are albumin, globulin, prothrombin and fibrinogen. Albumin maintains the osmotic pressure of the blood.

Globulin facilitates the transport of ions, hormones, lipids and assists in immune function. Both Prothrombin and Fibrinogen are involved in blood clotting. Organic constituents include urea, amino acids, glucose, fats and vitamins and the inorganic constituents include chlorides, carbonates and phosphates of potassium, sodium, calcium and magnesium. The composition of plasma is not always constant. Immediately after a meal, the blood in the hepatic portal vein has a very high concentration of glucose as it is transporting glucose from the intestine to the liver where it is stored. The concentration of the glucose in the blood gradually falls after sometime as most of the glucose is absorbed. If too much of protein is consumed, the body cannot store the excess amino acids formed from the digestion of proteins. The liver breaks down the excess amino acids and produces urea. Blood in the hepatic vein has a high concentration of urea than the blood in other vessels namely, hepatic portal vein and hepatic artery.

Liver receives its blood supply from two sources: the hepatic artery brings oxygenated blood from the heart, while the hepatic portal vein brings blood from the intestine and other abdominal organs. The blood is returned from the liver to the heart by the hepatic veins.

Formed elements

Red blood cells/corpuscles (erythrocytes), white blood cells/corpuscles (Leucocytes) and platelets are collectively called formed elements.

Red blood cells

Red blood cells are abundant than the other blood cells. There are about 5 million to 5.5 millions of RBC mm^{-3} of blood in a healthy man and 4.5-5.0 millions of RBC mm^{-3} in healthy women. The RBCs are very small with the diameter of about 7µm (micrometer). The structure of RBC is shown in Figure 7.1. The red colour of the RBC is due to the presence of a respiratory pigment, haemoglobin dissolved in the cytoplasm. Haemoglobin plays an important role in the transport of respiratory gases and facilitates the exchange of gases with the fluid outside the cell (tissue fluid). The biconcave shaped RBCs increases the surface area to volume ratio, hence oxygen diffuses quickly in and out of

the cell. The RBCs are devoid of nucleus, mitochondria, ribosomes and endoplasmic reticulum. The absence of these organelles accommodates more haemoglobin thereby maximising the oxygen carrying capacity of the cell. The average life span of RBCs in a healthy individual is about 120 days after which they are destroyed in the spleen (graveyafor reuse. Erythropoietin is a hormone secreted by the kidneys in response to low oxygen and helps in differentiation of stem cells of the bone marrow to erythrocytes (erythropoiesis) in adults. The ratio of red blood cells to blood plasma is expressed as Haematocrit (packed cell volume).

White blood cells (leucocytes) are colourless, amoeboid, nucleated cells devoid of haemoglobin and other pigments. Approximately 6000 to 8000 per cubic mm of WBCs are seen in the blood of an average healthy individual. Depending on the presence or absence of granules, WBCs are divided into two types, granulocytes and agranulocytes. Granulocytes are characterised by the presence of granules in the cytoplasm and are differentiated in the bone marrow. The granulocytes include neutrophils, eosinophils and basophils.

Neutrophils are also called heterophils or polymorphonuclear (cells with 3-4 lobes of nucleus connected with delicate threads) cells which constitute about 60%- 65% of the total WBCs. They are phagocytic in nature and appear in large numbers in and around the infected tissues.

Eosinophils have distinctly bilobed nucleus and the lobes are joined by thin strands. They are non-phagocytic and constitute about 2-3% of the total WBCs. Eosinophils increase during certain types of parasitic infections and allergic reactions.

Basophils are less numerous than any other type of WBCs constituting 0.5%- 1.0% of the total number of leucocytes. The cytoplasmic granules are large sized, but fewer than eosinophils. Nucleus is large sized and constricted into several lobes but not joined by delicate threads. Basophils secrete substances such as heparin, serotonin and histamines. They are also involved in inflammatory reactions.

Agranulocytes are characterised by the absence of granules in the cytoplasm and are differentiated in the lymph glands and spleen. These

are of two types, lymphocytes and monocytes. Lymphocytes constitute 28% of WBCs. These have large round nucleus and small amount of cytoplasm. The two types of lymphocytes are B and T cells. Both B and T cells are responsible for the immune responses of the body. B cells produce antibodies to neutralize the harmful effects of foreign substances and T cells are involved in cell mediated immunity.

Monocytes (Macrophages) are phagocytic cells that are similar to mast cells and have kidney shaped nucleus. They constitute 1-3% of the total WBCs. The macrophages of the central nervous system are the 'microglia', in the sinusoids of the liver they are called 'Kupffer cells' and in the pulmonary region they are the 'alveolar macrophages'.

Platelets are also called thrombocytes that are produced from megakaryocytes (special cells in bone marrow) and lack nuclei. Blood normally contains 1, 50,000 -3, 50,000 platelets mm23 of blood. They secrete substances involved in coagulation or clotting of blood. The reduction in platelet number can lead to clotting disorders that result in excessive loss of blood from the body.

Blood groups

Commonly two types of blood groupings are done. They are ABO and Rh which are widely used all over the world.

ABO blood grouping

Depending on the presence or absence of surface antigens on the RBCs, blood group in individual belongs to four different types namely, A, B, AB and O. The plasma of A, B and O individuals have natural antibodies (agglutinins) in them. Surface antigens are called agglutinogens. The antibodies (agglutinin) acting on agglutinogen A is called anti A and the agglutinin acting on agglutinogen B is called anti B. Agglutinogens are absent in O blood group. Agglutinogens A and B are present in AB blood group and do not contain anti A and anti B in them. Distribution of antigens and antibodies in blood groups are shown in Table 7.1. A, B and O are major allelic genes in ABO systems. All agglutinogens contain sucrose, D-galactose, N-acetyl glucosamine and 11 terminal amino acids. The attachments of the terminal amino acids

are dependent on the gene products of A and B. The reaction is catalysed by glycosyl transferase.

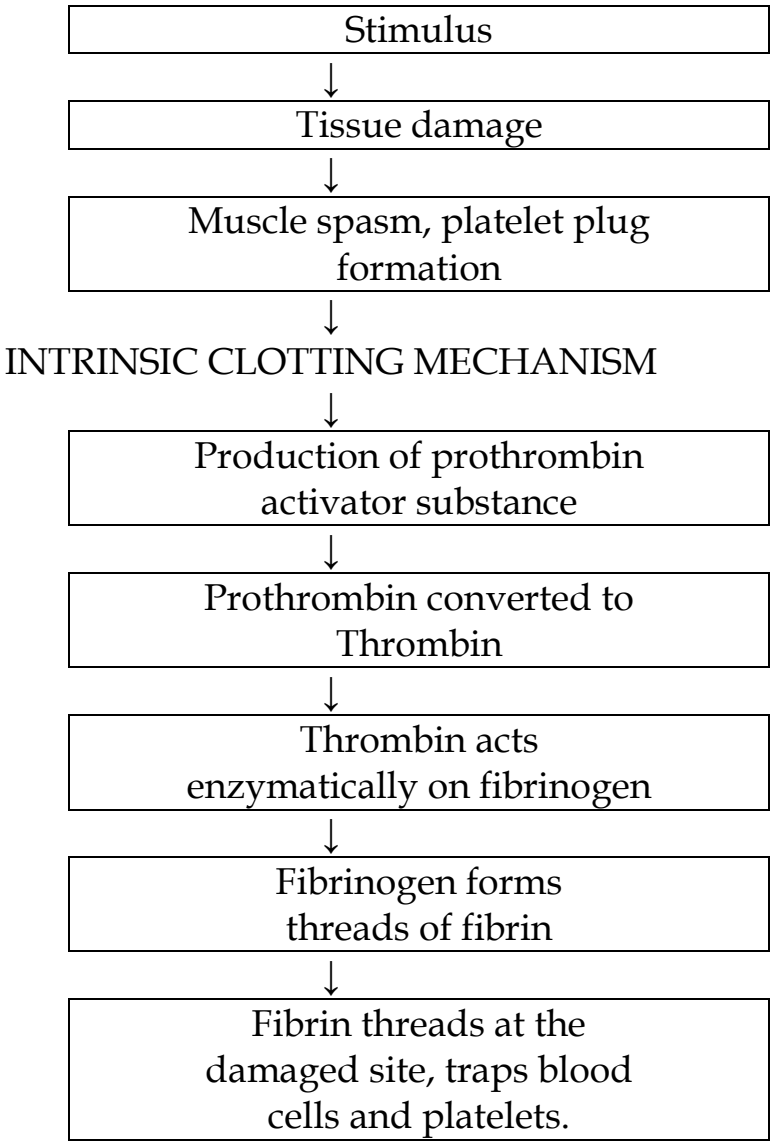
Blood group	Agglutinogens (antigens) on the RBC`	Agglutinin (antibodies) in the plasma
A	A	Anti B
B	B	Anti A
AB	AB	No antibodies
O	No antigens	Anti A and Anti B

Rh factor is a protein (D antigen) present on the surface of the red blood cells in majority (80%) of humans. This protein is similar to the protein present in Rhesus monkey, hence the term Rh. Individuals who carry the antigen D on the surface of the red blood cells are Rh1 (Rh positive) and the individuals who do not carry antigen D, are Rh2 (Rh negative). Rh factor compatibility is also checked before blood transfusion. When a pregnant women is Rh2 and the foetus is Rh1 incompatibility (mismatch) is observed. During the first pregnancy, the Rh2 antigens of the foetus does not get exposed to the mother's blood as both their blood are separated by placenta. However, small amount of the foetal antigen becomes exposed to the mother's blood during the birth of the first child. The mother's blood starts to synthesize D antibodies. But during subsequent pregnancies the Rh antibodies from the mother (Rh2) enters the foetal circulation and destroys the foetal RBCs. This becomes fatal to the foetus because the child suffers from anaemia and jaundice. This condition is called erythroblastosis foetalis. This condition can be avoided by administration of anti D antibodies (Rhocum) to the mother immediately after the first child birth.

Coagulation of blood

If you cut your finger or when you get yourself hurt, your wound bleeds for some time after which it stops to bleed. This is because the blood clots or coagulates in response to trauma. The mechanism by which excessive blood loss is prevented by the formation of clot is called blood coagulation or clotting of blood. Schematic representation of blood coagulation. The clotting process begins when the endothelium of the blood vessel is damaged and the connective tissue in its wall is

exposed to the blood. Platelets adhere to collagen fibres in the connective tissue and release substances that form the platelet plug which provides emergency protection against blood loss. Clotting factors released from the clumped platelets or damaged cells mix with clotting factors in the plasma. The protein called prothrombin is converted to its active form called thrombin in the presence of calcium and vitamin K. Thrombin helps in the conversion of fibrinogen to fibrin threads. The threads of fibrins become interlinked into a patch that traps blood cell and seals the injured vessel until the wound is healed. After sometime fibrin fibrils contract, squeezing out a straw-coloured fluid through a meshwork called serum (Plasma without fibrinogen is called serum). Heparin is an anticoagulant produced in small quantities by mast cells of connective tissue which prevents coagulation in small blood vessels.



Schematic representation of
blood coagulation in an injured blood vessel

Composition of lymph and its functions

About 90% of fluid that leaks from capillaries eventually seeps back into the capillaries and the remaining 10% is collected and returned to blood system by means of a series of tubules known as lymph vessels or lymphatics. The fluid inside the lymphatics is called lymph. The lymphatic system consists of a complex network of thin walled ducts (lymphatic vessels), filtering bodies (lymph nodes) and a large number of lymphocytic cell concentrations in various lymphoid organs. The lymphatic vessels have smooth walls that run parallel to the blood vessels, in the skin, along the respiratory and digestive tracts. These vessels serve as return ducts for the fluids that are continually diffusing out of the blood capillaries into the body tissues.

Lymph fluid must pass through the lymph nodes before it is returned to the blood. The lymph nodes that filter the fluid from the lymphatic vessels of the skin are highly concentrated in the neck, inguinal, axillaries, respiratory and digestive tracts. The lymph fluid flowing out of the lymph nodes flow into large collecting duct which finally drains into larger veins that runs beneath the collar bone, the subclavian vein and is emptied into the blood stream. The narrow passages in the lymph nodes are the sinusoids that are lined with macrophages. The lymph nodes successfully prevent the invading microorganisms from reaching the blood stream. Cells found in the lymphatics are the lymphocytes. Lymphocytes collected in the lymphatic fluid are carried via the arterial blood and are recycled back to the lymph. Fats are absorbed through lymph in the lacteals present in the villi of the intestinal wall.

Blood vessels – Arteries, Veins and capillaries

The vessels carrying the blood are of three types; they are the arteries, veins and capillaries. These vessels are hollow structures and have complex walls surrounding the lumen. The blood vessels in humans are composed of three layers, tunica intima, tunica media and tunica externa. The inner layer, tunica intima or tunica interna supports

the vascular endothelium, the middle layer, tunica media is composed of smooth muscles and an extra cellular matrix which contains a protein, elastin. The contraction and relaxation of the smooth muscles results in vasoconstriction and vasodilation. The outer layer, tunica externa or tunica adventitia is composed of collagen fibres. The structure of blood vessels is illustrated.

Arteries

The blood vessels that carry blood away from the heart are called arteries. The arteries usually lie deep inside the body. The walls of the arteries are thick, noncollapsible to withstand high pressure. Valves are absent and have a narrow lumen. All arteries carry oxygenated blood, except the pulmonary artery. The largest artery, the aorta (2.5 cm in diameter and 2 mm thick) branch into smaller arteries and culminates into the tissues as feed arteries. In the tissues the arteries branches into arterioles.

As blood enters an arteriole it may have a pressure of 85 mm Hg (11.3 KPa) but as it leaves and flows into the capillary, the pressure drops to 35 mm Hg (4.7 KPa). (Note 1 mm Hg =0.13 KPa. SI unit of mm Hg is KiloPascal (KPa)). Arterioles are small, narrow, and thin walled which are connected to the capillaries. A small sphincter lies at the junction between the arterioles and capillaries to regulate the blood supply. Arteries do not always branch into arterioles, they can also form anastomoses.

What are anastomoses? These are connections of one blood vessel (arteries) with another blood vessel. They provide alternate route of blood flow if the original blood vessel is blocked. For e.g., Arteries in the joints contain numerous anastomoses. This allows blood to flow freely even if one of the arteries closes during bending of the joints.

Capillaries

Capillary beds are made up of fine networks of capillaries. The capillaries are thin walled and consist of single layer of squamous epithelium. Tunica media and elastin fibres are absent. The capillary beds are the site for exchange of materials between blood and tissues.

The walls of the capillaries are guarded by semilunar valves. The blood volume in the capillaries is high but the flow of blood is slow. Mixed blood (oxygenated and deoxygenated) is present in the capillaries. The capillary bed may be flooded with blood or may be completely bypassed depending on the body conditions in a particular organ.

Veins

Veins have thinner walls and a larger lumen and hence can be easily stretched. They carry deoxygenated blood except, the pulmonary vein. The blood pressure is low and the lumen has a wide wall which is collapsible. Tunica media is thinner in veins than in arteries. Unidirectional flow of blood in veins is due to the presence of semilunar valves that prevents backflow of blood. Blood samples are usually taken from the veins rather than artery because of low pressure in the veins.

Coronary blood vessels

Blood vessels that supply blood to the cardiac muscles with all nutrients and removes wastes are the coronary arteries and veins. Heart muscle is supplied by two arteries namely right and left coronary arteries. These arteries are the first branch of the aorta. Arteries usually surround the heart in the manner of a crown, hence called coronary artery (L. Corona - crown).

Right ventricle and posterior portion of left ventricle are supplied by the right coronary artery. Anterior and lateral part of the left ventricle is supplied by the left coronary arteries.

Circulatory pathways

There are two types of circulatory systems, open and closed circulatory systems. Open circulatory system has haemolymph as the circulating fluid and is pumped by the heart, which flows through blood vessels into the sinuses. Sinuses are referred as haemocoel. Open circulatory system is seen in Arthropods and most Molluscs. In closed circulatory system blood is pumped by the heart and flows through blood vessels. Closed circulating system is seen in Annelids, Cephalopods and Vertebrates.

All vertebrates have muscular chambered heart. Fishes have two chambered heart. The heart in fishes consists of sinus venosus, an atrium, one ventricle and bulbus arteriosus or conus arteriosus. Single circulation is seen in fishes. Amphibians have two auricles and one ventricle and no inter ventricular septum whereas reptiles except crocodiles have two auricles and one ventricle and an incomplete inter ventricular septum. Thus mixing of oxygenated and deoxygenated blood takes place in the ventricles. This type of circulation is called incomplete double circulation. The left atrium receives oxygenated blood and the right atrium receives deoxygenated blood. Pulmonary and systemic circuits are seen in Amphibians and Reptiles. The Crocodiles, Birds and Mammals have two auricles or atrial chambers and two ventricles, the auricles and ventricles are separated by inter auricular septum and inter ventricular septum. Hence there is complete separation of oxygenated blood from the deoxygenated blood. Pulmonary and systemic circuits are evident. This type of circulation is called complete double circulation.

Human circulatory system

The structure of the heart was described by Raymond de viessens, in 1706. Human heart is made of special type of muscle called the cardiac muscle. It is situated in the thoracic cavity and its apex portion is slightly tilted towards left. It weighs about 300g in an adult. The size of our heart is roughly equal to a closed fist. Heart is divided into four chambers, upper two small auricles or atrium and lower two large ventricles. The walls of the ventricles are thicker than the auricles due to the presence of papillary muscles. The heart wall is made up of three layers, the outer epicardium, middle myocardium and inner endocardium. The space present between the membranes is called pericardial space and is filled with pericardial fluid.

The two auricles are separated by inter auricular septum and the two ventricles are separated by inter ventricular septum The separation of chambers avoids mixing of oxygenated and deoxygenated blood. The auricle communicates with the ventricle through an opening called auriculo ventricular aperture which is guarded by the auriculo ventricular valves. The opening between the right atrium and the right

ventricle is guarded by the tricuspid valve (three flaps or cusps), whereas a bicuspid (two flaps or cusps) or mitral valve guards the opening between the left atrium and left ventricle (Figure 7.6). The valves of the heart allows the blood to flow only in one direction, i.e., from the atria to the ventricles and from the ventricles to the pulmonary artery or the aorta. These valves prevent backward flow of blood.

The opening of right and left ventricles into the pulmonary artery and aorta are guarded by aortic and pulmonary valves and are called semilunar valves. Each semilunar valve is made of three halfmoon shaped cusps. The myocardium of the ventricle is thrown into irregular muscular ridges called trabeculae corneae. The trabeculae corneae are modified into chordae tendinae. The opening and closing of the semilunar valves are achieved by the chordae tendinae. The chordae tendinae are attached to the lower end of the heart by papillary muscles. Heart receives deoxygenated blood from various parts of the body through the inferior venacava and superior venacava which open into the right auricle. Oxygenated blood from lungs is drained into the left auricle through four pulmonary veins.

Origin and conduction of heart beat

The heart in human is myogenic (cardiomyocytes can produce spontaneous rhythmic depolarization that initiates contractions). The sequence of electrical conduction of heart is shown in Figure 7.7. The cardiac cells with fastest rhythm are called the Pacemaker cells, since they determine the contraction rate of the entire heart. These cells are located in the right sinuatrial (SA) node/ Pacemaker. On the left side of the right atrium is a node called auriculo ventricular node (AV node). Two special cardiac muscle fibres originate from the auriculo ventricular node and are called the bundle of His which runs down into the interventricular septum and the fibres spread into the ventricles. These fibres are called the Purkinje fibres.

Pacemaker cells produce excitation through depolarisation of their cell membrane. Early depolarisation is slow and takes place by sodium influx and reduction in potassium efflux. Minimum potential is required to activate voltage gated calcium (Ca+) channels that causes rapid

depolarisation which results in action potential. The pace maker cells repolarise slowly via K1 efflux.

HEART BEAT- Rhythmic contraction and expansion of heart is called heart beat. The contraction of the heart is called systole and the relaxation of the heart is called diastole. The heart normally beats 70-72 times per min in a human adult. During each cardiac cycle two sounds are produced that can be heard through a stethoscope. The first heart sound (lub) is associated with the closure of the tricuspid and bicuspid valves whereas second heart sound (dub) is associated with the closure of the semilunar valves. These sounds are of clinical diagnostic significance. An increased heart rate is called tachycardia and decreased heart rate is called bradycardia.

Cardiac Cycle

The events that occur at the beginning of heart beat and lasts until the beginning of next beat is called cardiac cycle. It lasts for 0.8 seconds. The series of events that takes place in a cardiac cycle.

PHASE 1: **Ventricular diastole-** The pressure in the auricles increases than that of the ventricular pressure. AV valves are open while the semi lunar valves are closed. Blood flows from the auricles into the ventricles passively.

PHASE 2: **Atrial systole -** The atria contracts while the ventricles are still relaxed. The contraction of the auricles pushes maximum volume of blood to the ventricles until they reach the end diastolic volume (EDV). EDV is related to the length of the cardiac muscle fibre. More the muscle is stretched, greater the EDV and the stroke volume.

PHASE 3: **Ventricular systole (isovolumetric contraction) –** The ventricular contraction forces the AV valves to close and increases the pressure inside the ventricles. The blood is then pumped from the ventricles into the aorta without change in the size of the muscle fibre length and ventricular chamber volume (isovolumetric contraction).

PHASE 4: **Ventricular systole (ventricular ejection) –** Increased ventricular pressure forces the semilunar valves to open and blood is

ejected out of the ventricles without backflow of blood. This point is the end of systolic volume (ESV).

PHASE 5: **(Ventricular diastole) –**The ventricles begins to relax, pressure in the arteries exceeds ventricular pressure, resulting in the closure of the semilunar valves. The heart returns to phase 1 of the cardiac cycle.

Cardiac output

The amount of blood pumped out by each ventricle per minute is called cardiac output(CO). It is a product of heart rate (HR) and stroke volume (SV). Heart rate or pulse is the number of beats per minute. Pulse pressure = systolic pressure – diastolic pressure. Stroke volume (SV) is the volume of blood pumped out by one ventricle with each beat. SV depends on ventricular contraction. CO = HR X SV. SV represents the difference between EDV (amount of blood that collects in a ventricle during diastole) and ESV (volume of blood remaining in the ventricle after contraction). SV = EDV - ESV. According to Frank – Starling law of the heart, the critical factor controlling SV is the degree to which the cardiac muscle cells are stretched just before they contract. The most important factor stretching cardiac muscle is the amount of blood returning to the heart and distending its ventricles, venous return. During vigorous exercise, SV may double as a result of venous return. Heart's pumping action normally maintains a balance between cardiac output and venous return. Because the heart is a double pump, each side can fail independently of the other. If the left side of the heart fails, it results in pulmonary congestion and if the right side fails, it results in peripheral congestion. Frank – Starling effect protects the heart from abnormal increase in blood volume.

Blood Pressure

Blood pressure is the pressure exerted on the surface of blood vessels by the blood. This pressure circulates the blood through arteries, veins and capillaries. There are two types of pressure, the systolic pressure and the diastolic pressure. Systolic pressure is the pressure in the arteries as the chambers of the heart contracts. Diastolic pressure is the pressure in the arteries when the heart chambers relax. Blood

pressure is measured using a sphygmomanometer (BP apparatus). It is expressed as systolic pressure / diastolic pressure. Normal blood pressure in man is about 120/80mm Hg. Mean arterial pressure is a function of cardiac output and resistance in the arterioles. The primary reflex pathway for homeostatic control of mean arterial pressure is the baroreceptor reflex. The baroreceptor reflex functions every morning when you get out of bed. When you are lying flat the gravitational force is evenly distributed. When you stand up, gravity causes blood to pool in the lower extremities. The decrease in blood pressure upon standing is known as orthostatic hypotension. Orthostatic reflex normally triggers baroreceptor reflex. This results in increased cardiac output and increased peripheral resistance which together increase the mean arterial pressure.

Electrocardiogram (ECG)

An electrocardiogram (ECG) records the electrical activity of the heart over a period of time using electrodes placed on the skin, arms, legs and chest. It records the changes in electrical potential across the heart during one cardiac cycle. The special flap of muscle which initiates the heart beat is called as sinu-auricular node or SA node in the right atrium. It spreads as a wave of contraction in the heart. The waves of the ECG are due to depolarization and not due to contraction of the heart. This wave of depolarisation occurs before the beginning of contraction of the cardiac muscle. A normal ECG shows 3 waves designated as P wave, QRS complex and T wave.

P Wave (Atrial depolarisation)

It is a small upward wave and indicates the depolarisation of the atria. This is the time taken for the excitation to spread through atria from SA node. Contraction of both atria lasts for around 0.8-1.0 sec.

PQ Interval (AV node delay)

It is the onset of P wave to the onset of QRS complex. This is from the start of depolarisation of the atria to the beginning of ventricular depolarisation. It is the time taken for the impulse to travel from the

atria to the ventricles (0.12-0.21sec). It is the measure of AV conduction time.

QRS Complex (Ventricular depolarisation)

No separate wave for atrial depolarization in the ECG is visible. Atrial depolarization occurs simultaneously with the ventricular depolarisation. The normal QRS complex lasts for 0.06-0.09 sec. QRS complex is shorter than the P wave, because depolarization spreads through the Purkinjie fibres. Prolonged QRS wave indicates delayed conduction through the ventricle, often caused due to ventricular hypertrophy or due to a block in the branches of the bundle of His.

ST Segment

It lies between the QRS complex and T wave. It is the time during which all regions of the ventricles are completely depolarized and reflects the long plateau phase before repolarisation. In the heart muscle, the prolonged depolarisation is due to retardation of K+ efflux and is responsible for the plateau. The ST segment lasts for 0.09 sec.

T wave (Ventricular repolarisation)

It represents ventricular repolarisation. The duration of the T wave is longer than QRS complex because repolarisation takes place simultaneously throughout the ventricular depolarisation.

Double circulation

Circulation of the blood was first described by William Harvey (1628). There are two types of blood circulation in vertebrates, single circulation and double circulation.

The blood circulates twice through the heart first on the right side then on the left side to complete one cardiac cycle.

The complete double blood circulation is more prominent in mammals because of the complete partition of all the chambers (Auricles and ventricles) in the heart.

In systemic circulation, the oxygenated blood entering the aorta from the left ventricle is carried by a network of arteries, arterioles and capillaries to the tissues. The deoxygenated blood from the tissue is collected by venules, veins and vena cava and emptied into the right atrium. In pulmonary circulation, the blood from heart (right ventricle) is taken to the lungs by pulmonary artery and the oxygenated blood from the lungs is emptied into the left auricle by the pulmonary vein.

Completely separated circuits have an important advantage. Different pressures are maintained in the pulmonary and systemic circulation. Why is this advantageous? In the lungs the capillaries must be very thin to allow gas exchange, but if the blood flows through these thin capillaries under high pressure the fluid can leak through or ruptures the capillary walls and can accumulate in the tissues. This increases the diffusion distance and reduces the efficiency of the gas exchange. In contrast high pressure is required to force blood through the long systemic circuits. Hence the arteries close to the heart have increased pressure than the arteries away from the heart. Completely separated circuits (pulmonary and systemic) allow these two different demands to be met with.

Regulation of cardiac activity

The type of heart in human is myogenic because the heart beat originates from the muscles of the heart. The nervous and endocrine systems work together with paracrine signals (metabolic activity) to influence the diameter of the arterioles and alter the blood flow. The neuronal control is achieved through autonomic nervous system (sympathetic and parasympathetic). Sympathetic neurons release norepinephrine and adrenal medulla releases epinephrine. The two hormones bind to β – adrenergic receptors and increase the heart rate. The parasympathetic neurons secrete acetylcholine that binds to muscarinic receptors and decreases the heart beat. Vasopressin and angiotensin II, involved in the regulation of the kidneys, results in vasoconstriction while natriuretic peptide promotes vasodilation. Vagus nerve is a parasympathetic nerve that supplies the atrium especially the SA and the AV nodes.

Disorders of the circulatory system

Hypertension

Hypertension is the most common circulatory disease. The normal blood pressure in man is 120/80 mmHg. In cases when the diastolic pressure exceeds 90 mm Hg and the systolic pressure exceeds 150 mm Hg persistently, the condition is called hypertension. Uncontrolled hypertension may damage the heart, brain and kidneys.

Coronary heart disease

Coronary heart disease occurs when the arteries are lined by atheroma. The buildup buildup of atheroma contains cholesterol, fibres, dead muscle and platelets and is termed Atherosclerosis. The cholesterol rich atheroma forms plaques in the inner lining of the arteries making them less elastic and reduces the blood flow. Plaque grows within the artery and tends to form blood clots, forming coronary thrombus. Thrombus in a coronary artery results in heart attack.

Stroke

Stroke is a condition when the blood vessels in the brain bursts, (Brain haemorrhage) or when there is a block in the artery that supplies the brain, (atherosclerosis) or thrombus. The part of the brain tissue that is supplied by this damaged artery dies due to lack of oxygen (cerebral infarction).

Angina pectoris

Angina pectoris (ischemic pain in the heart muscles) is experienced during early stages of coronary heart disease. Atheroma may partially block the coronary artery and reduce the blood supply to the heart. As a result, there is tightness or choking with difficulty in breathing. This leads to angina or chest pain. Usually it lasts for a short duration of time.

Myocardial infarction (Heart failure)

The prime defect in heart failure is a decrease in cardiac muscle contractility. The Frank- Starling curve shifts downwards and towards the right such that for a given EDV, a failing heart pumps out a smaller stroke volume than a normal healthy heart. When the blood supply to the heart muscle or myocardium is remarkably reduced it leads to death of the muscle fibres. This condition is called heart attack or myocardial infarction. The blood clot or thrombosis blocks the blood supply to the heart and weakens the muscle fibres. It is also called Ischemic heart disease due to lack of oxygen supply to the heart muscles. If this persists it leads to chest pain or angina. Prolonged angina leads to death of the heart muscle resulting in heart failure.

Rheumatoid Heart Disease

Rheumatic fever is an autoimmune disease which occurs 2-4 weeks after throat infection usually a streptococcal infection. The antibodies developed to combat the infection cause damage to the heart. Effects include fibrous nodules on the mitral valve, fibrosis of the connective tissue and accumulation of fluid in the pericardial cavity.

Diagnosis and Treatment

Angiogram

Angiogram is a procedure that uses a special dye and X-ray to see how blood flows through the coronary arteries of the heart and it can be used to detect abnormality in the blood vessels through out the body.

Angioplasty

Angioplasty is the stretching of an artery that is narrowed due to atherosclerosis. The risk involved in this procedure is minimal. During an angioplasty a small long balloon catheter is threaded through the blocked artery. A deflated balloon is attached to the catheter and the balloon is inflated to widen the arterial wall. Then the tube and the balloon are removed. A small metal scaffold called stent is left in place. This scaffolding keeps the blood vessel open and allows free flow of

blood. Slow releasing stents are now available that can release chemicals to prevent further block of the artery.

Varicose veins The veins are so dilated that the valves prevent back flow of blood. The veins lose their elasticity and become congested. Common sites are legs, rectal-anal regions (haemorrhoids), the oesophagus and the spermatic cord.

Embolism is the obstruction of the blood vessel by abnormal mass of materials such as fragment of the blood clot, bone fragment or an air bubble. Embolus may lodge in the lungs, coronary artery or liver and leads to death.

Aneurysm The weakened regions of the wall of the artery or veins bulges to form a balloon like sac. Unruptured aneurysm may exert pressure on the adjacent tissues or may burst causing massive haemorrhage.

Bypass Surgery

When the arteries that bring blood to the heart muscles (coronary artery) are blocked by plaque (accumulation of fat, cholesterol and other substances) the person is advised to undergo Bypass surgery. After the surgery the blood flow to coronary artery is increased and the person is relieved from chest pain. This is a major surgery where damaged blood vessel is replaced by the healthy one taken from different part of the body. Mostly it is taken from legs. During this surgery patients blood system is connected with a pump oxygenator (heart lung machine). After the completion of the surgery the blood vessel is connected to normal the circulation and the blood flows freely.

Heart Transplantation

A heart transplant is a surgical transplantation procedure which is done to replace a diseased or a damaged heart. This procedure is performed on a patient with end stage heart failure or severe coronary artery disease, when other medical ailments or surgical treatments have failed. The most common procedure is to take a functioning heart from a brain dead person (organ donor) and is transplanted in a person with a

damaged heart. After the heart transplant the average life span of the person increases.

Cardio pulmonary resuscitation (CPR)

In 1956, James Elam and Peter Safar were the first to use mouth to mouth resuscitation. CPR is a life saving procedure that is done at the time of emergency conditions such as when a person's breath or heart beat has stopped abruptly in case of drowning, electric shock or heart attack. CPR includes rescue of breath, which is achieved by mouth to mouth breathing, to deliver oxygen to the victim's lungs by external chest compressions which helps to circulate blood to the vital organs. CPR must be performed within 4 to 6 minutes after cessation of breath to prevent brain damage or death. Along with CPR, defibrillation is also done. Defibrillation means a brief electric shock is given to the heart to recover the function of the heart.

Each year over several million people worldwide die of heart disease, than from other conditions. For some patients heart transplant is the only hope. Raju was 62 years old when muscles of both the ventricles had deteriorated. He was lucky enough because biomedical engineers were able develop a pumping device called 'total artificial heart'. Raju's heart was completely removed and an artificial heart was put in place. He was able to go home within a few weeks. This artificial heart would have kept him in alive until suitable real heart was available for transplant.

First heart transplantation was performed in the year 1959. Human heart transplant was performed by Prof. Christian Bernard in South Africa in the year 1967, December 3 at Groote Schuur Hospital, Cape Town. Dr Anangipalli Venugopal was the first to perform heart transplant at AIIMS, India on August 3, 1994

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unit 8 - Excretion

Earliest animal life forms arose around 700 million years ago. They were marine organisms like the modern sponges. Each cell of a modern sponge is surrounded by sea water, but it maintains an intracellular ionic composition different from that of the sea water. Evolution led to changes in the organisation of the tissue layers followed by formation of specialized external tissue layers. This provided a barrier between the external environment and internal fluid resulting in the formation of extracellular fluid. Major changes in osmoregulation and ionic regulation occurred during the evolution of chordates. The ability to control extracellular fluid composition was essential for the diversification of animals to inhabit brackish water, fresh water and land. Animals that invaded land had the risk of desiccation and were unable to excrete metabolic waste directly into the water; hence there was a need for an alternate pathway to dispose the nitrogenous wastes.

Most animals rely on kidneys to control ionic and water balance. Some animals depend on external tissues such as the gills, skin and digestive mucosa to collectively regulate three homeostatic processes namely, osmotic regulation, ionic regulation and nitrogen excretion. Osmotic regulation is the control of tissue osmotic pressure which acts as a driving force for movement of water across biological membranes. Ionic regulation is the control of the ionic composition of body fluids. The process by which the body gets rid of the nitrogenous waste products of protein metabolism is called excretion. Nitrogen excretion is the pathway by which animals excrete ammonia, the toxic nitrogenous end product of protein catabolism. The removal of ammonia or other metabolic alternatives such as urea and uric acid is linked to ionic and osmotic homeostasis.

Fresh water vertebrates maintain higher salt concentrations in their body fluids; marine vertebrates maintain lower salt concentrations in their body fluids and terrestrial animals have more water in their body than the surrounding hence tend to lose water by evaporation. Osmoconformers are able to change their internal osmotic concentration with change in external environment as in marine molluscs and sharks.

Osmoregulators maintain their internal osmotic concentration irrespective of their external osmotic environment (example: Otters). Depending on the ability to tolerate changes in the external environment, animals are classified as stenohaline and euryhaline. The stenohaline animals can tolerate only narrow fluctuations in the salt concentration (example: Gold fish), whereas the euryhaline animals are able to tolerate wide fluctuations in the salt concentrations eg., Artemia, Tilapia and salmons.

The major nitrogenous waste products are ammonia, urea and uric acid. Other waste products of protein metabolism are trimethyl amine oxide (TMO) in marine teleosts, guanine in spiders, hippuric acid, allantonin, allantoic acid, ornithuric acid, creatinine, creatine, purines, pyramidines and pterines.

Modes of Excretion

Excretory system helps in collecting nitrogenous waste and expelling it into the external environment. Animals have evolved different strategies to get rid of these nitrogenous wastes. Ammonia produced during amino acid breakdown is toxic hence must be excreted either as ammonia, urea or uric acid. The type of nitrogenous end product an animal excretes depends upon the habitat of the animal. Ammonia requires large amount of water for its elimination, whereas uric acid, being the least toxic can be removed with the minimum loss of water, and urea can be stored in the body for considerable periods of time, as it is less toxic and less soluble in water than ammonia.
Animals that excrete most of its nitrogen in the form of ammonia are called ammonoteles. Many fishes, aquatic amphibians and aquatic insects are ammonotelic. In bony fishes, ammonia diffuses out across the body surface or through gill surface as ammonium ions. Reptiles, birds, land snails and insects excrete uric acid crystals, with a minimum loss of water and are called uricoteles. In terrestrial animals, less toxic urea and uric acid are produced to conserve water. Mammals and terrestrial amphibians mainly excrete urea and are called ureoteles. Earthworms while in soil are ureoteles and when in water are ammonoteles.

The animal kingdom presents a wide variety of excretory structures. Most invertebrates have a simple tubular structure in the

form of primitive kidneys called protonephridia and metanephridia. Vertebrates have complex tubular organs called kidneys. Protonephridia are excretory structures with specialized cells in the form of flame cells (cilia) in Platyhelminthes (example tapeworm) and Solenocytes (flagella) in Amphioxus. Nematodes have rennette cells, Metanephridia are the tubular excretory structures in annelids and molluscs. Malpighian tubules are the excretory structures in most insects. Antennal glands or green glands perform excretory function in crustaceans like prawns. Vertebrate kidney differs among taxa in relation to the environmental conditions.

Nephron is the structural and functional unit of kidneys. Reptiles have reduced glomerulus or lack glomerulus and Henle's loop and hence produce very little hypotonic urine, whereas mammalian kidneys produce concentrated (hyperosmotic) urine due to the presence of long Henle's loop. The Loop of Henle of the nephron has evolved to form hypertonic urine. Aglomerular kidneys of marine fishes produce little urine that is isoosmotic to the body fluid. Amphibians and fresh water fish lack Henle loop hence produce dilute urine (hypoosmotic).

The average bladder holds between 300ml and 600ml of urine. If the urinary system is healthy, urine may stay in the bladder for up to about 5 hours before excretion, depending on the amount of liquid consumed. Nerves send signals to the brain when the bladder needs to be emptied, with this indication one will feel the urge to empty the bladder. The muscle in the bladder wall is called the 'detrusor' muscle. One may suffer from stress if the muscles supporting the bladder are weakened. Pelvic floor exercise helps to strengthen these muscles.

Human excretory system
Structure of kidney

Excretory system in human consists of a pair of kidneys, a pair of ureters, urinary bladder and urethra (Figure. 8.2). Kidneys are reddish brown, bean shaped structures that lie in the superior lumbar region between the levels of the last thoracic and third lumber vertebra close to the dorsal inner wall of the abdominal cavity. The right kidney is placed slightly lower than the left kidney. Each kidney weighs an average of 120-170 grams. The outer layer of the kidney is covered by three layers

of supportive tissues namely, renal fascia, perirenal fat capsule and fibrous capsule.

The longitudinal section of kidney, an outer cortex, inner medulla and pelvis. The medulla is divided into a few conical tissue masses called medullary pyramids or renal pyramids. The part of cortex that extends in between the medullary pyramids is the renal columns of Bertini. The centre of the inner concave surface of the kidney has a notch called the renal hilum, through which ureter, blood vessels and nerves innervate. Inner to the hilum is a broad funnel shaped space called the renal pelvis with projection called calyces. The renal pelvis is continuous with the ureter once it leaves the hilum. The walls of the calyces, pelvis and ureter have smooth muscles which contracts rhythmically. The calyces collect the urine and empties into the ureter, which is stored in the urinary bladder temporarily. The urinary bladder opens into the urethra through which urine is expelled out.

Structure of a nephron

Each kidney has nearly one million complex tubular structures called nephron (Figure 8.4). Each nephron consists of a filtering corpuscle called renal corpuscle (malpighian body) and a renal tubule. The renal tubule opens into a longer tubule called the collecting duct. The renal tubule begins with a double walled cup shaped structure called the Bowman's capsule, which encloses a ball of capillaries that delivers fluid to the tubules, called the glomerulus . The Bowman's capsule and the glomerulus together constitute the renal corpuscle. The endothelium of glomerulus has many pores (fenestrae). The external parietal layer of the Bowman's capsule is made up of simple squamous epithelium and the visceral layer is made of epithelial cells called podocytes. The podocytes end in foot processes which cling to the basement membrane of the glomerulus. The openings between the foot processes are called filtration slits.

The renal tubule continues further to form the proximal convoluted tubule[PCT] followed by a U-shaped loop of Henle (Henle's loop) that has a thin descending and a thick ascending limb. The ascending limb continues as a highly coiled tubular region called the distal convoluted tubule [DCT]. The DCT of many nephrons open into a

straight tube called collecting duct. The collecting duct runs through the medullary pyramids in the region of the pelvis. Several collecting ducts fuse to form papillary duct that delivers urine into the calyces, which opens into the renal pelvis.

In the renal tubules, PCT and DCT of the nephron are situated in the cortical region of the kidney whereas the loop of Henle is in the medullary region. In majority of nephrons, the loop of Henle is too short and extends only very little into the medulla and are called cortical nephrons. Some nephrons have very long loop of Henle that run deep into the medulla and are called juxta medullary nephrons (JMN)
The capillary bed of the nephrons- First capillary bed of the nephron is the glomerulus and the other is the peritubular capillaries. The glomerular capillary bed is different from other capillary beds in that it is supplied by the afferent and drained by the efferent arteriole. The efferent arteriole that comes out of the glomerulus forms a fine capillary network around the renal tubule called the peritubular capillaries. The efferent arteriole serving the juxta medullary nephron forms bundles of long straight vessel called vasa recta and runs parallel to the loop of Henle. Vasa recta is absent or reduced in cortical nephrons.

Mechanism of urineformation in human

The nitrogenous waste formed as a result of breakdown of amino acids is converted to urea in the liver by the Ornithine cycle or urea cycle. Urine formation involves three main processes namely, glomerular filtration, tubular reabsorption and tubular secretion.

i) Glomerular Filtration: Blood enters the kidney from the renal artery, into the glomerulus. Blood is composed of large quantities of water, colloidal proteins, sugars, salts and nitrogenous end product. The first step in urine formation is the filtration of blood that takes place in the glomerulus. This is called glomerular filtration which is a passive process. The fluid that leaves the glomerular capillaries and enters the Bowman's capsule is called the glomerular filtrate. The glomerular membrane has a large surface area and is more permeable to water and small molecules present in the blood plasma. Blood enters the glomerulus faster with greater force through the afferent arteriole and leaves the glomerulus through the efferent arterioles, much slower. This

force is because of the difference in sizes between the afferent and efferent arteriole (afferent arteriole is wider than efferent arteriole) and glomerular hydrostatic pressure which is around 55mm Hg.

Kidneys produce about 180L of glomerular filtrate in 24 hours. The molecules such as water, glucose, amino acids and nitrogenous substances pass freely from the blood into the glomerulus. Molecules larger than 5nm are barred from entering the tubule. Glomerular pressure is the chief force that pushes water and solutes out of the blood and across the filtration membrane. The glomerular blood pressure (approximately 55 mmHg) is much higher than in other capillary beds. The two opposing forces are contributed by the plasma proteins in the capillaries. These includes, colloidal osmotic pressure (30 mmHg) and the capsular hydrostatic pressure (15 mmHg) due to the fluids in the glomerular capsule. The net filtration pressure of 10 mmHg is responsible for the renal filtration.

Net filtration Pressure 5 Glomerular
hydrostatic pressure 2 (Colloidal osmotic
pressure 1 Capsular hydrostatic pressure).

Net filtration pressure 5 55 mmHg
2 (30 mmHg 1 15 mmHg)5 10mmHg

The effective glomerular pressure of 10 mmHg results in ultrafiltration. Glomerular filtration rate (GFR) is the volume of filtrate formed min21 in all nephrons (glomerulus) of both the kidneys. In adults the GFR is approximately 120-125mL/min. Blood from the glomerulus is passed out through the efferent arteriole. The smooth muscle of the efferent arteriole contract resulting in vasoconstriction. Table 8.1 shows the relative concentrations of substances in the blood plasma and the glomerular filtrate. The glomerular filtrate is similar to blood plasma except that there are no plasma proteins.

Renal clearance is a parameter that reflects the amount of solute passing from the plasma to the urine in a given period of time. If the renal clearance is equal to the GFR it means that there is efficient filtration with little reabsorption and secretion. It is one of the parameters used to identify the efficiency of the kidney.

Concentration of substances in the blood plasma and in the glomerular filtrate

Substance	Concentration in blood Plasma/g dm-3	Concentration in glomerular filtrate/g dm-3
Water	900	900
Proteins	80.0	0.05
Aminoacids	0.5	0.5
Glucose	1.0	1.0
Urea	0.3	0.3
Uric acid	0.04	0.04
Creatinine	0.01	0.01
Inorganic ions (mainly Na1, K1 and Cl2)	7.2	7.2

A person with cirrhosis of the liver has lower than normal levels of plasma proteins and higher than normal GFR. Explain why a decrease in plasma protein would increase GFR.

In cortical nephrons, blood from efferent arteriole flows into peritubular capillary beds and enters the venous
system carrying with it recovered solutes and water from the interstitial fluid that surrounds the tubule.

Tubular Reabsorption

This involves movement of the filtrate back into the circulation. The volume of filtrate formed per day is around 170-180 L and the urine released is around 1.5 L per day, i.e., nearly 99% of the glomerular filtrate that has to be reabsorbed by the renal tubules as it contains certain substances needed by the body. This process is called selective reabsorption. Reabsorption takes place by the tubular epithelial cells in different segments of the nephron either by active

transport or passive transport, diffusion and osmosis.

Proximal convoluted Tubule (PCT)- Glucose, lactate, amino acids, Na1 and water in the filtrate is reabsorbed in the PCT. Sodium is reabsorbed by active transport through sodium- potassium
(Na1 K1) pump in the PCT. Small amounts of urea and uric acid are also reabsorbed.

Descending limb of Henle's loop is permeable to water due the presence of aquaporins, but not permeable to salts. Water is lost in the descending limb, hence Na1 and Cl2 gets concentrated in the filtrate .

Ascending limb of Henle's loop is impermeable to water but permeable to solutes such as Na1, Cl2 and K1 .

The distal convoluted tubule recovers water and secretes potassium into the tubule. Na1, Cl2 and water remains in the filtrate of the DCT (Figure 8.9(d)). Most of the reabsorption from this point is dependent on the body's need and is regulated by hormones. Reabsorption of bicarbonate (HCO32) takes place to regulate the blood pH. Homeostasis of K1 and Na1 in the blood is also regulated in this region.

Aquaporins are water-permeable channels (membrane transport proteins) that allow water to move across the epithelial cells in relation to the osmotic difference from the lumen to the interstitial fluid.

Collecting duct is permeable to water, secretes K1 (potassium ions are actively transported into the tubule) and reabsorbs Na1 to produce concentrated urine.

The change in permeability to water is due to the presence of number of water- permeable channels called aquaporins.

Tubular secretion- Substances such as H1, K1, NH41, creatinine and organic acids move into the filtrate from the peritubular capillaries into the tubular fluid. Most of the water is absorbed in the proximal convoluted tubule and Na1 is exchanged for water in the loop of Henle. Hypotonic fluid enters the distal convoluted tubule and substances such

as urea and salts pass from peritubular blood into the cells of DCT. The urine excreted contains both filtered and secreted substances. Once it enters the collecting duct, water is absorbed and concentrated hypertonic urine is formed. For every H1 secreted into the tubular filtrate, a Na1 is absorbed by the tubular cell. The H1 secreted combines with HCO32, HPO32 and NH32 and gets fixed as H2CO41, H2PO41 and NH41 respectively. Since H1 gets fixed in the fluid, reabsorption of H1 is prevented.

Osmolarity - The solute concentration of a solution of water is known as the solutions osmolarity, expressed as milliosmoles /liter (mOsm/L)

Formation of concentrated urine:

Formation of concentrated urine is accomplished by kidneys using counter current mechanisms. The major function of Henle's loop is to concentrate Na1 and Cl2. There is low osmolarity near the cortex and high osmolarity towards the medulla. This osmolarity in the medulla is due to the presence of the solute transporters and is maintained by the arrangement of the loop of Henle, collecting duct and vasa recta. This arrangement allows movement of solutes from the filtrate to the interstitial fluid. At the transition between the proximal convoluted tubule and the descending loop of Henle the osmolarity of the interstitial fluid is similar to that of the blood - about 300mOsm. Ascending and descending limbs of Henle, create a counter current multiplier (interaction between flow of filtrate through the limbs of Henle's and JMN) by active transport. Figure shows the counter current multiplier created by the long loops of Henle of the JM nephrons which creates medullary osmotic gradient. As the fluid enters the descending limb, water moves from the lumen into the interstitial fluid and the osmolarity decreases. To counteract this dilution the region of the ascending limb actively pumps solutes from the lumen into the interstitial fluid and the osmolarity increases to about 1200mOsm in medulla. This mismatch between water and salts creates osmotic gradient in the medulla. The osmotic gradient is also due to the permeability of the collecting duct to urea.

The vasa recta, maintains the medullary osmotic gradient via counter current exchanger (the flow of blood through the ascending and

descending vasa recta blood vessels) by passive transport. Figure 8.10 (b) shows counter current exchanger where the vasa recta preserves the medullary gradient while removing reabsorbed water and solutes. This system does not produce an osmotic gradient, but protects the medullaby removal of excess salts from the interstitial fluid and removing reabsorbed water. The vasa recta leave the kidney at the junction between the cortex and medulla. The interstitial fluid at this point is iso-osmotic to the blood. When the blood leaves the efferent arteriole and enters vasa recta the osmolarity in the medulla increases (1200mOsm) and results in passive uptake of solutes and loss of water. As the blood enters the cortex, the osmolarity in the blood decreases (300mOsm) and the blood loses solutes and gains water to form concentrated urine (hypertonic). Human kidneys can produce urine nearly four times concentrated than the initial filtrate formed.

List the pathways involved in the homeostatic compensation in case of severe dehydration.

Regulation of kidney function
ADH and Diabetes insipidus

The functioning of kidneys is efficiently monitored and regulated by hormonal feedback control mechanism involving the hypothalamus, juxta glomerular apparatus and to a certain extent the heart. Osmoreceptors in the hypothalamus are activated by changes in the blood volume, body fluid volume and ionic concentration. When there is excessive loss of fluid from the body or when there is an increase in the blood pressure, the osmoreceptors of the hypothalamus respond by stimulating the neurohypophysis to secrete the antidiuretic hormone (ADH) or vasopressin (a positive feedback). ADH facilitates reabsorption of water by increasing the number of aquaporins on the cell surface membrane of the distal convoluted tubule and collecting duct. This increase in aquaporins causes the movement of water from the lumen into the interstitial cells, thereby preventing excess loss of water by diuresis. When you drink excess amounts of your favourite juice, osmoreceptors of the hypothalamus is no longer stimulated and the release of ADH is suppressed from the neurohypophysis (negative feedback) and the aquaporins of the collecting ducts move into the cytoplasm. This makes the collecting ducts impermeable to water and

the excess fluid flows down the collecting duct without any water loss. Hence dilute urine is produced to maintain the blood volume. Vasopressin secretion is controlled by positive and negative feedback mechanism.

Angiotensin Converting Enzyme inhibitors (ACE inhibitors) are used to treat high blood pressure. Using a flow chart, explain why these drugs are helpful in treating hypertension.

Defects in ADH receptors or inability to secrete ADH leads to a condition called diabetes insipidus, characterized by excessive thirst and excretion of large quantities of dilute urine resulting in dehydration and fall in blood pressure.

Consider how different foods affect water and salt balance, and how the excretory system must respond to maintain homeostasis.

Renin angiotensin

Juxta glomerular apparatus (JGA) is a specialized tissue in the afferent arteriole of the nephron that consists of macula densa and granular cells. The macula densa cells sense distal tubular flow and affect afferent arteriole diameter, whereas the granular cells secrete an enzyme called renin. A fall in glomerular blood flow, glomerular blood pressure and glomerular filtration rate, can atctivate JG cells to release renin which converts a plasma protein, angiotensinogen (synthesized in the liver) to angiotensin I. Angiotensin converting enzyme (ACH) converts angiotensin I to angiotensin II. Angiotensin II stimulates Na1 reabsorption in the proximal convoluted tubule by vasoconstriction of the blood vessels and increases the glomerular blood pressure. Angiotensin II acts at different sites such as heart, kidney, brain, adrenal cortex and blood vessels. It stimulates adrenal cortex to secrete aldosterone that causes reabsorption of Na1 , K1 excretion and absorption of water from the distal convoluted tubule and collecting duct. This increases the glomerular blood pressure and glomerular filtration rate. This complex mechanism is generally known as Renin-Angiotensin- Aldosterone System (RAAS). Figure 8.11 shows the schematic representation of the the hypothalamus is no longer stimulated and the release of ADH is suppressed from the neurohypophysis (negative feedback) and the aquaporins of the

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schematic representation of the various hormones in the regulation of body fluid concentration.

Atrial natriuretic factor

Excessive stretch of cardiac atrial cells cause an increase in blood flow to the atria of the heart and release Atrial Natriuretic Peptide or factor (ANF) travels to the kidney where it increases Na^1 excretion and increases the blood flow to the glomerulus, acting on the afferent glomerular arterioles as a vasodilator or on efferent arterioles as a vasoconstrictor. It decreases aldosterone release from the adrenal cortex and also decreases release of renin, thereby decreasing angiotensin II. ANF acts antagonistically to the renin- angiotensin system, aldosterone and vasopressin.

Micturition

The process of release of urine from the bladder is called micturition or urination. Urine formed by the nephrons is ultimately carried to the urinary bladder where it is stored till it receives a voluntary signal from the central nervous system. The stretch receptors present in the urinary bladder are stimulated when it gets filled with urine. Stretching of the urinary bladder stimulates the CNS via the sensory neurons of the parasympathetic nervous system and brings about contraction of the bladder. Simultaneously, somatic motor neurons induce the sphincters to close. Smooth muscles contracts resulting in the opening of the internal sphincters passively and relaxing the external sphincter. When the stimulatory and inhibitory controls exceed the threshold, the sphincter opens and the urine is expelled out.
An adult human on an average excretes 1 to 1.5 L of urine per day. The urine formed is a yellow coloured watery fluid which is slightly acidic in nature (pH 6.0), Changes in diet may cause pH to vary between 4.5 to 8.0 and has a characteristic odour. The yellow colour of the urine is due to the presence of a pigment, urochrome. On an average, 25-30 gms of urea is excreted per day. Various metabolic disorders can affect the composition of urine. Analysis of urine helps in clinical diagnosis of various metabolic disorders and the malfunctioning of the kidneys. For example the presence of glucose (glucosuria) and ketone bodies (ketonuria) in the urine are indications of diabetes mellitus.

Hypotonic urine is formed when osmotic pressure of the body fluid is decreased due to water retention or solute loss when ADH secretion is lowered. If you drink large volume of water without eating anything salty, the total body fluid volume increases quickly and the osmolarity decreases. The kidneys increases the volume of urine excreted. The reverse happens when you eat salty food without drinking water.

Role of other organs in excretion

Apart from kidneys, organs such as lungs, liver and skin help to remove wastes. Our lungs remove large quantities of carbon dioxide (18 L/day) and significant quantities of water every day. Liver secretes bile containing substances like, bilirubin and biliverdin, cholesterol, steroid hormones, vitamins and drugs which are excreted out along with the digestive wastes.

Sweat and sebaceous glands in the skin eliminate certain wastes through their secretions. Sweat produced by the sweat glands primarily helps to cool the body and secondarily excretes Na1 and Cl2, small quantities of urea and lactate. Sebaceous glands eliminate certain substances like sterols, hydrocarbons and waxes through sebum that provides a protective oily covering for the skin. Small quantities of nitrogenous wastes are also excreted through saliva.

Disorders related to the Excretory System
Urinary tract infection

Female's urethra is very short and its external opening is close to the anal opening, hence improper toilet habits can easily carry faecal bacteria into the urethra. The urethral mucosa is continuous with the urinary tract and the inflammation of the urethra (urethritis) can ascend the tract to cause bladder inflammation (cystitis) or even renal inflammation (pyelitis or pyelonephritis). Symptoms include dysuria (painful urination), urinary urgency, fever and sometimes cloudy or blood tinged urine. When the kidneys are inflammed, back pain and severe headache often occur. Most urinary tract infections can be treated by antibiotics.

Renal Failure (Kidney Failure)- Failure of the kidneys to excrete wastes may lead to accumulation of urea with marked reduction in the urine output. Renal failure are of two types, Acute and chronic renal failure. In acute renal failure the kidney stops its function abruptly, but there are chances for recovery of kidney functions. In chronic renal failure there is a progressive loss of function of the nephrons which gradually decreases the function of kidneys.

Females are prone to recurring urinary tract infections as they have shorter urethras. With age prostate in males may enlarge which forces urethra to tighten restricting a normal urinary flow.

Uremia - Uremia is characterized by increase in urea and other non-protein nitrogenous substances like uric acid and creatinine in blood. Normal urea level in human blood is about 17-30mg/100mL of blood. The urea concentration rises as 10 times of normal levels during chronic renal failure.

Renal calculi- Kidney stone or calculi, also called renal stone or nephrolithiasis, is the formation of hard stone like masses in the renal tubules of renal pelvis. It is mainly due to the accumulation of soluble crystals of salts of sodium oxalates and certain phosphates. This result in severe pain called "renal colic pain" and can cause scars in the kidneys. Renal stones can be removed by techniques like pyleothotomy or lithotripsy.

Glomerulonephritis- It is also called Bright's disease and is characterized by inflammation of the glomeruli of both kidneys and is usually due to post-streptococcal infection that occurs in children. Symptoms are haematuria, proteinuria, salt and water retention, oligouria, hypertension and pulmonary oedema.

Haemodialysis

Malfunctiong of the kidneys can lead to accumalation of urea and other toxic substances, leading to kidney failure. In such patients toxic urea can be removed from the blood by a process called haemodialysis. A dialyzing machine or an artificial kidney is connected to the patient's body. A dialyzing machine consists of a long cellulose tube surrounded

by the dialysing fluid in a water bath. The patient's blood is drawn from a conveinent artery and pumped into the dialysing unit after adding an anticoagulant like heparin. The tiny pores in the dialysis tube allows small molecules such as glucose, salts and urea to enter into the water bath, whereas blood cells and protein molecules do not enter these pores. This stage is similar to the filtration process in the glomerulus. The dialysing liquid in the water bath consists of solution of salt and sugar in correct proportion in order to prevent loss of glucose and essential salts from the blood. The cleared blood is then pumped back to the body through a vein.

Kidney Transplantation

It is the ultimate method for correction of acute renal failures. This involves transfer of healthy kidney from one person (donor) to another person with kidney failure. The donated kidney may be taken from a healthy person who is declared brain dead or from sibling or close relatives to minimise the chances of rejection by the immune system of the host. Immunosuppressive drugs are usually administered to the patient to avoid tissue rejection.

The world's first successful human kidney transplantation was performed from one twins to antoher by Joseph E. Murray and his colleagues at Peter Bent Brigham Hospital, Boston in 1954. The first ever human kidney transplant performed in India was done at the King Edward Memorial Hospital at Mumbai in May 1965, using a cadaver donor in a nonrenal failure patient who had had hypernephroma. The first successful live donor kidney transplant in India was done at Christian Medical College Hospital, Vellore in January 1971 by Dr. Johnny and Dr. Mohan Rao.