Biology. Chapter 18…Body Fluids and Circulation. Synopsis

✍ **Basic Concepts :** ➢ Every structural unit of the biological machinery require continuous supply of both food and oxygen to sustain life. To ensure constant supply of food and oxygen in different cells and to remove metabolic wastes, a system knows as circulatory or vascular system has been devised.

➢ Many types of circulation have been evolved in response to the demands created by the increasing complexity of organisms.

✍ **Types of Circulation : 1. Intracellular circulation :** In single celled organisms, e.g. Paramecium and practically all the living cells cytoplasm shows regular streaming movements. This type of movement of cytoplasm is termed cyclosis.

Cyclosis helps in amoeboid locomotion in certain protozoans. It also helps in distribution of materials.

2. Extracellular circulation : It occurs outside the cells and is present in multicellular animals. It is of many types.

i) Water circulation : Sponges and Hydra circulate surrounding water through the cavities in their bodies.

a) Sponges : In sponges, food and oxygen are brought into the body and waste products and reproductive cells are carried out by water current.

b) Hydra : Hydra has a body cavity called **gastrovascular cavity** that opens outside through an aperture, the **mouth**. In coming water current brings food and oxygen for different cells and outgoing water current carries waste products including carbon dioxide.

ii) Parenchymal circulation : In flat worm, the space between the body wall and internal organs if filled with peculiar tissue called **parenchyma.** The cells of parenchyma have irregular processes, which form a loose network with fluid filled intercellular spaces. These cells transport digested food which diffuses from the intestine.

iii) Body Cavity Circulation : The body cavity of round worms is called **pseudocoel.** The pseudocoel is filled with pseudocoelomic fluid. This fluid transports food that diffuses from the intestine.

iv) Blood vascular system : A well developed blood vascular system is present in higher invertebrates from the annelids to the echinoderms and all the chordates. It is so because:

a) These have a thick body wall to prevent the evaporation of water of the body. So exchange of the materials between the body cells and environment by diffusion is not possible.

b) These have a higher metabolic rate and need greater supply of nutrients and oxygen; and the rapid removal of wastes and CO_2.

✍ **Annelids are the first metazoans to have a well developed circulatory system.**

Blood vascular system consists of three components:

a) Heart : it is a thick, muscular, automatic pulsating and contractile organ which pumps the blood vessels, Nereis (clam worm) and Amphioxus (sandworm) do not possess any heart.

b) Blood vessels : These are hollow, tubular vessels which conduct the blood from the heart to body tissues and from the tissues to the heart. These blood vessels are of three types.

i) Arteries : These are thick walled blood vessels which always carry the blood away from the heart to various body parts. These are elastic in nature, have narrow lumen, are deep seated in the body parts and have no valves in them. Blood flows at high pressure. These generally carry oxygenated blood in them, except the pulmonary artery which Carries deoxygenated blood to the lungs. ***Acidity is more in arterial blood than venous blood because of oxyhaemoglobin**

ii) Veins: These are thin walled blood vessels which always carry the blood from various body parts generally to the heart. These are slightly elastic in nature, superficial in position and have valves in them to prevent the back flow of blood. Blood flows in them at low pressure. These generally carry deoxygenated blood in them, except the pulmonary

vein which carries oxygenated blood to the left auricle. Larger arteries and veins have their own small vessels in their coats called vasa vasorum. These supply nourishment as well as oxygen to these blood vessels.

iii) Capillaries: The artery further divides into thinner branches called **arterioles** inside the organ. The arteriole further divides into capillaries. The capillaries are the thinnest blood vessels. Each capillary is lined by a single layer of flat

cells, called **endothelium.** The endothelium allows the exchange of materials like the nutrients, respiratory gases, waste products, the hormones etc. between the blood and the surrounding tissue cells. Capillaries rejoin and form the venous capillaries which further join to form the venules which finally join and form a vein.

✍ **Types of Blood Vascular System : 1) Open Circulatory System :** It is found in invertebrates such as annelids (e.g. Leech), arthropods (e.g. Prawn) and mollusks (e.g. mussel) except cephalopods. Here, the **haemolymph** does not remain confined to blood vessels but flows through open spaces and channels called **sinuses** or **haemocoel** in the tissues. In sinuses, the blood is in direct contact with the tissue cells. The flow of blood through open sinuses is very slow. The oxygen-carrying pigments are usually dissolved in the blood plasma.

2) Closed circulatory system: This system is prevalent in annelids and all vertebrates. Here, blood is retained. However,

these get complicated by incorporating several valves inside them and becoming compartmentalized. In such cases, the **sinus venosus** and **conus arteriosus** are displaced from their original positions and are actually incorporated into the right wall of atrium and ventral aorta respectively.

1) Fish heart: Fish heart is two chambered consisting of an **auricle** or **atrium** and a **ventricle**. Associated with them are two accessory chambers **– sinus venosus** and **conus arteriosus**. In fish, heart receives deoxygenated blood from the entire body except gills, in the sinus venosus and is pumped to gills via conus or bulbous aorta. The oxygenated blood from gills is collected into dorsal aorta and supplied to the body. In fish, heart receives only deoxygenated blood, hence it is called **venous heart.** During each circulation, blood enters the heart only once, so it is called single type of **circulation.**

2) Amphibian heart : It is formed of three chambers because of the division of auricle or atrium into two chambers. The right auricle receives deoxygenated blood from the body and left auricle receives oxygenated blood from the lungs. In auricular region the two types of blood are totally separated. The ventricle is single or undivided, so that the blood coming from the two auricles gets mixed in the ventricle. The two accessory chambers sinus-venosus and conus arteriosus are still present. Amphibians have **double circulation.**

3. Reptillian heart : Reptilian heart is incompletely four chambered having 2 auricles and two partially divided ventricles except in crocodiles where ventricle is completely divided.

4. Heart in birds and mammals : The mammalian and avian heart is four chambered having two auricles and two ventricles. The right half of heart is associated with pulmonary circulation. The right auricle receives deoxygenated blood from the body and right ventricle pumps this deoxygenated blood to the lungs. The left half of heart is associated with systemic circulation.

Human Circulatory System : Heart : It is situated almost in the middle of thoracic cavity between the lungs. Its lower Conical portion is tilted to the left, it is a hollow, muscular, cone-shaped organ. It is enclosed in a membranous sac called **pericardium**. It is formed of the following layers:

i) Fibrous pericardium: It is a tough loosely fitted and elastic sac around the heart. It is made up of tough white fibrous tissue.

ii) Serious pericardium: It is smooth and most and is formed of two thin layers.

a) Parietal layer forms lining of the fibrous pericardium.

b) Visceral layer or epicardium adheres to the heart forming its outer covering.

Between parietal and visceral layer of serous pericardium is the **pericardial space** filled with **pericardial fluid.**

- Functions: Pericardium protects heart from injury, and against friction. Pericardial fluid keeps the heart moist.

- **Structure of cardiac wall :** The wall of the heart in both auricles and ventricles is formed of the following three layers.

i) An outer thin layer: The epicardium is derived from serous pericardium.

ii) Middle muscular layer: The myocardium is formed of cardiac muscles. These keep contracting and relaxing nonstop throughout life.

iii) Inner delicate layer: The endocardium is formed of endothelial lining.

Structure of the Heart : The heart is four-chambered having **two auricles** and **two ventricles**. Heart is distinctly divided into an anterior smaller part i.e., **auricles** and the posterior larger part i.e. **ventricles** with the help of a

transverse groove called **auriculoventricular groove**. Another oblique groove divides the larger ventricular part into right and left ventricles. The groove is called interventricular groove and it is extended from the top of the heart backwards towards the right but never reaches the apex.

Auricles : The auricles are thin walled structures. The two auricles are separated from each other by a vertical partition called the **interauricular septum** or **interatrial septum.** This septum possesses a small oval depression called the **foramen ovale** to link the two auricles. During embryonic stage, the blood from the right auricle enters the left one without entering into the lungs which have not yet become functional. However, in the adult stage, this foramen ovale is closed as by now lungs become functional. It is called **fossa ovalis.**

The inner surface of the auricles is smooth, However, the auricular appendages posses a network of low ridges called **musculi pectinati.** Right auricle receives three vena cavae (right and left precavals and one postcaval). The opening of the postcaval is guarded by a membranous fold called Eustachian valve. The right auricle also receives a small coronary sinus to receive venous blood from the wall of the heart. Its opening is guarded by the **besian valve**.

The left auricle receives oxygenated blood from pulmonary veins.

Auricles open into the ventricles by respective **auriculoventricular aperture**. The right auriculoventricular aperture is guarded by a tricuspid valve. The left auriculoventricular aperture, on the other hand, is guarded by a **bicuspid**

valve or **mitral valve**. The free edges of the valves are attached to the papillary muscles or **columnate carneae** by **chordae tendineae**.

Ventricles : Ventricles are thick-walled as these have to pump blood to distance areas of the body. Walls of the left

Ventricles are comparatively thicker as the two ventricles are completely separated from each other by an oblique **interventricular septum**. The inner surface of the ventricles is raised into a sort of network of low, muscular ridges called the **columnae carneae**. Some of these ridges are large, conical and muscular and are called **musculus papillaris**.

The free edges of the tricuspid and bicuspid valves guarding the right and left auriculoventricular apertures are attached by **chordae tendineae.**

Pulmonary aorta originates from the right ventricle and carries venous blood to the lungs for its oxygenation. Three semilunar valves are present at the base of the pulmonary aorta which prevent the back flow of the blood.

Left aorta arises from the right anterior end of the left ventricle and carries oxygenated blood to various parts of the body. Three semilunar valves permit the passage of blood only from the ventricle to the aorta. A muscular strand

called **ligamentum arteriosum** is present in adults at the place where aorta crosses the pulmonary aorta. During embryonic condition, both the aorta are connected with each other by an artery called **ductus arteriosus (Botalli).**

✍ **Working of the Heart :** The deoxygenated blood from different parts of the body is poured into the right auricle by three venae cavae. The left auricle, on the other hand, receives aerated blood from the lungs by the pulmonary veins.

The auricles when filled contract and force the blood into the respective ventricles through auriculoventricular apertures. The tricuspid and bicuspid valves guide the blood into the ventricles. The blood does not return to the venae cavae and pulmonary veins as the wave of contraction, begins at the anterior end of the auricles and passes

towards the ventricles thus pushing the blood into the latter. In addition, the blood filled veins also offer resistance to the blood that may attempt to return from the auricles. The contraction of the ventricles exerts pressure on the enclosed blood. At the time of contraction of the ventricles, the flaps of the tricuspid and bicuspid valves are pushed

forward resulting in the closing of the respective auriculoventricular apertures. When the pressure in the ventricles exceeds, the semi lunar valves presents at the base of aorta open up resulting in the flow of non-aerated blood from the right ventricle into the aortic arch. The pressure in the ventricles falls below the level prevailing in the aorta

resulting in the closing down of the apertures with the help of semilunar valves. The pulmonary aorta carries the non- aerated blood to the lungs, whereas, theoretic arch distributes the aerated blood to the lungs, whereas, the aortic arch distributes the aerated blood to all parts of the body.

✍ **Cardiac Cycle**: It involves alternate contraction (called systole) and relaxation (called **diastole**) of heart all the rate of 70-72 times per minute at rest. Cardiac cycle is formed of three phases:

i) Atrial Systole: It involves contraction of atria which pushes blood to respective ventricles. There is no backflow of blood from the auricles to large veins because of presence of valves at the opening of inferior vena cava and coronary sinus. Atrial systole takes 0.1 second while atrial diastole is of about 0.7 seconds.

ii) Ventricular Systole: It involves simultaneous relaxation of atria **(atrial diastole)** and contraction of ventricles

(ventricular systole). Due to ventricular systole, the pressure on the blood in the ventricles is increased compared to that in the atria. The auriculoventricular valves close rapidly to prevent the backflow of blood from ventricles to auricles. This closing of auriculoventricular valves at the start of ventricular systole produces first heart sound called **"Lubb"** or systolic sound. It is louder and for a longer period.

The pressure in the ventricles increases than that in the great arteries (pulmonary and aortic arches), so semilunar Valves open and blood enters great arteries. Deoxygenated blood from right ventricles enters pulmonary arch which carries it to the lungs. Oxygenated blood from the left ventricle enters aortic arch which carries it to all other body parts. Ventricular systole takes about 0.3 seconds while ventricular diastole takes about 0.5 seconds.

iii) Joint Diastole: Ventricular systole is followed by ventricular diastole. As atria are already in diastole, all the chambers of heart enter the diastolic phase. It is called complete cardiac diastole or joint diastole. Ventricles relax and pressure in ventricles decreases than that in the great arteries. To prevent backflow of blood from great arteries to ventricles, the semilunar valves close rapidly. This rapid closure of semilunar valves at the beginning of ventricular diastolic sound. It is less loud and for a lesser period than systolic sound.

During complete cardiac diastole, blood from the great veins flows into the atria. Gradually, the pressure in the ventricles decreases and finally becomes lower than atrial pressure. The auriculoventricular valves open and blood from atria starts entering into relaxing ventricles. Complete cardiac diastole takes only 0.4 seconds. The heart sounds can be heard by an instrument called **stethoscope**.

✍ **Cardiac Output :** It is the volume of blood ejected from the heart in the aorta in one muinute, and is also called minute volume. It is calculated as the product of stroke volume and the rate of heart beat. Stroke volume is the volume of blood pumped during one heart beat.

Heart rate changes with age, size, sex, temperature, relax etc. During exercise, the heart rate may be 150 times per minute and the stroke volume over 150ml.

➢ **types of Hearts : i) Myogenic heart :** It is found in vertebrates. In a myogenic heart, the cardiac impulse originates in

The cardiac muscle fibres and is not brought to the heart by the nerve fibres. Molluscan hearts are also myogenic.

ii) Neurogenic heart : It is found in most crustaceans, some insects and annelids. In this, the excitation waves of the heart beat originate from nerve ganglion cells present on the dorsal surface of the heart.

✍ **Origin and Conduction of heart beat :** The heart is formed of cardiac muscles which have the property of excitability and conductivity. When the cardiac muscles are simulated by a specific stimulus, these get excited and initiate the waves of electric potential called **cardiac impulses** which are conducted along the special cardiac muscle fibres on the wall of the heart chambers. When a heart is separated from the body and its placed in a physiological saline solution (e.g. Ringer's solution), it goes on beating for some time.

Initiation of heart beat is under three special boundless of cardiac muscles called **nodal tissues:**

i) Sino-auricular node (S.A. node) : It lies in the right wall of the auricle, close to the opening of the superior vena cava. It represent sinus venosus which has completely merged into the wall of the right atrium. It is also called pacemaker as it is the first to originate cardiac impulses and determines the rate of heart beat. It maintains the basic rhythm of heart beat. These cardiac impulses are conducted along the tracts of special cardiac muscle fibres over both the auricles at the rate of 1 metre/second. These impulses cannot be passed to the wall of ventricles.

ii) Astrio-ventricular node (A.V. node): It is also called **pace-setter**. It lies in the right atrium near the junction of interauricular/ and interventricular septum. It is stimulated by the waves of contraction initiated by S. A node. The cardiac impulses are conducted to the muscles of the ventricles bundle of His and **Purkinje fibres** at the rate of **5 metres/second.**

iii) Bundle of His: It is also called A. V. bundle. It arises from the A. V. node, descends in the interventricular septum and divides into two branches which descend along two sides of interventricular septum and supply the wall of ventricle of their own side by a network of fine fibres called **Purkinje fibres** in the myocardium of the ventricles.

These bring about the contraction of the ventricles from the apex of heart which forces the blood into the pulmonary arch and aortic arch. When the S.A node is damaged, it is not able to generate the cardiac impulses, the heart beat becomes irregular. This condition is called **arrhythmia.** It is corrected by an artificial pacemaker. It is set in the chest of the patient, by surgical grafting, to pump the required amount of blood.

✍ **Control of Heart beat: i) Nervous control:** The rate of heart beat as well as straight of the beat are under two cardiovascular centers of the autonomic nervous system.

a) Cardiac acceleratory centre: It is associated with the sympathetic nerve fibres which, in turn, are associated with the S.A. node. These nerve fibres stimulate and increase the rate and depth of the contraction of the S.A. node through neuro transmitter chemical called adrenalin (epinephrine). This increases the rate of heart beats.

b) cardiac inhibitory centre: It is associated with the vagal or parasympathetic nerve fibres which, in turn, are associated with the S.A node. These nerve fibres inhibit and decrease the rate and depth of contraction of the S. A. node through a neurotransmitter chemical called acetylcholine.

ii) Hormonal control: It consists of two amine hormones-epinephrine, nor epinephrine which are secreted by adrenal medulla of the adrenal gland. Both hormones accelerate the rate of heart beats but operate in different conditions.

Epinephrine increases the heart beat during emergency conditions. Epinephrine increases the heart beat during emergency conditions. Epinephrine increases the heart beat during emergency conditions, while nor epinephrine increases heart beat during normal conditions.

✍ **Pulse**: **Pulse is defined as a wave of distention and recoiling felt in the peripheral artery.** Each ventricular systole starts a new pulse. It proceeds as a wave of expansion throughout the arteries disappearing in the capillaries. The pulse rate is same as the heart rate.

Pulse can be felt wherever an artery lies near the surface, such as **radial artery** at the wrist; **temporal artery** in front of ear; **common carotid artery** in the neck, facial artery on the corner of mouth, the brachial artery at the bend of elbow and in the leg near the ankle bone. The pulse normally travels at the rate of 5-8 metres/second. While blood flows at the rate of 300-500 mm/seconds in arteries.

✍ **Blood Pressure (B.P.)** The force of blood against the walls of blood vessels is known as blood pressure. The pressure of blood in the circulatory system depends upon:

i) Changes of the circulatory space due to contraction and relaxation of heart and blood vessels.
ii) Amount of blood entering and leaving a blood vessel.
iii) Total blood volume.
iv) Viscosity of blood.
v) Elasticity of blood vessels.

➢ **Systolic pressure** (SB.P.) is the pressure of blood during the systolic phase. It is maximum and is responsible for movement of blood in the arteries. **Diastolic pressure (D.P.)** is the blood pressure during the diastolic phase of heart, when blood is received in the heart.

Normal Systolic pressure is 120 mm Hg
Normal Diastolic pressure is 80 mm Hg

B. P. is represented by 120/80. In high blood pressure (hypertension), the systolic pressure is above 150 mmHg and diastolic pressure above 100 mmHg. In low blood pressure (hypotension) systolic pressure is les than 100 mm Hg and diastolic below 50 mmHg. High BP 220/120 may burst blood vessels of the brain.

High B.P. is usually associated with hardening of arteries in old age (arteriosclerosis), obesity, physical and emotional stress, smoking etc. The blood pressure is measured by **sphygmomanometer**.

➢ **Mean Arterial Pressure**: It is the average arterial pressure during complete heart beat and is defined as the pressure which determines the average rate of blood flow through the systemic vessels. As the blood remains in the systolic phase for shorter period and in the diastolic phase for longer period, so the mean

pressure of blood lies near the diastolic pressure. It is about 100 mm Hg in the aorta; 85 mm Hg at the junction of small arteries and arterioles 30mm Hg at the junction of arterioles and the capillaries; 10 mm Hg at the venous end of capillaries and about 10 mm Hg in the venae cavae near their opening into the right atrium.

➢ **Pulse Pressure**: The difference between the systolic and diastolic pressure is called pulse pressure.

Pulse pressure = systolic pressure – diastolic pressure 120 – 80 = 40 mm Hg

✍ **Electrocardiogram:** A graphic record of the electrical variations produced by the beating of the heart is called **electrocardiograph (ECG).** These variations are due to the development of electrical negativity of excited muscles as compared with unexcited tissues. An instrument used to observe the working of the heart is called electro cardiogram. Electrocardiogram was discovered by **Einthoven.** A normal ECG is composed of a P wave, a QRS complex and a T wave.

In this, P-wave indicates the impulse of contraction generated by the S.A. node. QRS-wave indicates contraction of ventricles and relaxation of auricles; T wave represents the relaxation of ventricles.

➢ In electrocardiography, P-Q interval (also called PR interval) is the time taken by the impulse to travel through atria. AV node and the rest of the conducting tissues.

➢ The ST intervals are the representation of time between the end of the spread of impulse through ventricles, and its repolarisation.

➢ The S-T segment is elevated in acute myocardial infraction, and depressed in a condition when the heart muscles receive insufficient oxygen.

➢ The ventricular repolarisation is represented as T wave. When the heart muscle receives insufficient oxygen, the T wave is flattened.

✍ **Pacemaker:** It is an electrical device which is connected to the heart for normalizing the rate of impulse generation so as to make the heart beat at normal rate (72/min in males and 80/min in females). It was invented by **Great batch** and **Chardack** (1960). Several types of pacemakers are available, e.g., external pacemaker, ventricular synchronized pacemaker, atrial synchronized pacemaker, epicardial pacemaker, endocardial pacemaker, etc.

External pacemaker is used in emergency as a temporary arrangement. In majority of patients' ventrically synchronized pacemakers are used. The pacemaker has an electrical battery called **pulse generator**. It is a long lasting lithium halide cell with a life of more than 10 years. There is a fine metallic **string** covered by a biocompatible plastic.

The string metallic **string** covered by a biocompatible plastic. The string bears an electrode at its tip. There is a low pass filter to check the effect to external electric currents. The battery or pulse generator is placed below the right

clavicle. The string is passed through superior vena cava, right atrium and right atrioventricular aperture to place the electrode over the apical end of right ventrile. The device is set to produce electric pulse to synchronise with the ventricular contraction.

➢ During rheumatic fever, and arteriosclerotic heart disease, (i.e., the formation of plaques and classification) the P-Q interval lengthness. This is due to the inflammation of atria and atrioventricular node.

➢ The normal PR interval lasts for 0.16 second. The enlarged Q and R waves are the indication of myocardial infraction.

Pacemakers are meant for correcting deficiency of impulse generation or transmission so that a person is able to lead a normal life. However, persons fitted with pacemaker device should avoid coming very near to microwave ovens, cellular phones, automobile ignition, etc., which produce waves or electric sparks. Periodic check up should be carried out for knowing the deficiency of pulse generator and its synchronization.

✍ **Circulation of Blood**: **1) Pulmonary circulation:** The deoxygenated blood from the right ventricle is pumped into **pulmonary arteries or pulmonary trunk**. It divides into two branches the right and left pulmonary arteries. The oxygenated blood from the lungs is collected by **pulmonary veins**. It carries the blood into the left auricle.

2) Systemic circulation: The left ventricle pumps oxygenated blood into the systemic arch which supplies it to body organs other than the lungs through a number of arteries. Deoxygenated blood from these organs is returned to the right auricle through two large veins, superior and inferior vena cavae.

➢ A vein which does not carry blood directly to the heart but forms a network of capillaries in another or intermediate organ before reaching the heart is called a **portal vein**. The components of the portal vein constitute the portal system. The vertebrates possess two or three portal systems. These are hepatic portal, renal portal and hypophyseal portal systems.

1) Hepatic Portal System: It is present in all vertebrates including man. It brings blood from the alimentary canal to the liver hence it is named as the hepatic portal system.

Significance of hepatic portal system: The hepatic portal system has the following significance.

i) The blood which comes from the alimentary canal contains digested food like glucose and amino acids.

ii) Harmful nitrogenous waste like ammonia is converted into which is later removed by kidneys.

iii) Liver produces blood proteins which are put into blood circulation.

2) Renal Portal System: It is well developed in fish and amphibians and is reduced in reptiles and birds and is absent in mammals. This system carries blood from the posterior region of the body to the kidneys by **renal portal veins**. The kidneys remove the waste products from the blood and then the blood is passed to the **postcaval by renal veins.**

3) Hypophyseal Portal System: This portal system is present in the anterior lobe of the pituitary gland (hypophysis), hence it is named pituitary portal system or hypophyseal portal system. **Hypophyseal portal vein** carries blood from the hypothalamus of the brain to the anterior lobe of the pituitary gland. This portal system enable the hormones of hypothalamus to reach the anterior lobe of the pituitary gland.

✍ **Some diseases of the Circulatory System**:

1) Heart Block: it is a condition in which impulses are interrupted at any point along the conducting system of the heart. Two common types of heart block are found.

i) A V Block : It occurs at the atrioventricular node. The impulses from the SA node do not reach the AV node.

ii) Bundle branch block: It involves one of the branches of the bundle of His.

2) Hypertenion (high blood pressure): it is defined as a resting arterial pressure exceeding 140/95 over a prolonged period of time.

3) Atherosclerosis: In this disease a thickness develops on the linear walls of the arteries due to deposition of fat that prevents the dilation of vessels. The vessels become smaller in diameter and cannot fully expand.

4) Haemorrhage: Haemorrhge is excessive loss of blood. The loss of blood decreases both the arterial and venous pressure.

5) Cerebrovascular Accident: It is also known as stroke in which the sudden interruption of blood flows to a portion of the brains because of block or rupture of a cerebral blood glucose.

6) Rheumatic Heart Disease: Rheumatic fever may cause permanent damage of one or more valves (mitral or aortic semilunar valves), pericarditis and myocarditis.

The heart muscles become weak and heart enlarges in size.

7) Arteriosclerosis: Hardening and loss of elasticity of the arteries is commonly referred to as arteriosclerosis.

8) Coronary thrombosis: A clot may form in the lumen of a coronary artery, it is called coronary thrombosis.

9) Tachycardia: The heart beats rapidly.

10) Brachycardia: The heart beats slowly.

11) Heart block: In this condition there are two arterial beats for each ventricular contraction.

12) Ventricular fibrillation: Different regions of ventricle contract at random.

13) Angina pectoris: due to inadequate blood supply to the heart muscles as a result of arteriosclerosis severe pain occurs in the breast region.

14) Myocardial damage: Insufficient supply of blood to heart muscles causes damage and results in heart attack.

➢ **Lymph:** Lymph = Blood – RBC. i.e. Plasma + WBC. Lymph form second circulatory system and is also known as subsidiary circulatory system. It is a part of tissue fluid. It is colorless. RBCs are absent. WBCs are more. Lymph has

little oxygen. Lymph has more metabolic waste and CO_2; Insoluble proteins are more in lymph. Soluble proteins are less in lymph.

➢ **Function:** Lymph acts as middle man between blood and tissue. Lymph returns blood proteins from tissue fluid again to blood. All interchanges of nutrients and waste products between blood and tissues take place through tissue fluid which on entering the lymphatic vessels is known as lymph.

Lacteals of intestine. Lacteals are associated with absorption of fat in the form of fatty acid and glycerol. Lymph Capillaries are united to form lymph vessel which are similar to vein in structure.

b) Cisterna Chyli: It collects lymph from leg region. Pelvic region and abdominal cavity.

c) Thoracic Lymphatic Duct: It arises from cisterna chyle; collects lymph from legs, pelvic cavity abdominal cavity. It also receives lymph from left side of chest, head, neck and left arm. It also receives lymph from the region of subclavian part and it is connected to the left subclavin vein.

d) Right Lymphatic Duct: It is very short. It collects the lymph from right side of head, chest, neck, right arm and right subclavian part. It is connected with right the subclavian vein.

✍ **Excretory Products and Their Elimination:**

➢ **basic Concepts:** The process of removal of metabolic waste from the tissues of the body to the exterior is known as excretion.

➢ **Excretory Products**: Excretory waste materials in animals include

1) Carbon dioxide 2) Nitrogenous wastes 3) Excess water 4) Pigments 5) Excess of inorganic salts.

1. Carbon dioxide: It is continuously formed in the body and is removed from the body through respiratory organs in vertebrates. In small animals, it is eliminated by diffusion through the body surface.

2. Nitrogenous wastes: Proteins are the main source of introducing nitrogen into the body by way of different amino acids. Inside the body, proteins are metabolized to yield various nitrogenous substances such as ammonia, urea and uric acid, as nitrogen cannot be eliminated as free nitrogen. Besides ammonia, urea and uric acid, other nitrogenous wastes include guanine, xanthine and hypoxanthine, trimethylamine oxide, creatine, creatinine, hippuric acid, ornithuric acid and also pterydines.

Ammonia: It is highly toxic and is removed from the body very rapidly. It is highly soluble in water. It is removed rapidly by the process of simple diffusion to the exterior. Ammonia is formed by oxidative deamination process,

chiefly in the liver. It is rapidly converted into urea in the liver and then excreted. It may also be removed rapidly by deamination of keto acids.

Urea: In mammals, ammonia is converted into harmless urea in the liver. Urea is highly soluble in water and is excreted out of the body in the form of urine.

Urine acid: In insects, reptiles and birds, uric acid is formed from ammonia. It is less toxic than ammonia and its Insoluble in water. Formation of uric acids in these animals is an adaptation to conserve water since it is eliminated with very little quantity of water.

Certain animals excrete other nitrogenous waste products. For instance, spiders excrete guanine. In certain insects, xanthine and hypoxanthine are excreted. Marine teleosts (bony fish) excrete trimethylamine oxide. Allantoin is excreted by embryo.

✍ **Paterns of Excretion: 1. Ammonotelism**: Ammonotelism is the elimination of nitrogenous waste chiefly as ammonia.

It is highly toxic and hence should be removed from the body very quickly. For example, in aquatic vertebrates (e.g., teleost fishes), coelenterates (e.g., sea anemones, Hydra), annelids, some crustaceans, molluscs (cephalopods and

pelecypods) and even echinoderms excrete ammonia as nitrogenous waste. Bony fishes and tailed amphibians like salamanders are known to excrete ammonia in urine.

2. Ureotelism: Elimination of uria as the chief nitrogenous waste is termed as ureotelism. Urea is formed in the liver cells by combination of ammonia and carbon dioxide. Urea, being less toxic than ammonia, can be slowly lost from the body, e.g., elasmobranch fish, amphibians and mammals. Aquatic reptiles e.g., alligators and turtles are also ureotelic.

There are instances when a particular animal in one set of conditions is ammonotelic but in a different set of conditions turns ureotelic, e.g., Lung fishes. The same is true of some animals which excrete different wastes in different stages of their life cycle. For instance, aquatic tadpole of frog is ammonotelic but adult frog is ureotelic.

3. Uricotelism: Elimination of uric acid as the chief nitrogenous waste is termed as uricotelism. It is much less toxic than ammonia and urea. Uric acid is almost insoluble in water and is excreted out in nearly solid state. E.g., insects, some land crustaceans, land snails, reptiles, snakes, lizards and birds.

✍ **Excretory Organs: 1. Protozoans:** In acellular animals e.g. protozoans, excretion of waste materials occurs merely by diffusion or osmosis across the cellular membranes into the surrounding water. Nitrogenous waste is ammonia.

2. Sponges: In sponges too, the main excretory product is ammonia. It leaves the cells by diffusion into the water that fills the canals.

3. Coelenterates: They pass out waste materials, chiefly ammonia, by diffusion from all the cells e.g., Hydra. The water that has entered the coelenteron, leaves out of this cavity along with waste material.

4. Flatworms: Planarians, liverflukes, tapeworms have flame cells (solenocytes) with bundles of vibratile cilia for removal of waste products. The flame cells receive the wastes from the surrounding fluid by diffusion and discharge these to the exterior by way of excretory ducts. Flame cells in fact regulate the water content of the body.

5. Round worms: In round worms, excretory system includes H-shaped renette cell and assoiated longitudinal canaliculi opening out at the excretory pore.

6. Annelids: Excretory organs in annelids (earthworms, leech, sandworms) are in the form of coiled tubes called nephridia. It extracts waste materials from the blood and discharges them into the gut or out of the body to the exterior by **nephridiopore**. Some nephridia draw waste matter from the coelomic fluid by nephrostomes. In earthworm, chloragogan cells are also meant for excretion. In leech, special botryoidal tissues are present as excretory organ.

7. Arthropods: i) Insects, centipedes and millipedes. These have numerous blind malpighian tubles which float in the haemolymph and open into the gut. These malpighian tubules extract waste materials from haemolymph and discharge them into the gut. In the gut, most of the water and useful inorganic ions are reabsorbed while the waste product uric acid is excreted out.

ii) Crustaceans: Prawn has a pair of antennary or green glands and a median renal sac for excretion and osmoregulation. The green glands lie at the base of the antennae and open out. The excretory organs of crustaceans are a pair of Antennary glands, a pair of lateral ducts and a renal sac. Antennary gland lies in the base of antenna and is formed of an end sac, a labyrinth and a bladder. The end sac extracts the nitrogenous wastes from blood and passes them into labyrinth where useful substances are reabsorbed by active transport. Bladder receives the waste from both labyrinth

and renal sac. These are finally expelled out through the renal pore present at the tip of the ureter.

iii) Scorpions and spiders: These have malpighian tubules or coxal glands or both for excretion.

8. Molluscs: In molluscs, are present 1 or 2 pairs of kidneys to discharge the waste matter into the mantle cavity. In fresh water forms, these perhaps carry out osmoregulation as well. In Unio, Kebers organ and organ of Bojanus are meant for excretion.

9. Echinoderms: These animals e. g., starfish lack special excretory organs. They are excreted out by diffusion through the thin walls of gills and tubefeet.

10. In man and other vertebrated, Kidneys are the major excretory organs. These are also called primary excretory organs since they eliminate the principal nitrogenous metabolic waste materials. Besides kidneys, some other organs

such as lungs, liver, intestine and skin also remove certain metabolic wastes besides their normal functions. These are known as accessory or additional excretory organs.

i) Liver: It is important for removing cholesterol, bile salts and other salts which are finally eliminated by the intestine along with faecal matter.

ii**) Integument**: it also plays an important role in eliminating urea through sweet glands.

iii) Pair of lungs which maintain the concentration of oxygen and carbon dioxide.
iv) Pair of kidneys which maintain chemical composition of body fluids. These eliminate nitrogenous wastes, excess of water, salts and other excess substances. Kidneys are of various types.

a) Archinephric kidney: It is also called ancestral kidney. Such a kidney is found in the larvae of certain cyclostomes (e.g., myxine) but do not occur in any adult vertebrate. Glomeruli are only present in some of the posterior tubules.

b) Pronephric Kidney: It appears as an embryonic functional kidney in cyclostomes, fishes and amphibians. It is non functional in the embryonic life of reptiles, birds and mammals. It is retained throughout life an adult cyclostomes and a few body fishes. Each tubule has a glomerulus.

c) Mesonephric Kidney: it is also called middle kidney. In lamprey, most adult fishes and amphibians, mesonephric kidney is functional both in embryo as well as adults. In reptiles, birds and mammals it is functional in embryos and is replaced by metanephric kidney in the adults. It consists of a large number of tubules which develop internal glomeruli enclosed in capsules forming Malpighian bodies.

In sharks and caecilians (limbless amphibians) tubules extend posteriorly throughout the length of coelom, such a kidney is called a opisthonephric kidney.

d) metanephric Kidney: it is also called posterior kidney. Nephrons are large in number. The glomeruli are very well developed. Henle's loop is well developed. Metanephric kidneys are found in adult amniotes (reptiles, birds and mammals).