

BODY FLUIDS & CIRCULATION

SYNOPSIS

BLOOD PLASMA

- Study of blood is hematology.
- Volume of blood is adult human being 5 to 6 lit.
- Blood and lymph are fluid connective tissues which help in circulation of various substances.
- Blood is a special connective tissue consists of fluid matrix called plasma and formed elements.
- Plasma is a straw colored, viscous fluid constitutes 55% of blood.
- 90-90% of plasma is water; 6-8% of it is plasma proteins and other substances.
- Major plasma proteins of blood Albumin and globulins (the smallest and the most abundant plasma protein).
- Albumin it helps in maintaining osmotic balance / blood colloid osmotic pressure.
- Fall in the levels of albumin in results in oedema.
- Globulins are of three types namely alpha, beta and gamma.
- Gamma globulins are antibodies and are involved in defensive mechanism, hence called immunoglobulins.
- Plasma proteins act as acid-base buffers and maintain p^H of blood at 7.4.
- Blood clotting proteins of plasma are fibrinogen and prothrombin.
- Plasma without clotting factors is called serum.
- All the plasma proteins are produced in liver, globulins formed in lymphoid organs in addition to the liver.
- Plasma also contains small amounts of minerals like Na^+ , Ca^{++} , Mg^{++} , HCO_3^- , Cl^- etc.
- Erythrocytes, leucocytes and platelets are collectively called – Formed elements.
- Formed elements constitute 45% of blood.

RBC: -

- The most abundant of all the formed elements in blood are Erythrocytes / RBC.
- Number of RBC in a healthy adult man on an average 5 million to 5.5 million per mm^3 decrease in the number of RBC is Erythrocytopenia, Abnormal rise in RBC count is polycythemia.
- The process of formation of formed elements – Haemopoiesis / haematopoiesis.
- In the earliest stages of embryogenesis formed elements are formed from the yolk sac mesoderm.
- Liver and spleen serve as “temporary haemopoietic tissues” in the later stages of embryonic development.
- In the final stage of embryonic development and after birth formed elements are formed from – Red bone marrow.
- RBC of human beings and other mammals (except camels and llamas) circular, biconcave, and enucleated.
- Biconcave nature provides a large surface area to volume ratio thus providing more area for the exchange of gases.

- People who live at the higher altitudes seems to be polycythemic, at higher altitudes partial pressure of oxygen decreases, which causes the shortage of oxygen, this stimulates the kidneys to secrete erythropoietin into blood.
- Erythropoietin stimulates the bone marrow to increase the production of RBC.
- Vitamins required for maturation of RBC- B_{12} , folic acid.
- Nucleus and other membrane bounded cell organelles are lost in the reticulocyte stage of RBC development.
- Iron containing chromoprotein complex present in RBC, that imparts red colour of RBC-is Haemoglobin.
- A healthy individual has 12-16 grams of Haemoglobin / 100ml of blood.
- Each haemoglobin molecule has 4 polypeptide chains ($2\alpha, 2\beta$) and a polypeptide chain has one haem molecule with one Fe^{+2} which is capable of carrying one O_2 molecule.
- Average life span of RBC 120 days.
- The worn out RBC are destroyed in spleen (graveyard of RBC / reservoir of blood) and also in liver.

WBC (leucocytes): -

- Nucleated colorless, complete cells of blood – WBC.
- Number of WBC on an average is 6000 – 8000 / mm^3 .
- Amoeboid movement of WBC into extra vascular areas is diapedesis.
- Process of formation of WBC – Leucopoiesis.
- Slight increase in WBC count during infection and allergy is Leucocytosis.
- Abnormal increase in number of WBC – leukemia.
- Fall in WBC cannot is Leucocytopenia.
- Leucocytes are generally short lived.
- Granulocytes (which have specific cytoplasmic granules that can be stained with specific dyes) are basophils, eosinophils and neutrophils.
- Agranulocytes (without specific cytoplasmic granules) are monocytes and lymphocytes.
- Least among all the type of WBC are-Basophils (0.4 to 1%).
- The most abundant of all the type of WBC – Neutrophils (60-65%).
- WBC that secretes heparin, histamine, serotonin and are involved in inflammatory reactions are-Basophils.
- WBC that resist infections and also associated with allergic reactions and are Eosinophils
- Phagocytic WBCs are neutrophils and monocytes.
- Microscopic policeman of blood are neutrophils
- Percentage of various types of leucocytes (WBC) in a health person- basophils-0.4 to 1%, eosinophils-2 to 3%, neutrophils-60-65%, lymphocytes-20 to 25%, monocytes-6-8%.
- Nucleus of basophils is divided into irregular lobes, eosinophils are bilobed, neutrophils are multilobed, lymphocytes are spherical, and monocytes are bean shaped or reniform.
- WBC responsible for immune reactions and play a key role in the immunological reactions are lymphocytes.
- WBC that can be differentiated into macrophages upon entry into the connective tissues-monocytes.

BLOOD PLATELETES OR THROMBOCYTES

- Thrombocytes are produced from megakaryocytes Red bone marrow by Fragmentation.
- Number of thrombocytes is-1, 50,000 to 3, 50,000 / mm^3 .
- Life span of platelets-7 to 10 days.

- Platelets secrete blood clotting factor thromboplastin, involved in the coagulation of blood.
- A reduction in number of blood platelets is-Thrombocytopenia, it leads to clotting disorders.

Coagulation of blood or Haemostasis

- A mechanism to prevent excessive loss of blood when an injury is made is blood clotting / coagulation.
- A blood clot or coagulum is formed mainly by network of fibrin threads in which dead and damaged formed elements are entrapped.
- In blood coagulation an enzyme complex called thrombokinase is formed by cascade process (a series of linked enzymatic reactions).
- Thrombokinase converts inactive prothrombin of plasma to active thrombin.
- Thrombin converts inactive fibrinogen to active fibrin threads.
- Soluble fibrin can be converted into insoluble fibrin threads by fibrin stabilizing factor (13th factor) released from platelets.
- About 13 factors are involved in the cascade process of blood clotting.
- The first four factors of blood clotting are fibrinogen, prothrombin thromboplastin and Ca⁺² ions respectively.
- Calcium ions play key role in blood clotting are considered to be 4th factor.
- Heparin is an anticoagulant increases antithrombin activity and prevents clotting in the blood vessels.
- When injury is made it stimulates the platelets to release blood clotting factors such as Hageman factor (Factor XII) which initiates blood clotting.
- Blood clotting factors released from the damaged tissue that initiate blood clotting-tissue factor or tissue thromboplastin.
- Vitamin required for the synthesis of certain blood clotting factors is vitamin-K (Naphthoquinone).
- Other anticoagulants – Hemolysins in the saliva of mosquitoes, hirudin in the saliva of leeches and warfarin (coumadin) of plants.
- EDTA, citrates, Oxalates are the calcium in removers used in storing the blood in blood banks.
- Abnormal clot formed in the blood vessels is known as thrombus.

LYMPH

- Lymph is a portion of blood without RBC, platelets and plasma proteins of high molecular weight.
- The most important centre for the formation of lymph is interstitial space at the arteriolar ends.
- When blood passes through capillaries some part of the blood moves out of capillaries into interstitial spaces between cells, it forms extracellular fluid or tissue fluid.
- Exchange of nutrients, gases between blood and cells always occurs through tissue fluid, Hence it is called a middle man between blood and tissues.
- Tissue fluid of interstitial spaces is collected by lymphatic system that includes lymphatic vessels, ducts, lymph nodes, lymphatic organs.
- Finally lymph released into right sub clavian vein by right lymphatic duct, and into left subclavian vein by left lymphatic duct or thoracic duct.
- Lymphatic system is a open type of system, movement of lymph is mainly due to squeezing action of surrounding muscles.
- Digested fats in the form of chylomicrons and fat soluble vitamins absorbed through lymph in the lacteals of intestinal villi.

Circulatory path ways

- Blood pumped by heart passes through large vessels into open spaces or sinuses is called open circulatory system.
- Capillaries are absent in open circulatory system.
- Animals with open circulatory system-arthropods, on cephalopod molluscs and urochordates.
- In open circulatory system blood mixes with interstitial fluid and bathes the cells of body, hence blood and tissue fluid are not distinguished.
- Flow of blood (Haemolymph) occurs slowly in open circulatory system due to fact that the heart can not produce enough pressure to make the blood flow rapidly.
- Blood pumped by the heart is always circulated through a closed network of blood vessels is closed circulatory system.
- Animals that show closed circulatory system are annelids, cephalopod molluscs and chordates (except urochordates).
- Blood circulates in the body with high pressure and enhances the speed and efficiency of circulation.
- Closed circulatory system is more advantageous as the flow of fluids can be more precisely regulated.
- Heart of fishes is two chambered with one atrium and a ventricle.
- Heart of fishes is venous heart (as it contains only deoxygenated blood) and described as branchial heart (as it pumps deoxygenated blood to gills directly).
- Heart of fishes shows single circulation in which heart receives deoxygenated blood from the body parts and pumps it to gills for oxygenation.
- In amphibians and reptiles heart is three chambered with right and left atria and one ventricle.
- Heart of amphibians and reptiles shows incomplete double circulation in which mixed blood is pumped.
- In amphibians and reptiles heart is three chambered with right and left atria and one ventricle.
- Heart of birds and mammals is 4 chambered, oxygenated and deoxygenated blood is completely separated from each other through complete double circulation and heart pumps oxygenate blood to body parts and deoxygenated blood to lungs separately.

Human circulatory system

- Heart is central pumping organs of circulatory system, derived from mesoderm.
- It is located in the mediastinum of the thoracic cavity between two lungs little towards left.
- Heart is protected by double walled membranous bag called pericardium.
- Outer layer is fibrous layer and inner layer is serous layer, in between them there is a pericardial cavity filled with pericardial fluid.
- Inflammation of serous pericardium is pericarditis, it produces extreme pain during heart beat.
- Wall of heart has three layers an outer serous layer is called epicardium, middle thick muscular layer is called myocardium and inner simple squamous epithelial layer is called endocardium.
- Heart of human beings is 4 chambered with two receiving chambers, the atria and two pumping chambers, the ventricles.
- Deep groove present obliquely between atria and ventricles is coronary sulcus.
- Two atria are internally separated by thin inter atrial septum and ventricles are separated by thick inter ventricular septum.
- Atrium and ventricles of same side are separated by a thick fibrous tissue called atrio ventricular septum.
- Two atria of foetal heart are communicated with each other by foramen ovale of interatrial septum.
- In adults foramen ovale is closed and represented by slight oval depression called fossa ovalis.

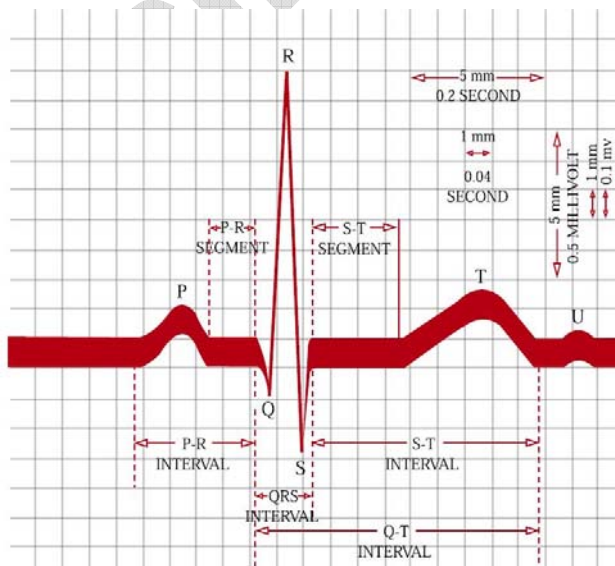
- Right atrium receives deoxygenated blood by two precavals and one post caval, opening of post caval into right atrium is guarded by a rudimentary membranous fold, the eustachian valve in adult.
- Opening of coronary sinus into the left precaval is guarded by Thebasian valve (valve of Thebesius).
- Left atrium receives deoxygenated blood from lungs through four pulmonary veins.
- Right atrium opens into right ventricle through atrio-ventricular aperture which is guarded by Tricuspid valve formed of three triangular, muscular flaps.
- Left atrio ventricular aperture is guarded by bicuspid valve or mitral valve.
- Wall of the left ventricle is thickest of all chambers, because it has to exert the pressure for pumping of blood over long distance.
- Inner surface of ventricles is raised into muscular columns called papillary muscles (trabeculae carnae)
- Thread like tendons that connect the papillary muscles to flaps of tricuspid and bicuspid valves are chordae tendinae.
- Two large aortic arches arise directly from the right and left ventricles respectively are pulmonary aorta and systemic aorta.
- Three crescent shaped valves present at the base of each of aortic each are called semilunar valves.
- All the heart valves prevent back ward flow of blood.
- During early embryonic stage a temporary blood vessel that stunts blood from the pulmonary aorta into systemic aorta is ducts arteriosus.
- Soon after birth ductus arteriosus closes, leaving a non functional ligamentum arteriosum.
- A specialized autorhythmic cardiac musculature distributed in the heart wall is called nodal tissue; it forms sino-atrial-node (SAN) and atrio-ventricular node (AVN).
- A path of nodal tissue present in the right upper corner of right atrium below the opening of post caval vein is SAN.
- Sino-Atrial node (SAN) which have highest rhythmicity among all cardiac muscles. So that it is called pacemaker of heart.
- Cardiac impulses normally generated from SAN.
- Another mass of nodal tissue seen in the lower left corner of the right atrium close to atrioventricular septum is AVN.
- A bundle of nodal tissue continues from AVN and passes through atrio-ventricular septum and inter ventricular septum is – AV bundle or bundle of His.
- Bundle of His forms right and left branches which further divide into many branches in the wall of ventricles called-purkinje fibres.
- Nodal musculature is auto rhythmic or auto excitable and has ability to generate action potentials without external or internal stimulus.
- SAN can generate maximum number of action potentials ie 70-75/min.
- SAN, AVN, bundle of His and purkinje fibres together form conduction system of heart.

CARDIAC CYCLE:

- Sequence of events that occur in the heart during one beat is cardiac cycle.
- Cardiac cycle consists of systole (contraction) of atria and ventricles and diastole (Relaxation) of atria and ventricles
- Duration of cardiac cycle when heart beats at the rate of 75 times/minis 0.8 sec.,
- Atrial systole 0.1 sec, Atrial diastole 0.7 sec, ventricular systole 0.3 sec ventricular diastole 0.5 sec, complete cardiac diastole-0.4 sec.
- Heart beat and metabolic rate and directly proportional to each other and inversely proportional to size and surface area of body.
- Heart beat increases during fever.

- In abnormal conditions when S.A node fails, the AV node generates the impulse called nodal rhythm.
- LUB sound (1st sound) in the heart beat is produced during ventricular systole due to sudden closure of tricuspid and bicuspid valves.
- Dup sound (2nd sound) heart beat is produced during ventricular diastole is due to sudden closure of semi lunar valves.
- LUB is long, low pitch and louder sound; DUP is short, high pitch soft sound.
- Volume of blood ejected out by left ventricle (or right ventricle) in each beat is called stroke volume, it is 70 ml.
- Volume of blood leaving right / left ventricle per minute is cardiac output.
- Cardiac out put increases during vigorous exercise and in fever
- Increased cardiac activity-tachycardia decreased cardiac activity-Bradycardia.
- Rate of heart beat in just born baby-130 to 150 times/minute, at the age of 5 years -100 times, at the age of 20 years -72 times
- Normal systolic BP -120 mm Hg, diastolic BP -80 mm Hg.
- Difference between systolic and diastolic pressure – pulse pressure.
- Ratio between systolic pressure to diastolic pressure to pulse pressure is 3:2:1
- Pulse pressure is observed in Radial artery of wrist, it is 40 mm Hg.
- Abnormal cardiac rhythm – arrhythmia.
- Rapid heart rate caused by stress, anxiety, drugs, a due to elevated body temperature – Tachycardia.
- Slow heart rate common during excess vagal stimulation, sleep and low temperature-Bradycardia.
- In healthy adult human beings heart beats at the rate of 72-80 times/min.
- Heart rate is under cent role of through ANS (sympathetic nervous system accelerates the heart beat, parasympathetic nervous system / vagus supply decreases heart-rate).
- Nor epinephrine increased heart rate, acetylcholine decreases heart rate.
- Elevated levels of K^+ or Na^+ decreases heart rate, elevated levels of intracellular Ca^{+2} increases heart rate.
- Heart rate is increased during fever, severe exercise.
- Heart rate is some what faster in adult females.

ECG: Electrocardiogram



- Record to detect heart conditions by measuring the electric activity of heart.
- Instrument is electrocardiograph.
- ECG has P wave, QRS complex and T-wave.
- P-Wave represents depolarization of atrium (atrial systole) caused by SA node activation.
- QRS complex represents ventricular depolarization (ventricular systole).
- T-wave represents repolarization of ventricle (ventricular diastole).
- Determination of heart beat rate of an individual done obviously by counting number of QRS complex per a minute.
- Large P-wave indicates an enlargement of atrium.
- Enlarged R-wave indicates enlargement of ventricles.
- Tall T-wave/Inverted T-wave indicates myocardial ischemia.
- Beginning of P-wave to the QRS complex in PR interval.
- Prolonged P-R interval indicates coronary artery disease, Rheumatic fever.
- S-T segment connects QRS complex and T-wave.
- Elevated S-T-segment (above base line) indicates acute myocardial infarction.
- Depressed S-T segment (below base line) is seen when heart muscles receive insufficient oxygen.
- Beginning of QRS complex to the end of T-wave is QT interval.
- Lengthened QT interval indicates myocardial damage, myocardial ischemia, and conduction abnormalities.

Double circulation

- Physiology of blood circulation was first described by William Harvey (Father of human physiology).
- In the heart birds and mammals complete separation of oxygenated and deoxygenated blood takes place.
- Heart of birds and mammals pumps into two closed circuits, the systemic circulation and pulmonary circulation.
- In the systemic circulation left atrium receives oxygenated blood (OB) from lungs through pulmonary veins and left ventricle pumps OB to organ systems through left systemic arch.
- In the pulmonary circulation right atrium receives deoxygenated blood (DOB) from different parts of body except lungs through three caval veins, right ventricle pumps DO to lungs for oxygenation through pulmonary arteries
- Disorders of circulatory system (cardiovascular disorder)
- Hypertension (high blood pressure): Blood pressure higher than normal (120/80), increased blood pressure above 140 mm Hg (systolic) and 90 mm Hg (diastolic) is hypertension.
- Hypertension lead to heart disease and also affects brain, kidney.
- Hypotension: Low blood pressure, it occurs due to severe blood loss.
- Coronary artery disease (CAD): It is often refers to as atherosclerosis, in which lumen of coronary artery narrow due to deposition of calcium, fat, cholesterol and fibrous tissue affective supply of blood to wall of heart.
- Arteriosclerosis-It refers to thickening the walls of arteries and loss of elasticity.
- Myocardial ischemia-partial obstruction of blood flow in the coronary arteries due to atherosclerosis.
- Angina pectoris-Acute chest pain (strangles chest) when the supply of oxygen to the heart wall is insufficient.
- Myocardial infarction (MI)-(Heart attack)-Sudden decrease in coronary blood supply it leads to death.
- MI occurs frequently due to thrombosis in right coronary artery.
- Stroke it is a sudden neurological disorder often caused by decreased blood supply to a part of brain.

- Heart failure: It is the state of heart when is not pumping enough blood effectively to meet the needs of the body.
- Cyanosis: Symptom of inadequate heart function in babies (blue baby) suffering from congenital heart disease, low O₂ level in peripheral blood vessels make the skin look blue.
- Ectopia cordis is Location of heart out side of thoracic cavity.
- Cardiac arrest-Stoppage of heart beat.
- Heart block-Defective transmission of cardiac impulses from atrium to the ventricle.

Blood Groups:

- Karl Landsteiner first observed ABO blood grouping in human beings.
- ABO blood grouping is based on the presence and absence of two surface antigens namely A and B on the surface of RBC and presence of antibodies anti-A and anti -B in the plasma.

S.No.	Blood group	Antigen on RBC	Antibodies in plasma	Can donate blood to	Can receive blood form
1	A	A	Anti-B	A, AB	A, O
2	B	B	Anti-A	B, AB	B,O
3	AB	A,B	Nil	AB	A, B, AB, O
4	O	Nil	Anti-A Anti-B	A, B, AB, O	O

Universal donor group is O – ve.

Universal recipient group is AB+ve.

Rh grouping

- Land Steiner, Levine and other discovered another antigen called Rh factor first on RBC Rhesus monkeys later on humans.
- Humans with Rh factor on RBC are Rh positive (more than 85%), humans without Rh factor on RBC are RH negative (very low).
- If a Rh negative person is exposed to Rh positive blood, he will produce Rh antibodies (Anti-D antibodies) against Rh antigen (Rh factor).
- Rh incompatibility is observed between Rh-ve blood of a pregnant mother with Rh+ve blood of the foetus.
- In erythroblastosis fetalis -subsequent Rh+ body will be affected when Rh+ve man marries to Rh-ve woman but the first body is safe.
- Soon after parturition of the first Rh+ve baby mother given Rh antibody injection to have normal baby in the next pregnancy