Blood and blood circulation

Blood is the main circulatory medium in the human body. It is a red coloured fluid connective tissue.

1. Components of Blood

The blood consists of two main components. The fluid plasma and the formed elements (blood cells) which are found suspended in the plasma.

Plasma

It is slightly alkaline, containing non-cellular substance which constitutes about 55% of the blood. Organic substances like proteins, glucose, urea, enzymes, hormones, vitamins and minerals are present in the plasma.

Formed Elements of Blood

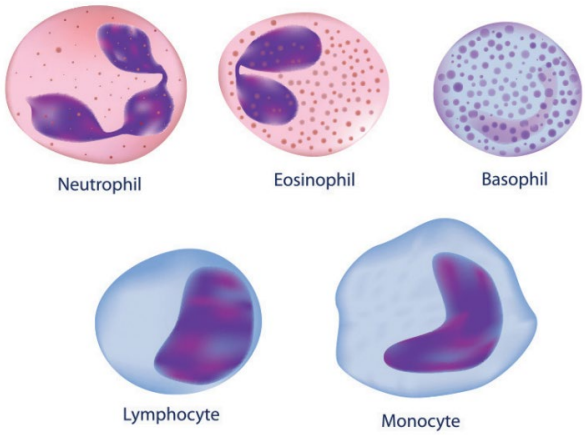
- Red blood corpuscles (RBC) or Erythrocytes
- White blood corpuscles (WBC) or Leucocytes
- Blood platelets or Thrombocytes.

1. Red blood corpuscles (Erythrocytes)

They are the most abundant cells in the human body. RBCs are formed in the bone marrow. The RBCs impart red colour to the blood due to presence of respiratory pigment haemoglobin. Matured mammalian RBCs do not have cell organelles and nucleus. They are biconcave and disc-shaped. Their life span is about 120 days. RBC is involved in the transport of oxygen from lungs to tissues.

2. White blood corpuscles (Leucocytes)

WBC's are colourless. They do not have haemoglobin and are nucleated cells. It is found in the bone marrow, spleen, thymus and lymph nodes. They are capable of amoeboid movement.



The white blood corpuscles can be grouped into two categories: 1. Granulocytes, 2. Agranulocytes.

Granulocytes

They contain granules in their cytoplasm. Their nucleus is irregular or lobed. The granulocytes are of three types: i. Neutrophils, ii. Eosinophils, iii. Basophils

i. Neutrophils

They are large in size and have a 2 - 7 lobed nucleus. These corpuscles form 60% - 65% of the total leucocytes. Their numbers are increased during infection and inflammation.

ii. Eosinophils

It has a bilobed nucleus and constitute 2% - 3% of the total leucocytes. Their number increases during conditions of allergy and parasitic infections. It brings about detoxification of toxins.

iii. Basophils

Basophils have lobed nucleus. They form 0.5-1.0% of the total leucocytes. They release chemicals during the process of inflammation.

Agranulocytes

Granules are not found in the cytoplasm of these cells. The agranulocytes are of two types:

i. Lymphocytes ii. Monocytes

i. Lymphocytes

These are about 20-25% of the total leucocytes. They produce antibodies during bacterial and viral infections.

ii. Monocytes

They are the largest of the leucocytes and are amoeboid in shape. These cells form 5 - 6 % of the total leucocytes.They are phagocytic and can engulf bacteria.

3. Blood Platelets or Thrombocytes

These are small and colourless. They do not have nucleus. There are about 2,50,000 – 4,00,000 platelets / cubic mm of blood. Life span of platelets is 8–10 days. They play an important role in clotting of blood. Platelets form clot at the site of injury and prevent blood loss.

Functions of blood

1. Transport of respiratory gases (Oxygen and CO2).
2. Transport of digested food materials to the different body cells.
3. Transport of hormones.
4. Transport of nitrogenous excretory products like ammonia, urea and uric acid.
5. It is involved in protection of the body and defense against diseases.
6. It acts as buffer and also helps in regulation of pH and body temperature.
7. It maintains proper water balance in the body.

2. Types of Circulatory System

Animals possess two types of circulatory system. They are, 1. Open type, 2. Closed type

1. Open type

In open type the blood is pumped by heart into blood vessels that open into blood spaces called as sinuses. These sinuses are the body cavities which are called haemocoel. Capillary system is absent. e.g. Arthropods, Molluscs and Ascidians.

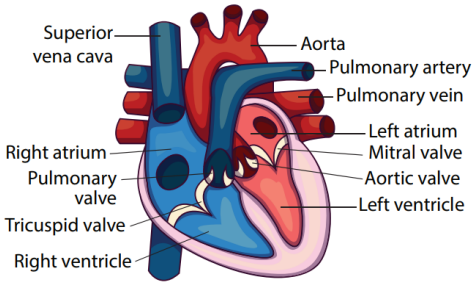
2. Closed type

In closed type the blood flows in a complete circuit around the body through specific blood vessels. The blood flows from arteries to veins through small blood vessels called capillaries. e.g Vertebrates.

3. Structure of Human Heart

Heart is a muscular pumping organ that pumps out the blood into the blood vessels. Human heart is situated between the lungs, slightly tilted toward the left and above the diaphragm in the thoracic cavity. The heart is made of specialized type of muscle called the cardiac muscle.

The heart is enclosed in a double walled sac called pericardium. It contains lubricating pericardial fluid which reduces friction during heart beat and protects it from mechanical injuries.



The human heart is four chambered. The two upper thin walled chambers of the heart are called auricle or atria (sing: atrium) and two lower thick walled chambers are called ventricles. The chambers are separated by partition called septum. The septum between auricles and ventricles prevents the mixing of oxygenated and deoxygenated blood.

The two auricles are separated from each other by interatrial septum.The left atrium is smaller than the right atrium. The right atrium receives deoxygenated blood from different parts of the body through the main veins superior vena cava, inferior vena cava and coronary sinus. Pulmonary veins bring oxygenated blood to the left atrium from the lungs. The right and left auricles pump blood into the right and left ventricles respectively.

The ventricles form the lower part of the heart. The two ventricles are separated from each other by an interventricular septum. The left and right ventricles have thick walls because the ventricles have to pump out blood with force away from the heart. From the right ventricle arises the pulmonary trunk which bifurcates to form right and left pulmonary arteries. The right and left pulmonary arteries supply deoxygenated blood to the lungs of the respective side. The left ventricle is longer and narrower than the right ventricle. The walls are about three times thicker than the right ventricle. The left ventricle gives rise to aorta. The oxygenated blood is supplied by the aorta to various organs of the body. The coronary arteries supply blood to the heart.

Valves: The valves are the muscular flaps that regulate the flow of blood in a single direction and prevent back flow of blood. The heart contains three types of valves.

Right atrioventricular valve: It is located between the right auricle and right ventricle. It has three thin triangular leaf like flaps and therefore called tricuspid valve. The apices of the flaps are held in position by chordae tendinae arising from the muscular projection of the ventricle wall known as papillary muscles.

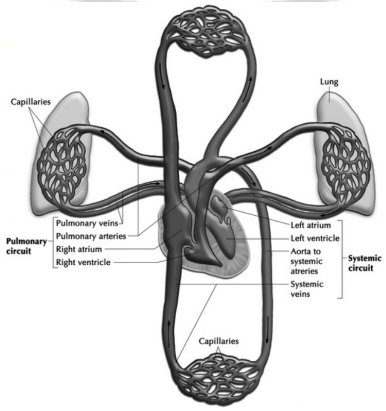
Left atrioventricular valve: It is located between the left auricle and left ventricle. It has two cusps and therefore called bicuspid or mitral valve.

Semilunar valves: The major arteries (pulmonary artery and aorta) which leave the heart have semilunar valves which prevent backward flow of blood into the ventricles. They are the pulmonary and aortic semilunar valves.

4. Types of Blood Circulation

The blood circulates in our body as oxygenated and deoxygenated blood. The types of circulation are:

1. **Systemic circulation:** Circulation of oxygenated blood from the left ventricle of the heart to various organs of the body and return of deoxygenated blood to the right atrium. Aorta carries oxygenated blood to all the organs of the body.
2. **Pulmonary circulation:** The path of pulmonary circulation starts in the right ventricle. Pulmonary artery arises from the right ventricle and reaches the lungs with deoxygenated blood. Pulmonary veins collect the oxygenated blood from the lungs and supplies it to the left atrium of the heart.
3. **Coronary circulation:** The supply of blood to the heart muscles (cardiac muscles) is called as coronary circulation. Cardiac muscles receive oxygenated blood from coronary arteries that originate from the aortic arch. Deoxygenated blood from the cardiac muscles drains into the right atrium by the coronary sinuses.



When the blood circulates twice through the heart in one complete cycle it is called double circulation. In double circulation the oxygenated blood do not mix with the deoxygenated blood.

However, in some animals the oxygenated and deoxygenated blood are mixed and pass through the heart only once. This type of circulation is called single circulation. e.g., fishes, amphibians and certain reptiles.

5. Heart Beat

One complete contraction (systole) and relaxation (diastole) of the atrium and ventricles of the heart constitute heartbeat. The heart normally beats 72 – 75 times per minute.

Initiation and conduction of Heart beat

The human heart is myogenic in nature. Contraction is initiated by a specialized portion of the heart muscle, the sino-atrial (SA) node which is situated in the wall of the right atrium near the opening of the superior vena cava. The SA node is broader at the top and tapering below. It is made up of thin fibres.

Sino-atrial node acts as the 'pacemaker' of the heart because it is capable of initiating impulse which can stimulate the heart muscles to contract. The impulse from the sinoatrial node spreads as a wave of contraction over the right and left atrial wall pushing the blood through the atrioventricular valves into the ventricles. The wave of contraction from SA node reaches the atrioventricular (AV) node which is stimulated to emit an impulse of contraction spreading to the ventricular muscle via the atrioventricular bundle and the Purkinje fibres.

Pulse: When the heart beats the blood is forced into the arteries. The expansion of the artery every time the blood is forced into it is called pulse. It can be felt by placing the fingertip on the artery near the wrist. Normal pulse rate ranges from 70 – 90 / min.

6. 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 is shown Figure 7.3. 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 strawcoloured 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.

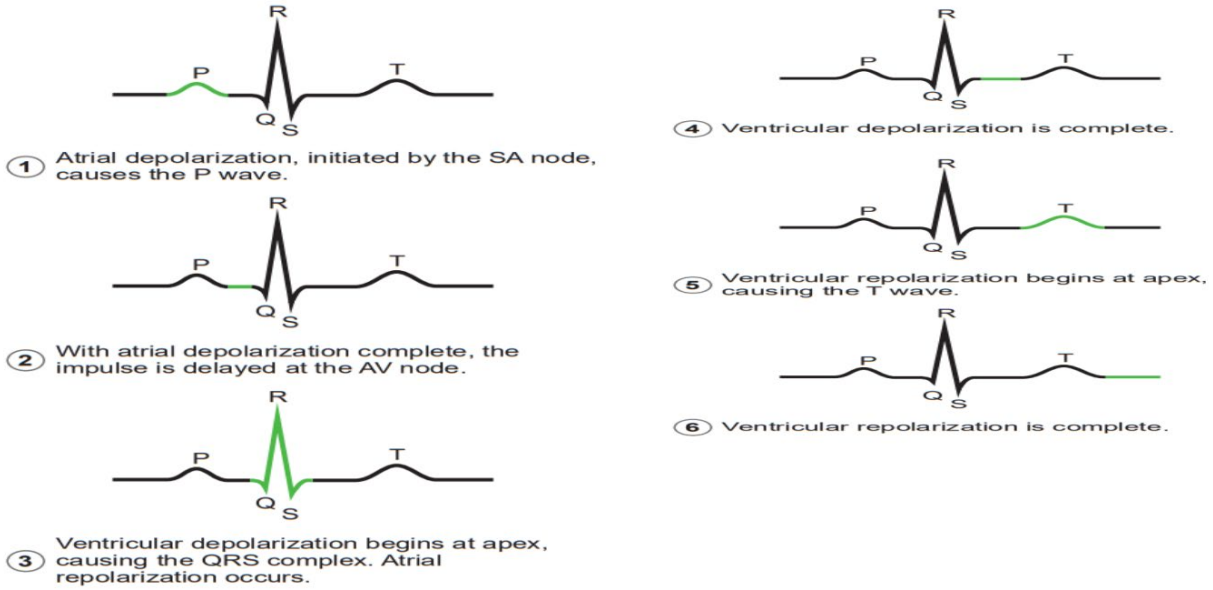
Coronary blood vessels

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.

7. 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.



1. 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.

2. 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.

3. QRS Complex (Ventricular depolarisation)

No separate wave for atrial depolarisation in the ECG is visible. Atrial depolarisation 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 depolarisation 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.

4. ST Segment

It lies between the QRS complex and T wave. It is the time during which all regions of the ventricles are completely depolarised 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.

5. 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 depolarization.

8. 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.

9. Disorders of the circulatory system

1. 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.

2. Coronary heart disease

Coronary heart disease occurs when the arteries are lined by atheroma. The build-up 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.

3. 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).

4. 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.

5. 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.

6. 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.