Body Fluids and Circulation

Components of Blood and Lymph (Detail Study)

Need for Transport inside Our Body

- **In Digestive System:** The nutrients absorbed from the digested food need to be transported to each cell to perform their functions.
- **In Excretory System:** All the wastes generated need to be collected from whole body and flushed out.
- **In Endocrine System:** The hormones produced need to be sent to each and every part of our body.
- **In Respiratory System:** The oxygen and CO_2 need to be transported through out the body.

Blood: Connective tissue consisting of fluid matrix, plasma, and formed elements

Functions of Blood

(i) Transportation

- Transport of digested food from alimentary canal to tissues
- Transport of oxygen from lungs to the tissues
- Transport of carbon dioxide from tissues to lungs
- Transport of excretory material
- Distribution of hormones from endocrine glands
- Distribution of heat throughout the body

(ii) Protection

- Formation of clot in case of cut, thus preventing blood loss
- Protecting body from bacteria
- Production of antitoxins and antibodies

Components of Blood: It consists of fluid part, called plasma, and cellular elements that consist of red blood cells, white blood cells, and platelets.

Plasma

- 55% of blood
- Plasma = 90-92 % water + 6-8% proteins
- Proteins present
  Fibrinogen – blood clotting

Globulins – defence mechanisms
Albumins – osmotic balance

- Also contain mineral, glucose, amino acids, and lipids in traces
  Blood clotting factors are present in inactive form in plasma.
- Serum = Plasma – Clotting factors

Formed Elements

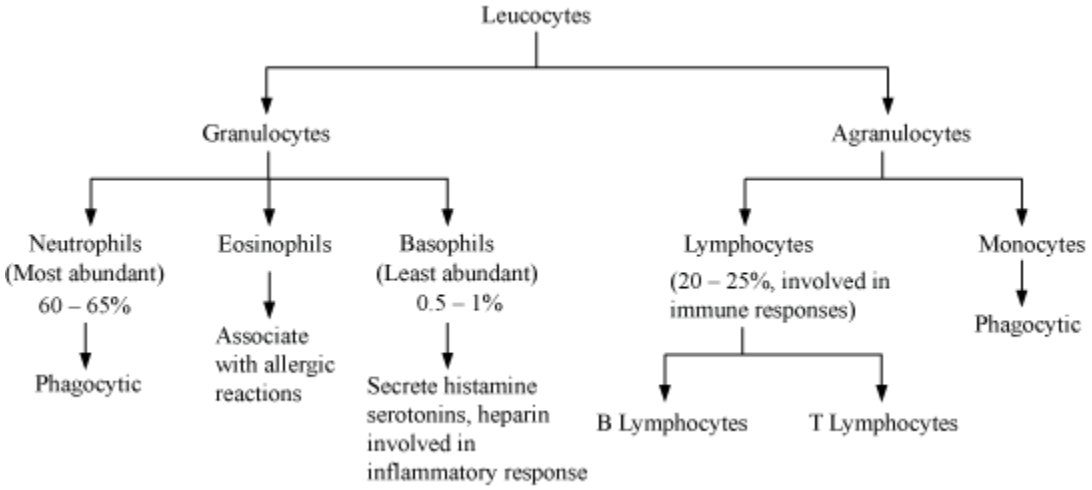
Formed elements (45% of blood)		
Erythrocytes	**Leucocytes**	**Platelets (Thrombocytes)**
Most abundant: 5–5.5 million/mm^3 of blood	Relatively lesser in number: 6000–8000/ mm^3 of blood	1.5–3.5 × 105/mm^3 of blood
Formed in red bone marrow; average life span is of 120 days; destroyed in spleen, hence spleen is called the graveyard of RBCs	Have different sites for formation	Formed in megakaryocytes
Biconcave and devoid of nucleus	Nucleated	Anucleated
Contain haemoglobin and hence involved in transport of respiratory gases Average value of haemoglobin – 12-16 gm/100 ml of blood	Play major role in defence system of body	Involved in blood clotting

Red Blood Cells (RBCs) - These are responsible to carry oxygen through the body.

- **Haemoglobin** : A chief chemical constituent of RBCs. It is present inside stroma - a spongy body of RBCs.
- It is made up of iron and protein.
- It easily combines with oxygen forming oxyhaemoglobin, an unstable compound that easily donates oxygen to the needy tissues.
- It also carries a small amount of CO_2 in the form of carbaminohaemoglobin.
- **Carbon monoxide Poisoning**
- Haemoglobin has high affinity towards carbon monoxide as it forms a more stable compound carboxyhaemoglobin (HbCO).
- It results in decreased efficiency of oxygen transport by blood, leading to less supply of oxygen in the body.
- It may result even in death.

Increased Efficiency of RBCs
The mammalian red blood cells are more efficient as compared to others as they lack certain cell organelles. The factors that makes them more efficient are:

- Loss of nucleus: This makes them biconcave in shape hence, increasing their surface area to volume ratio to maximise oxygen absorption.
- Loss of mitochondria: Lack of mitochondria means that no cellular respiration can occur in the RBCs. Thus all the oxygen absorbed from the lungs are transported to the tissues as they don't need it for themselves any more.
- No endoplasmic reticulum: It results in increased flexibility for their movement through the constricted capillaries.



Functions of Leucocytes (WBCs)
The basic function of white blood cells is body defence.

- **Phagocytosis**: This is a defence mechanism in which the WBCs engulf the solid substances like bacteria.
- **Inflammation**: Inflammation is a result of reaction of tissues to injuries and to localised invasion of germs. The leucocytes (especially monocytes and neutrophils) reach the inflamed area by migrating through blood vessel walls (**diapedesis**). They can then fight against the disease causing germs and also destroy the damaged cells by phagocytosis.
- **Formation of Antibodies**: These are produced by WBCs (lymphocytes) to kill or neutralise the germs and poison from them. These are stimulated by introducing weakened germs through vaccination.

Lymph

- Lymph is the fluid released out of blood capillaries leaving behind larger proteins and formed elements.

- It consists of water and some water soluble substances.
- It has some mineral distribution as present in plasma.
- The network of lymph vessels composes lymphatic system.

Uses

- Lymph contains lymphocytes that are involved in immune response.
- Lymph carries nutrients, hormones, etc.
- Lymph absorbs fats in lacteals found in intestinal villi.

Blood Coagulation

Blood Coagulation:

- Clotting is required to prevent excessive loss of blood from the body.
- Blood clot - formed by threads of fibrin in which formed elements are trapped.
- Prothrombin (inactive form) $\xrightarrow{\text{thrombokinase}}$ thrombin (active form)
- Fibrinogen (inactive form) $\xrightarrow{\text{thrombin}}$ fibrin (active form)
- Mechanism of coagulation is a cascade of reactions involving several clotting factors.
- Calcium plays an important role in blood clotting mechanism.
- **Serum :** The Clear liquid squeezed out of the network of fabrin in which the blood cells are trapped is called Serum.

Blood Groups and Rh Factor

Blood groups

- Widely used blood grouping – ABO and Rh

ABO Grouping

- Surface antigens A and B are present on RBCs.
- Antibodies are produced against corresponding antigens.

Blood Group	Antigen on RBC	Antibody on plasma	Donor's Group
A	A	Anti B	A, O
B	B	Anti A	B, O
AB	A, B	Nil	AB, A, B, O
O	Nil	Anti A, B	O

- Universal Donor – Blood group 'O'

- Universal recipient – Blood group ‘AB’

Rh Grouping

- Individuals with Rh antigens present on RBCs are Rh positive and those without it are Rh negative.
- If Rh –ve mother bears an Rh +ve child during first pregnancy when mother’s blood is exposed to Rh +ve antigens, then anti – Rh antibodies are produced in her blood.
- During subsequent pregnancies, these antibodies may destroy RBCs of the foetus. This results in severe anaemia and jaundice to new born. This condition is called *erythroblastosis foetalis.*
- During Rh incompatibility, the first child is safe or may have anaemia.
- However, this condition can be avoided for subsequent pregnancies by administering anti-Rh antibodies of mother immediately after delivery of first child.

Human Circulatory System

Human Circulatory System

- Humans have a closed circulatory system: Blood pumped by the heart always flows through a closed network of blood vessels.

- Human circulatory system consists of:

- Muscular, four-chambered heart

- A network of closed, branching blood vessels – veins, arteries and capillaries

- Blood

Blood vessels

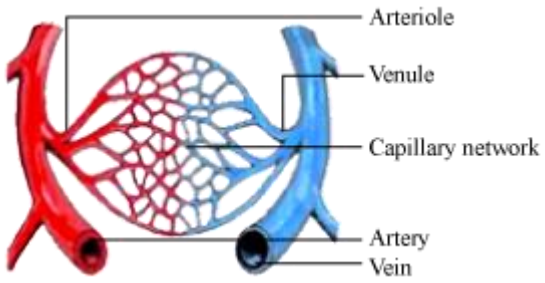
Arteries are tough, elastic tubes that carry blood from the heart and supply it to various organs of the body. As the arteries move away from the heart (i.e., on reaching organs and tissues), they divide into smaller vessels. **Arteriole** is the smallest or the final branch of artery. These are highly muscular and can easily change their diameter. **Arteries** are red in colour because they carry oxygenated blood.

The smallest blood vessels are called **capillaries**. They have very thin walls and lack muscles. The capillaries can easily dilate **(vasodilation)** and contract **(vasoconstriction)**, thus can regulate the blood supply to different organs.

Functions Of Capillaries:

- It allows the outward diffusion of Oxygen

- It allows the WBCs to squeeze out of capillary walls
- It allows inward and outward diffusion of urea, glucose, hormones etc.



Capillaries in organs and tissues gradually reunite and increase in size. The smallest of the united common branch are called a **venule**. The venules then join to form the **veins**. Veins collect blood from different organs and tissues and transport it to the heart. They are thin-walled as compared to arteries. This is because they bring back blood from the organs to the heart and blood is no longer under pressure. These veins carry deoxygenated blood into the heart.

Differences between Arteries and Veins

Artery	Vein
Carries blood towards organs and away from heart	Carries blood towards heart and away from organs
Carries fully oxygenated blood (except pulmonary artery)	Carries deoxygenated blood (except pulmonary vein)
Has no valves	Has valves to prevent backflow of blood
Has elastic, thick and muscular walls	Has non-elastic, thin and less muscular walls
Is deeply placed	Is superficial
Branched and decreases in size	Unites and increases in size
Can constrict and dilate	Cannot constrict
Has jerky blood flow under great pressure	Has smooth and continuous blood flow under very little pressure

Hepatic portal system

Hepatic portal system consists of a network of veins that facilitate the recirculation of

blood to the **liver** from digestive tract and spleen. The major blood vessels of this system includes **hepatic portal vein**, **inferior mesentric vein**, **superior mesentric vein** and **gastrosplenic vein**.

Significance of hepatic portal system

Hepatic portal system allows metabolization of digested substances in the liver before they are propagated to the systemic circulation. Certain toxic substances can be inactivated by the liver metabolism and excreted from the body. Thus, hepatic portal system plays an important role in the elimination of toxic substances from the body. Practical significance of hepatic portal system can be observed in the filed of pharmacology. Many drugs such as nitroglycerine can be inactivated through liver metabolism. Such drugs are therefore not administered through oral means because hepatic portal system can transfer them to the liver and make them ineffective.

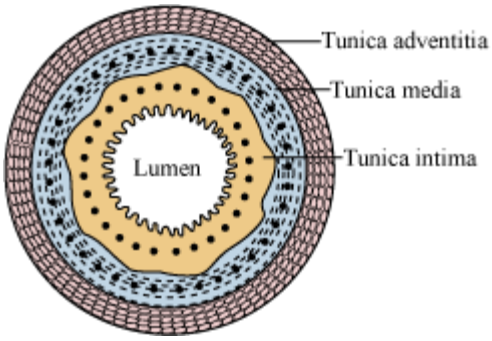
Blood Vessels

We know that blood flows inside the blood vessels and it performs functions such as transporting oxygen and nutrients to all cells of the body. We also know that it helps in removing waste materials, including carbon dioxide, from the body.

Let's summarise the features of blood vessels.

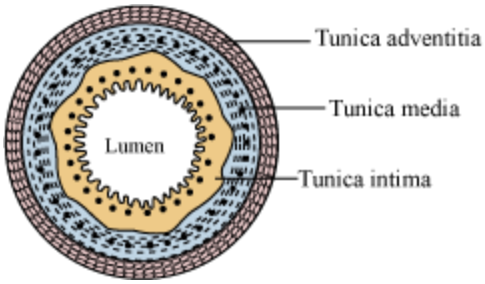
Structure of blood vessels

Arteries are thick-walled, muscular and elastic. They consist of three layers: tunica adventitia, tunica media and tunica intima.

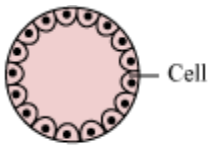


Arteries divide into smaller arterioles, which further branch to form meta-arterioles and finally capillaries. The structure of arteries is related to their function. Arteries have thick and elastic walls which are appropriate for the blood flowing under high pressure in these blood vessels.

Veins, on the other hand, have thin and non-elastic walls. Such structure is appropriate for veins since blood flows at a comparatively lower pressure and speed in veins.



Capillaries are only one cell thick. A single layer of endothelial cells constitute capillaries. Capillaries are thin so as to facilitate the exchange of materials such as gases, dissolved food and excretory products through them.



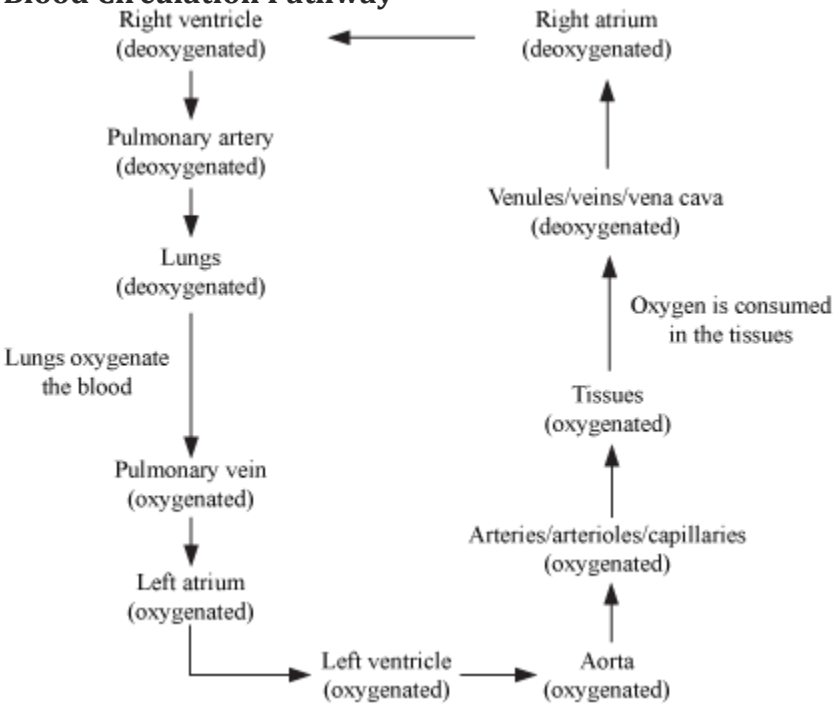
Endothelial Cells

Double Circulation and Cardiac Cycle

Double Circulation

- In human beings, oxygenated blood is received by the left atria while deoxygenated blood is received by the right atria, which then pass it on to their respective ventricles.
- This prevents the oxygenated and deoxygenated blood from mixing. This unique pathway is called double circulation.
- Double circulation consists of two parts: **pulmonary circulation and systemic circulation**.
- In systemic circulation, the deoxygenated blood is collected from all the body parts and transported to the heart through vains. The collected blood is poured into the right atrium through superior and inferior **vena cava**. Once the blood is oxygenated, it is transported back to various body parts from the left ventricle of the heart through **aorta**.
- In pulmonary circulation, pulmonary artery collects deoxygenated blood from the right ventricle of heart and carries it to the lungs. After gaseous exchange in the blood, the pulmonary veins collect the oxygenated blood from the lungs and carry it to the left atrium of the heart.

Blood Circulation Pathway



Hepatic Portal System

- **Portal Vein :** A vein that starts and ends with capillaries.

  The veins coming from intestines and stomach does not directly delivers the blood to the **posterior vena cava.** Instead, they enter into the liver combined together as **hepatic portal vein**, which then splits into numerous capillaries. This is opposite to the characteristic of vein. Later these capillaries combine to form hepatic vein which later joins the posterior vena cava. This whole system is known as hepatic portal system.

- Hepatic portal system helps in assimilation of different nutrients absorbed by blood during digestion process in the liver.
- It also helps in detoxification of blood in the liver.

Cardiac Cycle

- Cardiac cycle is the sequence of events which occur from the beginning of one heart beat to the beginning of the next heart beat.
- In the beginning, all the 4 chambers of the heart are in a state of joint diastole (relaxation).
- Tricuspid and bicuspid valves open and blood from the veins and the vena cava flow into the atria, and then into the ventricles because of the opening of the valves.
- SAN generates an action potential, and both atria undergo contraction (Atrial systole).
- The flow of blood into the ventricles increases by 30%.

- The action potential is conducted towards the ventricles through the AVN and the AV bundles, from where the bundle of His transmits this action potential over the entire cardiac musculature.
- The ventricles contract (ventricular systole) and the atria relax (atrial diastole) as a result of the conduction of action potential.
- Ventricular pressure increases. Hence, bicuspid and tricuspid valves close, to prevent the backflow of blood into the atria. Further increase in pressure in the ventricles leads to the opening of the semilunar valves.
- Blood from the ventricles flow into the pulmonary artery and the aorta, and subsequently into the circulatory pathways.
- Consequently, the ventricles relax (ventricular diastole), ventricular pressure falls, and the semilunar valves close to prevent the backflow of blood into the ventricles.
- Ventricular pressure further falls. As a result, the bicuspid and tricuspid valves open. This is because pressure is exerted on the atria by the blood entering them through the veins.
- Once again, joint diastole is experienced and the entire cycle is repeated.

Pulse

The distension felt because of the contraction of heart, every time when blood passes through the arteries, is referred as pulse. This alternate expansion and recoil of the arteries occur because of the elastic nature of artery walls. A pulse rate can give indirect measure of the heart beats.

Blood Pressure

- The pressure exerted by blood through the arteries on their walls.
- There are two limits to the blood pressure:
- **Systolic Pressure (upper limit)**: When fresh blood is pushed through artery due to ventricular contraction of heart
- **Diastolic Pressure (lower limit)**: When the wave has passed over
- The normal blood pressure for an adult is 120 (systolic) and 80 (diastolic)

Cardiac output

- Heart beats: Average 72 times/minute (heart rate)
- Duration of cardiac cycle is 0.8 seconds.
- Stroke volume: Amount of blood pumped by the heart in one cardiac cycle
  Stroke volume = 70 mL
- Cardiac output = Stroke volume × Heart rate
  = 70 mL × 72 times / min
  ~ 5000 mL

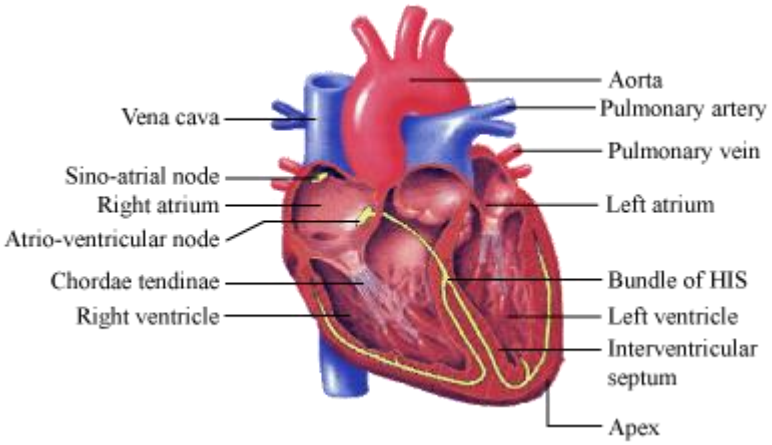
Heart Sounds

- Lub: First heart sound, associated with the closure of the tricuspid and bicuspid valves
- Dub: Second heart sound, associated with the closure of the semilunar valves

- These heart sounds are of diagnostic significance.

Structure of Heart

Heart



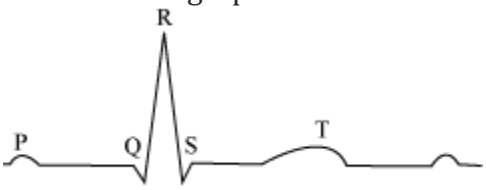
- Location: Thoracic cavity in between the lungs; slightly tilted to the left
- Protected by a double-walled pericardium, enclosing the pericardial fluid
- Has 4 chambers: 2 upper chambers – right and left atria
- 2 lower chambers – right and left ventricles
- Inter-atrial septum: Separates the right and the left atria
- Inter-ventricular septum: Separates the right and the left ventricles
- Atrio-ventricular septum: Separates the atria and the ventricles of the same sides
- Septa have openings through which the two chambers on the same sides are connected.
- Tricuspid valve: Present between the right atria and the right ventricle
- Bicuspid (mitral) valve: Present between the left atria and the left ventricle
- Semilunar valves: Guard the openings of the right and the left ventricles into the pulmonary artery and the aorta respectively.
- Special cardiac musculature called nodal tissue is distributed throughout the heart.
- Sinoatrial node (SAN): Present at the upper right corner of the right atrium
- Atrio-ventricular node (AVN): Present at the lower left corner of the right atrium
- AV bundle (a bundle of nodal fibres) continues from the AVN and passes through the atrio-ventricular septa to reach the inter-ventricular septum.
- There, it divides immediately into right and left bundles. From these branches, minute fibres arise throughout the ventricular musculature. These fibres are called purkinje fibres.
- Right and left bundles + Purkinje fibres = Bundle of His
- Significance of nodal musculature: Auto-excitable; generates and maintains action potential to sustain the rhythmic contraction activity of the heart
- Pacemaker of the heart – Sino-atrial node (SAN)
- Heart beats 70–75 times/min

Electrocardiograph

- Electrocardiogram: Graphical representation of the activity of the heart during a cardiac cycle

- Patient is connected to ECG at 3 leads (one to each wrist and to the left ankle)

- Electrocardiogram: Graph obtained
  Electrocardiograph: Machine used



- Each peak of the electrocardiogram corresponds to a specific electrical cardiac activity.

- Waves of a normal/standard electrocardiogram:

- **P wave** – electrical depolarisation of the atria, leading to atrial systole

- **QRS complex** – electrical depolarisation of the ventricles, leading to ventricular systole

- **T wave** – electrical repolarisation of the ventricles, marking the end of systole

- Number of QRS complexes = Rate of heart beat
- Any deviation from the standard shape of an ECG graph indicates a disease or abnormality.

  Let us understand how the waves corresponds to the various movements of heart with the help of this animation.

  Regulation of Heart Activity

  Regulation of Heart Activity

- Nodal tissues – Auto-regulate the heart activity intrinsically; so the heart is myogenic
- Autonomic nervous system (ANS) regulates the heart activity. Neural centre is present in medulla oblongata to moderate the process.
- Both sympathetic and parasympathetic nerves are parts of ANS.
- Sympathetic nerves provide signals to increase heart beat rate, ventricular contraction, and hence cardiac output.
- Parasympathetic nerves provide signals to decrease heart beat rate, speed of conduction of action potential, and hence cardiac output.

  Circulatory System Disorders

  Disorders of Circulatory System

- **Hypertension**

- Normal blood pressure – 120/80 [120 mm Hg – systolic and 80 mm Hg – diastolic]
- If blood pressure of an individual comes out to be equal to or more than 140/90, then we say that he suffers from high blood pressure or hypertension.
- It affects heart, kidneys, brain, and other vital organs.

- **Coronary Artery Disease (CAD)**

- Blood vessels supplying blood to heart muscles are blocked by deposits of calcium, fat, cholesterol, or fibrous tissues.
- Common term used – Atherosclerosis

- **Angina (Angina Pectoris)**

- Enough oxygen does not reach heart muscles.
- Main symptom – Acute chest pain
- Can occur at any age but common in middle aged and elderly

- **Heart Failure**

- Pumping of blood is not enough to meet the requirements of body.
- Common term – congestive heart failure since congestion of lungs is one of the main symptoms

- **Heart attack**

- Situation when the heart muscles get damaged due to short supply of blood

- **Cardiac arrest**

- Situation where heart suddenly and without warning stops beating
- No blood can be pumped to the rest of the body.