BODY FLUIDS AND CIRCULATION

BLOOD

INTRODUCTION

System which transports materials like nutrients, gases, hormones etc. to the various parts of the body and removes waste materials from the body cells is known as circulatory system.

TYPES OF CIRCULATORY SYSTEM

Circulatory system is of two types:

(A) Open circulatory system–

- In this system circulatory fluid flows in the body cavity without any special closed tubular system.
- Circulatory fluid is filled in spaces called haemocoel and circulating fluid is called haemolymph.
- In this system, cells directly come in contact with haemolymph.
- E.g. Arthropoda, all molluscs except Cephalopods.

(B) Closed Circulatory system-

- In this circulatory system fluid flows in the closed tubes called blood vessels.
- Cells do not remain directly in contact with the blood.
- Closed blood circulation is more effiecient.
- E.g. Annelids (except leeches), Chordates (except Urochordata), Cephalopods (Sepia, Octopus).

HUMAN CIRCULATORY SYSTEM

In human beings, circulatory system is of two types –

(1) Blood (2) Lymph

Matrix is liquid & fibre free

(A) Blood Vascular System:–

- In this system, circulatory fluid is blood.
- This system includes blood, blood vessels, and heart.
- This is found in higher invertebrates and all vertebrates.

(B) Lymphatic System:–

- In this system, circulatory fluid is lymph.
- This system includes lymph, lymphoid tissue and lymph vessels.
- It is found in higher vertebrates.

BLOOD

Study of Blood — Haematology

Process of blood formation Haemopoiesis (in bone marrow).

- Colour — Red
- PH — 7.4 (Slightly alkaline)
- By weight — 7 to 8% of body weight
- By volume — 5 - 6 litres in male and 4 - 5 litres in female.
- Blood is a false CT because:-

a. Cells of blood have no power of division.

b. Fibres are completely absent in blood.

c. Matrix of blood is produced & synthesized by liver and lymphoid organs,

Composition of Blood

- Liquid Part — Matrix — Plasma — 55%
  Solid Part — Blood corpuscles — 45% (RBC, WBC & Platelets)

PLASMA

- Matrix of blood is called Plasma.
- It is pale yellow in colour due to urobillinogen. (Billirubin)

Composition of plasma

Water : 90% – 92%

Solid part : 8 – 10%

In which inorganic and organic compounds are present.

Organic Part of Plasma — 7 - 9%

1. Proteins

6 - 7% Maximum

(A) Albumin → 4% (Max.)

Produced & synthesized by liver.
Smallest Plasma Protein.
Responsible to maintain BCOP (28 - 32 mm Hg.)

(B) Globulin: - 2- 2.5%.

Ratio of albumin & globulin is 2: 1.
Produce and secreted by liver and lymphoid organs.
Transport or catty substance in body.
Destory bacteria virus & toxic substances.

In blood 3 type of globulins are present.

1. **α–Globulin -** Produced by liver.
   Eg. Ceruloplasrnin- Cu carrying protein.

2. **β–Giobulin** — produced by liver
   Eg. Transferin- Fe carrying protein.

3. **γ–Giobulin —** produced by lymphoid organs
   Present in the fourth of antibodies which destroy bacteria, virus & toxic substance. Also called Immunoglobulins. These are of 5 types.

- lg G (γ lmmuno)
- lg A (α Immunoglobin)
- lg M (μ Immuno)
- lg D (δ Immuno)
- Ig E (ε Immuno)

4. **Prothrombin** – 0.3% Produced by liver

5. **Fibrinogen** – 0.3% Produced by liver
   – Largest plasma protein.
   – Help in blood clotting.

BLOOD CORPUSCLES

RCB

Erythrocytes (Red blood Corpuscles)

- Mammalian RBC's are biconcave, circular & none nucleated.
- At the time of origin nucleus is present in the RBC but it degenerates during maturation process.

- Biconcave shape of RBC increases surface area.
- Due to absence of nucleus & presence of biconcave shape more Haemoglobin can be filled in RBC. Exception: - Camel & Lama are mammals with biconvex, oval shaped
- In RBC endoplasmic reticulum is absent so endoskeleton is composed of structural protein, fats and cholesterol present in the form of network called stromatin which is a spongy cytoskeleton.
- Plasma membrane of RBC is called Donnan's membrane. It is highly permeable to some ions like Cl^- & HCO_3^- ions and impermeable to Na^+ & K^+ ions. It is called Donnan's phenomenon.
- Due to presence of stromatin spongy cytoskeleton & flexible plasma membrane RBC (7.5μ) can pass through less diameter blood capillaries (5μ).
- In RBC higher cell organelles like mitochondria & Golgi complex is absent.
- Due to absence of mitochondria anaerobic respiration takes place in RBC.
- In RBC enzyme of glycolysis process are present, while enzyme of Krebs cycle are absent.
- Antigen of blood group is present on the surface of RBC.
- If Rh Antigen is present then it is also found on the surface of RBC.
- Single RBC is pale yellow in colour while group of RBC appear red in colour.
- In RBC red coloured respiratory pigment haemoglobin is present.
- In each RBC 26.5 crores molecules of Hb are present.
- Molecular weight of each molecule of haemoglobin – 67,200 Dalton.
- In composition of RBC 60% Hp & 40% solid part is present. Only Hb. Constitutes 36% of total weight of RBC and 90% on dry weight.

Haemoglobin

It is composed of two components

- Haem - 5%
- Globin - 95% Protein part

Haem (Iron and Porphyrin)

1. Iron present in the form of Fe^{+2}

2. Each molecule of Hb carries 4 molecules of O_2.

Globin: Each molecule of globin protein is composed of 4 polypeptide chains. Polypeptide chains are of 4types.

- α polypeptide chain having 141 amino acids.
- β polypeptide chain having 146 amino acids.
- γ polypeptide chain having 146 amino acids.
- δ polypeptide chain having 146 amino acids.

On the basis of these polypeptide chains 3 type of Hb are formed in human –

- Hb A_1 (Adult Hb) — $2\alpha + 2\beta$
- Hb A_2 (Adult -2) — $2\alpha + 2\delta$
- Hb F (Foetal Hb) — $2\alpha + 2\gamma$

(Oxygen binding capacity-of foetal Hb is more than adult Hb.)

Size of RBC

Human – 7.5 μ

Change in the size of RBC is called as Anisocytosis.

- Due to Vit. B_{12} deficiency RBC become larger in size called as Macrocytes. These are immature RBC which are destroyed in spleen. In these RBCs amount of haemoglobin is normal.
- Due to Fe deficiency RBC become smaller in size called as Microcytes. They are also destroyed in spleen. In these RBCs amount of haemoglobin is less.

Shape of RBC –

- Biconcave
- Change in the shape of RBC is called as Poikilocytosis.
- Uremia- RBC become irregular in shape (Burr cells).
- Sickle cell anaemia-RBC become sickle shaped.
- If RBC is kept in hypertonic solution it will shrink (crenation).
- In Hypotonic solution it will brust.

Life span of RBC is 120 days

Avg. life span of RBC in all mammals 120 - 127 days.

RBC count
Number of RBC in per cubic mm of blood is called RBC count.

Human (Male)	5.5 million	±1 Million
Human (Female)	4.5 million	
Newly born boby	6.8 million	
Robbit	7 million	
Frog	0.4 million	

Decrease in RBC count condition is called Anaemia.

- **Macrocytic anaemia –** Due to Vit. B 12 deficiency macroytes are formed which are destroyed in spleen.
- **Microcytic anaemia –** Due to Fe deficiency microcytes are formed.
- **Normocytic anaemia –** Excess blood loss.

Formation of RBC

- Process of formation of RBC is called Erythropoiesis.
- Organs which produce RBC's called Erythropoietic organs.
- Hormone which stimulate Erthyropoiesis is called erythropoetin synthesize by Kidney & little quantity by liver.
- 1st RBC produced by yolk sac.
- During embryonic life RBC are produced by Liver, Spleen, Placenta, Thymus galnd.
- In adult stage RBC is produced by RBM which filled in between trabeculae of spongy bones.
- 1% RBC are destroy daily but in same number new RBC are entered in the blood.
- Destruction of RBC occur in spleen. So spleen is called Graveyard of RBC.
- Spleen stores excess blood corpuscles so it is called Blood Bank of body.

WBC

- WBC (White Blood Corpuscles) are also called as leucocytes because they are colourless. TLC- Total leucocyte count. Number of WBC /mm^3 6000 – 8000/mm^3 ($\pm$ 2000 – 3000)

- **Leucocytosis: -** Increase in TLC. This condition occur in bacterial & viral infection.
- **Leukocytopenia: -** Decrease in TLC. Normally TLC increases in bacterial & viral infection but in typhoid & AIDS, TLC decreases.
- **Leukemic: -** Abnormal increase in TLC (more than 1 Lakh) it is called as blood cancer.

On the basis of nucleus & nature of cytoplasm, Leucocyte are of two types.

1. Granulocytes

- In their cytoplasm granules are present which can be stained by specific dye.
- Nucleus is multilobed and lobes are interconnected by protoplasmic strand.
- Due to presence of lobed nucleus they are called as polymorph nuclear WBC.
- Produced in Bone marrow-
- They are (i) Acidophils, (ii) Basophils & (iii) Neutrophils

2. Agranulocytes

- Cytoplasm is clear and agranular.
- Nucleus do not divide in lobes so called as mononuclear WBC.
- Produced in bone marrow.
- They are of 2 types (i) Monocytes (ii) Lymphocytes

(i) Granulocytes		• Cytoplasm has granules, nucleus lobed.		
(a) Eosinophils	• 2–3% of leucocytes	• Bilobed nucleus, coarse granules in cytoplasm, take acidic stain.	• Bone marrow, • Life 4 to 8 hours in the blood, 4 to 5 days in the tissue	• Resist infections, associated with allergic reactions.
(b) Basophils	• 0.5–1.0% of leucocytes.	• Two to three lobed nucleus, fewer number of coarse granules, take basic stain.	• Bone marrow, • Life 4 to 8 hours in the blood, 4 to 5 days in the tissues	• Release histamine, serotonin and heparin, involved in inflammatory reactions.
(c) Neutrophils	• 60–65% of leucocytes.	• Two to seven lobed nucleus, fine granules, do not take acidic as well as basic stains.	• Bone marrow, • Life 4 to 8 hours in the blood, 4 to 5 days in the tissue	• Phagocytic, engulf germs and dead cells.

(ii) Agranulocytes		• Cytoplasm lacks granules, nucleus not lobed.		
(a) Lymphocytes	• 20–25% of leucocytes.	• Large rounded mucleus, scanty cytoplasm.	• Bone marrow and Thymus, • Life few hours to many years.	• Motile, non-phagocytic, secrete antibodies, help in healing.
(b) Monocytes	• 6–8% of leucocytes	• Largest of all types of leucocytes, nucleus bean shaped, enough cytoplasm.	• Bone marrow • Life 10 to 20 hours.	• Motile, phagocytic, engulf germs and cell debris, often change into macrophages.

PLATELETS

- Size 2 - 3 μ.
- Life span - 2 - 4/5 days.
- Count- 1.5 - 3.5 lakh/mm^3.
- Also known as Thrombocytes
- They are non-nucleated and derived from megakaryocyte cells of bone marrow.
- In shape platelets are disc like, oval shaped or biconvex.
- In their cytoplasm basophilic granules are present which can be stained by methylene blue.
- Maximum part of cytoplasm is composed of contractile protein Thrombosthenin.
- Decrease in number of blood platelets is called Thrombocytopenia.
- Critical count of thrombocytes is 40,000/mm^3. If number is less than critical count then red spot or rashes appears on the skin called Purpura disease.

Function

- Repair endothelium of blood vascular system by the formation of platelet plug because they have tendency to attach on gelatinous or mucilaginous surface,
- Synthesize thromboplastin which help in blood clotting.
- Synthesize serotonin (5-hydroxytriptamine).

BLOOD GROUPS:

Human beings have more than 30 types of antigens on the surface of blood cells. They give rise to different types of blood groups.

- Two such groups blood ABO and Rh are widely used all over the world.

(A) ABO Blood Groups:

- Karl Landsteiner (1900) reported first time ABO blood groups in human beings. He discovered A, B and O blood groups.

- ABO grouping is based on the presence or absence of two surface antigens (chemicals that can induce immune response) namely A and B on the RBCs. Similarly, the plasma of different individuals contains two natural antibodies (proteins produced in response to antigens).

- The distribution of antigens and antibodies four blood groups is given below in the table.

Blood Groups and Donor Compatibility				
Blood Group	**Antigen on RBCs**	**Antibodies in Plasma**	**Donor's Group (Can get blood from)**	**Recipient's Group (can give blood to)**
A	A	anti-B	A, O	A, AB
B	B	anti-A	B, O	B, AB
AB	A, B	None	A, B, AB, O	AB
O	None	anti A, B	O	A, B, AB, O

- During blood transfusion, any blood cannot be used. The blood of a donor has to be carefully matched with the blood of a recipient before blood transfusion, to avoid severe problems of clumping (destruction of RBC).

- The group O blood can be donated to persons with any other blood group. Therefore, the individuals with blood group O are called 'universal donors'.

- Persons with AB group can accept blood from persons with any group of blood. Therefore, such persons are called 'universal recipients'.

(B) Rh (Rhesus) blood groups:

- **Landsteiner and Weiner** (1940) discovered another antigen on the surface of red blood corpuscles of rhesus monkey and many human beings. They called it as Rh factor or Rh-antigen.

- Depending on the race, 80 to 99 percent of humans possess this factor and are Rh positive (Rh+). Others who do not have this factor are known as Rh negative (Rh^-).

- The formation of Rh protein is controlled by a dominant gene, which may be designated as R. Thus, RR (homozygous dominant) and Rr (heterozygous) individuals are Rh positive, and rr (homozygous recessive) individuals are Rh negative.

- Phenotypically, Rh positive and Rh negative individuals are normal. The problem arises when an Rh -ve person, is exposed to Rh + ve blood during blood transfusion or pregnancy.

(C) Consequences of blood transfusion:

i. Incompatibility during blood transfusion –

- The first transfusion of Rh^+ blood into the person with Rh^- blood causes no harm. However, the recipient starts preparing antibodies (anti Rh factor) against Rh antigen in his/her blood.

- If the recipient person receives Rh^+ blood second time, the anti Rh factor present in his/her blood attacks and destroy red blood corpuscles of the received blood.

ii. Incompatibility during pregnancy –

- A special case of Rh incompatibility (mismatching) has been observed between the Rh^- blood of a pregnant mother and Rh^+ blood of the foetus. The Rh antigens of the foetus do not get exposed to the Rh- blood of the mother in the first pregnancy as the two bloods are well separated by the placenta. However, during the delivery of the first child, there is a possibility of exposure of the maternal blood to the Rh^+ blood from the foetus.

- In such cases, the mother starts preparing antibodies (anti-Rh factor) against Rh antigen in her blood. In case of her subsequent pregnancies, the Rh antibodies from the maternal (Rh^-) blood can leak into the blood of foetus (Rh^+) and destroy the foetal RBCs.

- This could be fatal to the foetus or could cause severe anaemia and jaundice in the baby, i.e., the haemolytic disease of the new born (HDN). This condition is called erythroblastosis foetalis (destruction of the erythrocytes of foetus). This can be avoided by administering anti-Rh antibodies to the mother immediately after the delivery of the first child.

BLOOD CLOTTING

- Blood flows from cut or wound but after sometimes it stops automatically, it is called clotting of blood.

- Bleeding time 1 - 3 min.
  Clotting time 2 - 8 min.
  Sometimes clots are also formed in intact blood vessels which are of two types.

Thrombus Clot

- Static clots which grow bigger & bigger & ultimately block the blood vessels.

- If this clot is formed in the coronary vessels then called as coronary thrombosis which can cause heart attack.

- If found in brain, then called as cephalic thrombus causes paralysis.

Ambolus clot

- Moving clots which flow with blood.
- More harmful due to their moving nature.

Mechanism of blood clotting

(Enzyme Cascade theory)

- Proposed by Macfarlane & Co-workers.
- According to this theory there are 3 steps in blood clotting.

1. Releasing of Thromboplastin :

Injured tissue synthesize exothromboplastin and platelets synthesize end thromboplastin. Both these thromboplastin react with plasma proteins in the presence of Ca^{++} ions to form Prothrombin's enzymes. Cfhrombokinase)
This enzyme inactivate heparin. (Antiheparin)

2.Conversion of Prothrombin into Thrombin

Prothrombin's enzyme convert inactive prothrombin into active thrombin in the presence of Ca^{++} ion.

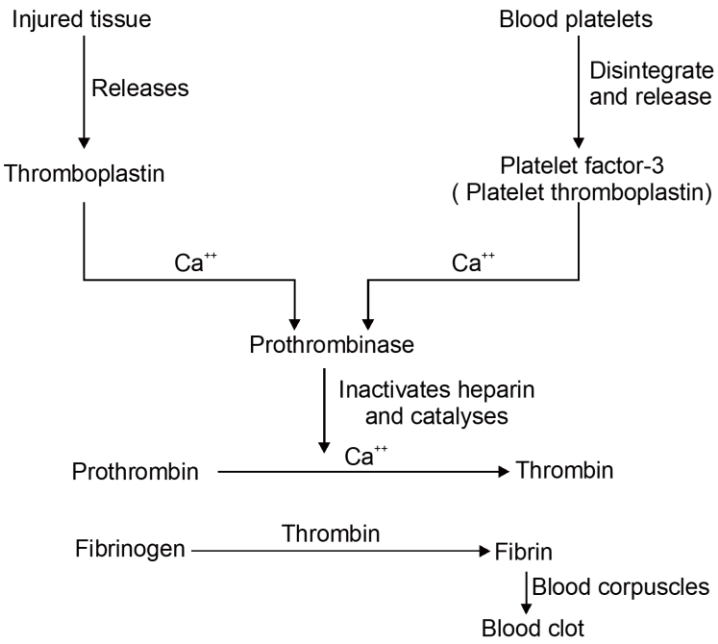
3.Conversion of fibrinogen into fibrin

Fibrinogen is soluble protein of plasma. Thrombin protein polymerise monomers of fibrinogen to form insoluble fibrous protein fibrin.

Fibrin fibres form network on cut or wound in which blood corpuscles got trapped. This form clotting of blood.

After clotting a pale yellow liquid oozes from clot called Serum. In which antibodies are found.

Blood – Corpuscles = Plasma
Plasma – fibrinogen = Seri,



Clotting Factors:-

- 13 factors help in blood clotting.
- These factors are mainly produced in liver.
- Vitamin K is required in the synthesis of these clotting factors.
- These factors are represented in Roman number.

Clotting Factor	Synonyms	Source	Pathways of Activation
I	Fibrinogen	Liver	Common
II	Prothrombin	Liver	Common
III	Thromboplastin	Damaged tissue and activated platelets	Extrinsic
IV	Calcium	Diet, bones, and platelets	All
V	Proaccelerin, Labile factor, Accelerator globin (Ac-globin)	Liver and platlets	Extrinsic and intrinsic
VI	Proconvertin (Serum Prothrombin Conversion Accelerator or SPCA)	Liver	Extrinsic
VII	Antihaemophilic factor (AHF).	Liver	Intrinsic
VIII	Plasma thromboplastin component (PTC), Christmas factor, Antihaemophilic factor B	Liver	Intrinsic
IX	Stuart Power factor, thrombokinase	Liver	Extrinsic and intrinsic
X	Plasma thromboplastin antecedent (PTA), Antihaemophilic factor C.	Liver	Intrinsic

XI	Hagemen factor, Glass factor	Liver	Intrinsic
XII	Fibrin stabilizing factor (FSF), Loki Lorand factor.	Liver and platlets	Common

Functions of blood: Blood serves following functions in the body

- It transports O_2 from the respiratory organs to the tissues and CO_2 from the tissues to the respiratory organs.
- It transports the digested food from the alimentary canal to the different body tissue cells.
- Hormones are carried by blood from the endocrine glands to the target organ.
- It transports excretory matter to the kidneys or other excretory organs.
- It allows the transfer of heat from the deeper tissues to surface of the bodywhere it can be lost.
- Some leucocytes are phagocytic in nature, and certain leucocytes produce antitoxins to neutralize the toxins released by the foreign germs.
- It maintains the body temperature to a constant level after distributing heat within the body.
- The clotting factors present in the blood plasma prevent loss of blood from the site of injury due to the formation of clot.

Special points-

- **Packed cell volume** (PCV):- % volume or Total number of blood corpuscles in blood.
- **Haematocrit Volume**: - %volume or only number of RBC in blood.
- PCV ≈ HV because 99% of packed cell volume is contributed by RBC & in rest 1% WBC & Platelets are present.
- In RBC carbonic anhydrase enzyme is present which increases rate of formation & dissociation of carbonic acid by 5000 times. (Fastest catalyst (with zinc))
- 1 gm Hb carries 1.34 ml O_2.
- 100 ml blood contain 15 gm Hb.
- 100 ml blood transport 20 ml O_2.
- **Size of RBC**
  Largest RBC- Amphiuma 75- 80 μ (Class: Amphibian)

  Smallest RBC- Musk Deer 2.5 μ (Class: Mammalia)

- Largest RBC among all mammals in elephant 9 - 11 μ.

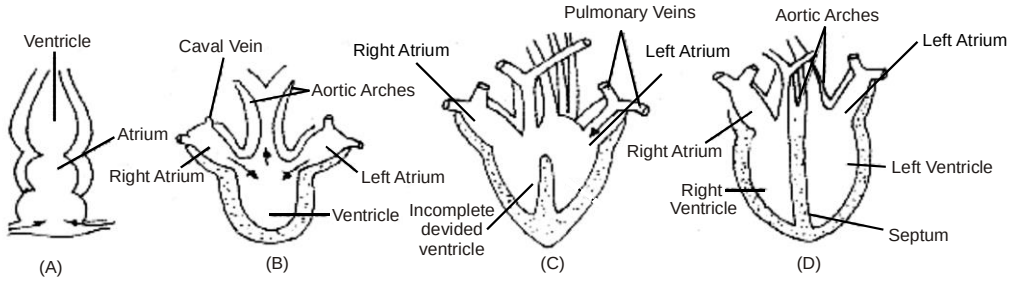
New Born Baby	—	100	days
Rabbit	—	80	days
Frog	—	100	days

- Increase in the RBC count condition is called polycythaemia. This condition occurs at hill station.
- Kidney is an erthyropoetic organ in frog.
- In resting and slow flowing blood, the RBC form piles called Roulaux by adhering together due to surface tension.
- Minute pits of disintegrated red blood corpuscles in known as Haemoconia.
- In female neutrophils Barr body is attached with lobe of nucleus which is formed by the modification of x chromosomes. It help in sex detection.
- AB blood group is discoverd by De-costello and Sturli.
- Oxygen association of Adult Hb is more than HbF.

HEART

- Study of Heart Cardiology. (Karadia– heart, logos– study)
- Heart is a thick, muscular, contractile, autonomic pumping organ of blood vascular system.
- Vetebrates have a single heart. It is hollow, muscular organ composed of cardiac muscle fibres.
- Heart is divided into inter communiating cambers. The number of chambers is different in different groups of vertebrates.

Group	No. of chambers in the heart	Name of chambers in the heart
Fishes	2	1 auricles + 1 ventricle
Amphibians	3	2 auricles + 1 ventricle
Reptiles	3 or incomplete 4 chambers	2 auricles + 2 incompletely devided ventricles
Aves	4	2 auricles + 2 ventricles
Human & Mammals	4	2 atrium + 2 ventricles



Hearts of different vertebrates A – Fish; B – Amphibian; C – Reptilian; D – Mammalian

1. Fishes have "Venous-Heart" In their heart, deoxygenated blood enters from one side and from the other side to the gills for oxygenation. This is called the "Single Heart Circuit."

2. In amphibians and Reptiles the auricles are divided into right and left. Right auricle gets deoxygenated and left auricle gets oxygenated blood from the body. But only 1 ventricle is present or is incompletely divided so after coming here the pure and impure blood mix up. This is called incomplete double circulation.

3. In some reptiles (Crocodile, Gavialis and Alligator) and in all birds and mammals the heart is divided into 2 auricles and 2 ventricles so while circulating inside the heart the pure and impure blood remain separated. The right portion of the heart collects impure blood from the body and sends it to the lungs for purification, while the left portion takes pure blood from the lungs and distributes it to the whole body. This is called Double circulation.

- The right portion of the heart is called as the "Pulmonary-Heart" and the left portion is termed as the "Systemic-heart". This is termed as "Double Circulation of Heart" because the blood has to pass through the heart twice before being delivered to systemic organs.

Sinus Venous and Conus Arteriosus- They are accessory sacs connected to the heart. They are found in Fish and amphibian. They are absent in birds and mammals. In Reptiles sinus venosus present but conus arteriosus absent.

HUMAN HEART

Positon: Heart is present in mediastinum of thoracic cavity. The space between two lungs is called mediastinum.

Colour: Reddish brown.

Weight: In males 300 gm (0.45% of body weight). In females 230-280 gm (0.40% of body weight)

Size: It's about 12 cm long and 9 cm broad. Its upper part is broad called base and lower part is narrow & pointed called apex.

Covering: Heart is covered by pericardium

STRUCTURE OF HEART

- Heart the mesodermally derived organ, is situated in the thoracic cavity in between the lungs, and slightly tilted to the left.

- Heart has size of clenched fist, weight 300 gm. Its triangular superior-broad portion is tilted slightly towards right (dorsal) side. Its lower narrow portion is tilted towards left side.

- Heart is protected by a double layered bag called pericardium. The narrow space in between these two membranes is called pericardial cavity in which pericardial fluid is present. Pericardial fluid provide moisture to heart and reduces frictions.

- It is secreted by the pericardium. Pericardial cavity is a true coelom (as it lies between two layers of mesoderm).

Wall of Heart: The wall of heart is made of three layers.

1. Epicardium - outermost layer, Made of simple squamous epithelium.

2. Myocardium - middle layer, thickest, Made of cardiac muscles which are striated but involuntary.

3. Endocardium – innermost layer, Made of simple squamous epithelium.
Thickness of wall of Heart depends on Myocardium.

- The heart of man is four chambered. Two relatively small upper chambers called Atria and two larger lower 15 chambers called ventricles.
- The atrium and the ventricle of the same side are separated by a thick fibrous tissue called the atrio-ventricular septum.
- The right and left atria are separated by a thin muscular wall called Inter atrial septum. Which shifed slighty is towards left. So right atrium is slightly bigger than left atrium.

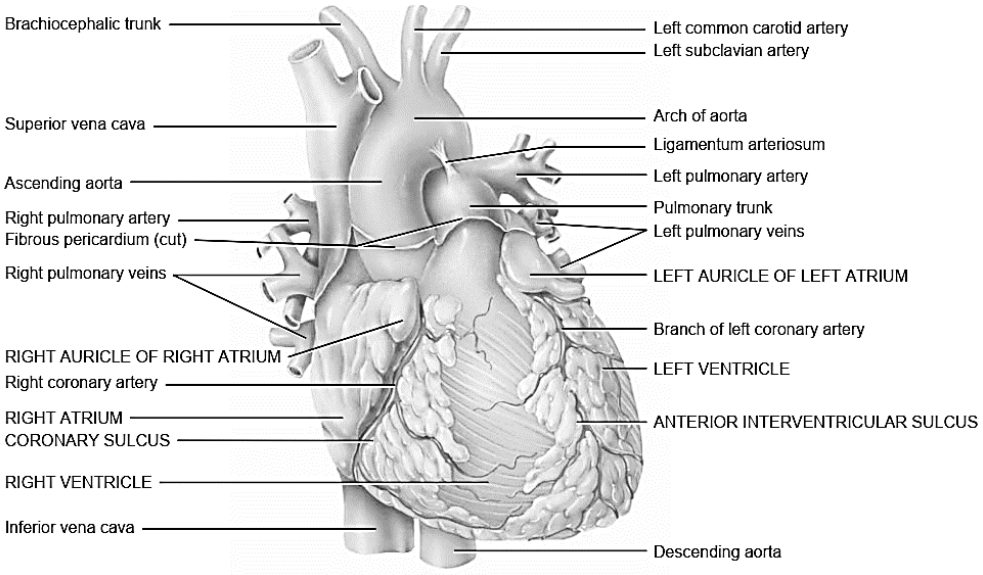


Fig. Human heart in front view

Ventricular part is broad, muscular and of light colour. Ventricles have thicker walls than auricles.

- The septa which divide the two ventricles are termed as lnter-venticular septum. It is oblique or tilted toward Right. It does not reach till the tip or apex of the heart, so the right ventricle is smaller than the left ventricle.
- Left ventricle is more muscular and thick walled then right because it has to pump blood into those arteries which take blood throughout the body while right ventricle has to pump blood only to the lungs.
- Left ventricle is the largest chamber of heart.

Systemic heart –

Left part of the heart (i.e. left atrium and left ventricle) contain the blood which is to be pumped into the systemic circulation, therefore it is called systemic heart. The main purpose of such a circulation is to transport oxygen, as well as nutrients to the body tissues and to remove carbon dioxide and other harmful nitrogenous waste from them.

Pulmonary heart –

Right part of the heart (i.e. right atrium and right ventricle) contain the blood which is to be pumped in pulmonary circulation for oxygenation, therefore it is called pulmonary heart. The pulmonary circulation is responsible for regular oxygenation of the impure deoxygenated blood which is received by the right auricle,

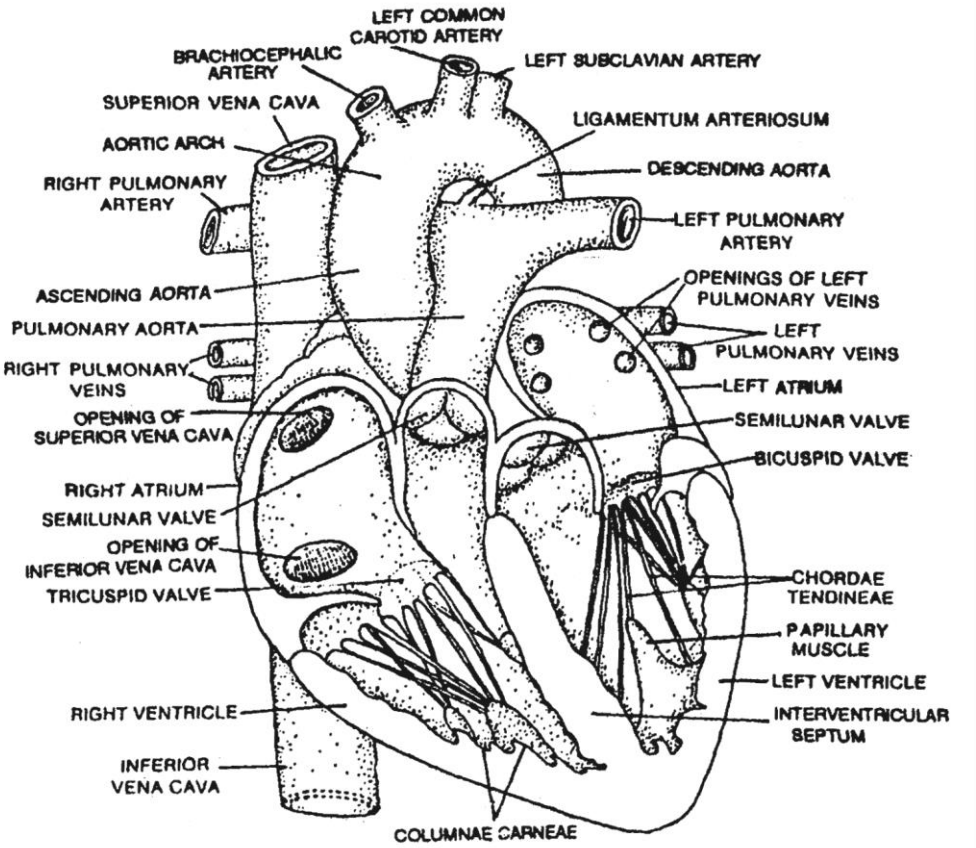


Fig. Structure of the heart: internal anatomy.

Vessels

- Right Atrium - Receives one S.V.C., one I.V.C. and one opening of coronary sinus in man. SVC = superior vena cava; IVC = inferior vena cava. The SVC & IVC bring impure blood from the upper and lower body parts respectively. The Coronary sinus receives impure blood from the rt. & It. Coronary veins and drains it in the right auricle

- Right Ventricle - Receives impure blood through right AV foramen from right atrium. Drains the impure blood into pulmonary artery through which it reaches lungs for oxygenation.

- Left atrium - Receives oxygenated blood from lungs via pulmonary vein. This pure blood is drained into left ventricle through left AV foramen. In human four pulmonary veins open into LA through separate openings.

- Left Ventricle - Drains pure blood into the Aorta from where it is supplied to systemic Organs:

Wall

Atrium - The inner wall surface here presents a series of transverse muscular ridges called musculi peotinati. They run forwards and downwards towards AV foramen, giving appearance of the teeth of a comb (combed muscles).

Ventricles - The inner wall is rough due to presence of muscular ridges trabeculae carnae or columnae carnae. These continue as papillary muscles, whose one end is attached to the ventricular wall and the other end connected to the cusps of AV valves by chordae tendinae. These chorda tendinae are collagenous and inelastic chords, one end of which is inserted in the papillary muscles and other end is connected to the flaps of AV valves. These are meant for preventing the pushing of flaps into atrium during ventricular contraction.

Valves

Rt. Atrium: Superior vena cava, inferior vena cava and coronary sinus open in right atrium. The IVC which opens below this has its opening guarded by a valve called Eustachian valve (during embryonic life the valve guides the inferior vena caval blood to the left atrium through foramen ovale) the opening of coronary sinus in rt. Atrium is guarded by the besian valve.

Lt. Atrium: At its inlet is pulmonary vein (four veins in man and two in rabbit), these have no guarding valve.

AV foramen: The right AV foramen has a unidirectional valve called tricuspid valve (made of three flaps or cusps) which allows entry of Blood from Rt. Atrium to Rt ventricle and prevents its backflow. The unidirectional valve present on left AV foramen is made of two cusps only hence called bicuspid valve. (Also called as the Mitral valve).

Rt. Ventricle: Its outlet is in the pulmonary artery. It is guarded by a pulmonary semilunar valve.

Lt. Ventricle: Its outlet is in the systemic aorta. This opening is guarded by an aortic semilunar valve. Both these semilunar valves are made of three cusps each and are unidirectional in nature.
The valves in the heart allows the flow of blood only in one direction from atria to the ventricles from the ventricles to the pulmonary aorta. These valves prevent any backward flow.

Special points-

- Total number of valves in human embryonic heart are six - Tricuspid, bicuspid, pulmonary, semilunar, aortic semilunar, Thebasian and Eustachian. Thebasian and eustachian valves merge into the musculature of their respective veins after birth.

- In embryonic heart small opening, foramen ovale is present at interatrial septum which after birth is modified to fossa ovalis.

- In embryonic heart a small duct, ductus arteriosus is present which connect pulmonary artery and aorta, which after birth is modified to ligamentum arteriosum.

Blood supply of heart (Coronary circulation)

The oxygenated blood is supplied to the heart musculature for its consumption with the help of two coronary arteries, left and right. These arteries arise from the common origin at arch of aorta the left and right coronary arteries then further subdivides into a number of branches carrying blood to different regions of heart. The deoxygenated blood from heart walls return back via coronary veins which drain into the coronary sinus. The coronary sinus opens in the right atrium.

HEART BEAT

- The wall of heart is made up of cardiac muscles which have the property of excitability and conductivity.

- The heart collects blood through both the atria and then distributes it through the ventricles. The action of systole and its relaxation is called a diastole.

- Rhythmic contraction and relaxation of heart is called heartbeat. One heart beat includes one systole and one diastole.

- In systole, heart pumps blood into lungs and various parts of body through arteries. In diastole, heart receives blood from lungs and various parts of body through veins.

Rate of heart beat: Number of heart beats per minute.
Human: 70-75/min. (Average 72/min.)
Foetus: 140-160/min.
New born: 120-140/min.
Child: 100/min.
Rabbit: 210/min.
Shrew: 600-800/min. (Maximum)
Blue whale: < 25/min. (Minimum)
Elephant: 28/min.
Frog: 64/min
Rat: 300/min.

Rate of heart beat increases

- After taking food
- Exercise
- Decreased blood Ph
- Increased acidity and CO_2 concentration
- Increased temperature
- Tension/shock
- In high B.P.

On the basis of origin of heart beat, there are two types of heart

1. **Neurogenic heart:** In this heart beat is initiated by a nerve impulse coming from a nerve ganglion situated near the heart. So in this wave of contraction is generated outside the heart in the ganglion. If nerve supply is cut off then heart beat stops. E.g. Invertebrates (some annelids, most arthropods).

2. **Myogenic heart:** In this heart, beat is originated by a group of muscle fibres which is situated in the wall of the heart. So in this wave of contraction is generated inside the heart. E.g. Vertebrates (e. g. humans), molluscs.

Special conducting system of heart

- The human heart is myogenic (myo: muscle, genic: orginating from). In this heart beat originates from a neuromuscular tissue which is called SA node (Sinu atrial node). It is also called pace maker/heart of heart. SA node lies in the wall of the right atrium near the opening of the superior vena cava. From the SA node muscle fibres arise which are situated in the wall of atria.

- In the heart another neuromuscular tissue called atrio-ventricular node (AV node) is present. It is present in the right atrium at the base of inter atrial septum.

- From the AV node, a group of muscle fibres called Bundle of His arises and it is situated in the interventricular septum.

- Bundle of His is divided into left and right branches. Each branch is divided into many small fibres which are present in the wall of ventricles. These fibres are called Purkinje fibres.

Direction of impulse: SA node ⟶ AV node ⟶ Bundle of His ⟶ Purkinje fibres.

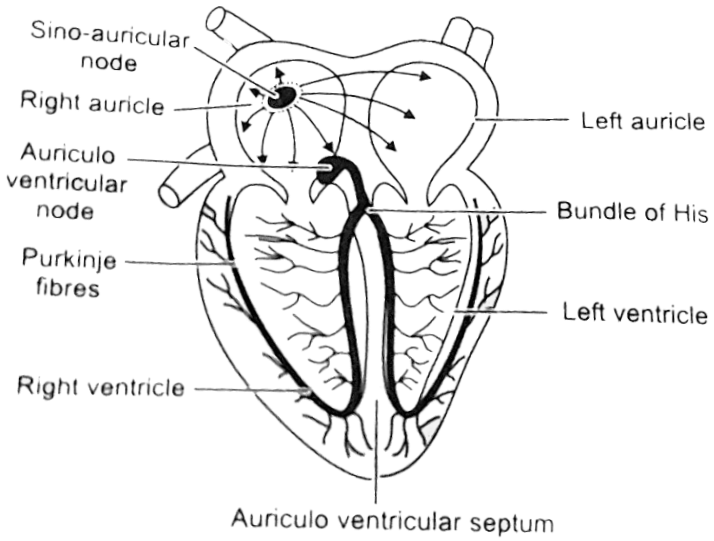


Diagram of the conducting system in human heart

Regulation of beat
Centre for heart beat Regulation is located in medulla oblongata. (Brain stem)

1. Nervous Control-

- The "Cardiac-centre" (neural centre) which regulates heart-beat is found in Medulla-oblongata of the brain it can moderate the cardiac function through ANS. This cardiac-centre has two units –

i. Cardio- accelerator centre.

ii. Cardio-inhibitory centre.

- From the cardio-acceleratory centre, a pair of sympathetic nerves go into the S.A. node. Neural signals through the sympathetic nerves can increase the rate of heart beat the strength of ventricular contraction and there by cardiac output.

- While the cardio-inhibitory centre sends impulses to the S.A. node through cardiac branch of Vagus-nerve. From the parasympathetic nerve-fibres, hormone Acetyl-choline is secreted which decrease the heart rate, speed of conduction of action potential and the cardiac output.

2. Hormonal control: Adrenal medulla hormone (Adrenaline, nor adrenaline) and Thyroxine hormone of thyroid gland increase heart rate and the cardiac output.

Key Point

Hormonal control	Adrenaline	–	↑ Rate
	Nor adrenaline	–	↑ Rate
	Thyroxine	–	↑ Rate
Autonomic Nervous System	Sympathetic	–	↑ Rate
	Parasympathetic	–	↑ Rate
	Vagal stimulation releases Acetyl choline	–	↑ Rate

Tachycardia. It is the condition where heart rate exceeds 90 per minute for an average adult.

Common causes of tachycardia:-

- Temperature.
- Stimulation by sympathetic nerves
- Weak condition of the heart
- Shock/loss of blood
- Exercise

Bradycardia: It is the condition where the heart rate falls below 60 per minute in an average adult.

Common causes of bradycardia:-

- Temperature
- Stimulation by parasympathetic Vagus nerve
- Stronger condition of the heart

CARDIAC CYCLE

The cardiac events that occur from the begining of one heartbeat to begining of the next are called cardiac cycle. The action potential travels rapidly through both atria and then through the AV bundle into the wall of ventricles. Because of special arrangement of the conducting system from the atria to the ventricles, there is a delay of more than $l/10^{th}$ a second between passages of the cardiac impulse from the atria into the ventricles. This allows the atria to contract ahead of the ventricles, there by pumping blood into the ventricles before the strong ventricular contraction begins.
Thus the atria are the primer pumps for the ventricles, and ventricles then provide the major source of power for moving blood through the vascular system.

Cardiac-Cycle:-

The process of heart-beat begins from the time of embryonal development. Once the heart beat starts, it continues throughout the life (inherent capacity). In resting stage of man in 1 minute the heart beats around 72 times and during this 1minute, 5 liters of blood is pumped to different parts of the body through heart through left ventricle.

- The serial wise or sequential changes which take place in the heart are called cardiac-cycle.
- The contraction of the atria is termed as atrial-systole and their relaxation is called atrial-diastole.
- Same way the contraction and relaxation of ventricles is termed as ventricular systole and ventricular diastole,
- The time of cardiac-cycle is the reverse ratio of heart beat per minute. If heart beat per minute is 72, then the time of cardiac-cycle is $60/72 = 0.8$ seconds.

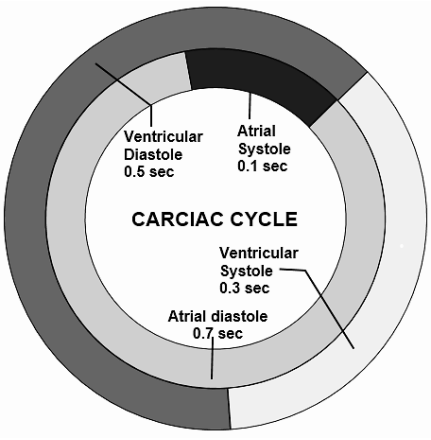
Events of cardiac cycle

1. Ventricular cycle (0.8 sec): 0.3

- ventricle systole: 0.5
- ventricle diastole

2. Atrial cycle (0.8) sec

- atrial systole: 0.1 sec
- atrial diastole: 0.7 sec



So,

Total duration of systole of heart: 0.4 sec
Total duration of joint diastole: $0.8 - 0.4 = 0.4$ sec

1. Ventricular systole

It is an important process because by the contraction in ventricles blood flows in arches. There are four stages in ventricular systole.

- **Isometric contraction:** By the contraction in wall of ventricles, pressure increases in ventricles, so cuspid valves of atrioventricular valves become closed. At this moment first heart sound is heard in the form of lubb.

- **Period of ejection:** Due to increased pressure in ventricles, cuspid valves become close and semilunar valves of arches open up. So blood flows in arches.

- **Protodiastole:** Due to ejection of blood, pressure decreases in ventricles, so flow of blood from ventricles to arches also decreases called protodiastole.
  Note: During ventricular systole, atria receive blood from veins and get filled with blood.

2. Ventricular diastole: Two stages

- **Isometric relaxation:** Due to ejection of blood from ventricles to arches, pressure decreases in ventricles and pressure increases in arches. When it becomes more than ventricles semilunar valve of arches become close. At this moment second heart sound is heard in form of dup.

- **Rapid inflow:** Due to ejection of blood, pressure decreases in ventricles and atria filled with blood so pressure become more in atria. So cuspid valve of A.V. foramen open up and blood rapidly enter into ventricle called rapid inflow.

- **Diastasis:** After rapid inflow, flow of blood from atria to ventricle decrease. Now atria transfer blood to ventricle at the same rate at which they receive blood from veins called diastasis.

- **Second rapid inflow:** During atrial systole

3. Atrial systole

At the end of ventricular diastole, atria contract and transfer more blood in ventricles, this decreases pressure in atria.

4. Atrial diastole

Due to ventricular systole, pressure increase in ventricle and it exceeds atrial pressure. Therefore cuspid valve of AV foramen closed and then atria start relaxation called atrial diastole.

Volumes of blood related with cardiac cycle

During diastole, filling of the ventricles normally increases the volume of each ventricle to about 120 mililitres. This volume is known as end diastolic volume. Then as the ventricles empty during systole, the volume decreases by about 70 mililitres, which is called the stroke volume. (i.e. the volume of blood pumped by each ventricle in the aorta in one stroke or beat). The remaining volume in each ventricle is now about 50 mililitres is called end systolic volume.
The fraction of the end diastolic volume which is ejected out is called the ejection fraction. (Usually around 60% or 7/12). EF = SV / EDV

Cardiac output it is the amount of blood pumped by the each ventricle per minute. Its value in a normal adult is about 5 liter/minute.

Cardiac output = stroke volume x heart rate.

- End diastolic volume ⇒ 120 ml.
- End systolic volume ⇒ 50 ml.
- Stroke Volume = EDV – ESV = 70 ml (approx.)

Heart – Sound

- During each cardiac cycle two prominent sounds are produced.
- These "Lubb" and "Dup" sounds of the heart can be heard with the help of an instrument called “Stethoscope"(invented by lennec).

BLOOD PRESSURE

- The pressure exerted by the flow of blood on the elastic walls of the arteries is called blood pressure.
- Normal healthy person B.P. is = 120/80 mm of Hg.
- The instrument used to measure B.P. is sphygmomanometer.
- B.P. is usually taken in left brachial artery.
- It has two stages.

Systolic pressure: It is the higher limit of B.P. It shows the state of heart systole. Its value is 120 mm of Hg.

Diastolic pressure: It is lower limit of B.P. It shows state of relaxation in heart. Its value is 80 mm of Hg.

- The difference between systolic and diastolic pressure is called pulse pressure. Its value is 40 mm of Hg.

- Pulsation in the arteries is called pulse rate. It can measure in the artery which is situated at the surface of body. Like - radial artery of wrist, carotid artery of neck, temporal artery near the neck, brachial artery. The instrument used to measures pulse rate is sphygmomanometer.

- The pressure varies with age. It is also influenced by the rate of heart beat.

ELECTROCARDIOGRAM (ECG)

- Electrical changes take place in a cardiac cycle in heart. The recording of electrical potential generated by the spread of cardiac impulse, is called ECG. It is a graphic record of the electric current produded by excitation of the cardiac muscles. The instrument used for this is called "**electrocardiograph**".

A normal ECG has three parts - P wave, QRS complex, T-wave.

1. The P wave is a small upward wave that indicates the depolarisation of atria. It means spread of impulse from SA node throughout atria.

2. QRS complex has three separate Q, R and S waves. This complex indicates depolarisation of ventricles.

3. T-wave indicates the repolarisation of ventricles. It represents the potential generated by the recovery of ventricles from depolarisation state.

- P-Q interval is the time taken by impulse to travel through atria, AV node and the rest of the conducting tissues.

- The ST interval is representation of time between the end of the spread of impulse through ventricles and its repolarisation.

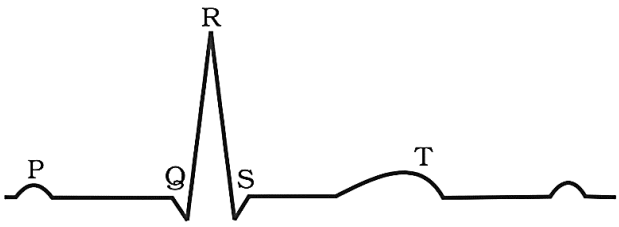


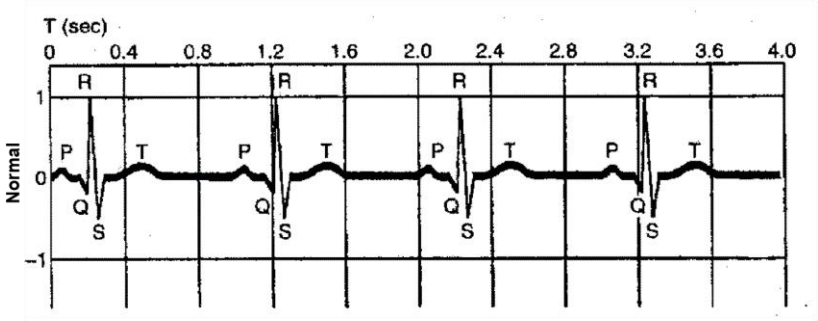
Fig. Diagrammatic presentation of a standard ECG

- **Significance of ECG:** It is used for knowledge of some cardiac disorders.

1. Cardiac arrest **2.** Coronary Ischemia

3. Valvular disease **4.** Pericarditis

5. Cardiomegaly **6.** Myocardial infarction



Normal Electrocardiogram (ECG)

Disorders related to the circulatory system

1. Hypertension :

It is also called high blood pressure. Hypertension or high blood pressure is the occurrence of persistent systolic arterial pressure of more than 140 mm Hg and diastolic arterial pressure of more than 90 mm Hg. Hypertension is of two types primary and secondary.

High blood pressure must be managed. Excessive high blood pressure, say 220/120 mm Hg. Is dangerous as it may cause haemorrhages in different parts of body causing blindness (due to optic arteries), nephritis (renal artery), brain stroke or CVA (Cerebra vascular accident) (due to rupturing of cerebral artery).

2. Hypotension :

It is also called low blood pressure. Hypotension or low blood pressure is the occurrence of persistent systolic arterial pressure of less than 110 mm Hg and diastolic arterial pressure of less than 70 mm Hg. It is caused by persistent vasodilation of arterioles, reduced ventricular pumping, valvular defects, anaemia and deficient diet.

3. Varicose Veins :

On prolonged standing or due to defect in the valves of the veins of the legs. These veins may become dilated, torturous and thickened (Most commonly affected is the saphenous vein). Such veins become clearly visible and prominent. Treatment is surgical removal of such veins.

	Atherosclerosis	Arteriosclerosis
1.	Deposition of lipids (Cholesterol) on the walls (such depositions are called atheromatous plaque)	Hardening of arteries due to thickening along with deposition of calcium salts with cholesterol.
2.	Takes place in Lumen of large and medium size arteries of body	Can take place in medium to small Arteries of limbs.
3.	Plaques are formed due to proliferation Of smooth muscles of the inner wall of arteries (due to platelet derived growth Factors).	No plaque formation occurs, but the arteries are stiff and rigid due to Calcification.
4.	Narrowing of Artery	Hardening· of artery.
5.	Artery lumen may get blocked res ulting In no blood supply.	Artery becomes hard, loses its capacity of distention and may rupture

4. Heart Failure :

Heart failure means the state of heart when it is not pumping blood effectively enough to meet the needs of the body. It is sometimes called congestive heart failure because congestion of the lungs is one of the main symptoms of this disease. Heart failure is not the same as cardiac arrest (when the heart stops beating) or a heart attack (when the heart muscle is suddenly damaged by an inadequate blood supply).

5. Heart-block :

When A.V. Node gets damaged, so contractions do not reach up to ventricles this event is called heart block.

6. Angina

It is also called the 'angina pectoris. It appears when no enough oxygen is reaching the heart muscle. As a result, symptom of acute chest pain appears. Angina can occur in men and women of any age but it is more common among the middle aged and elderly persons. It occurs due to the conditions that adversely affect the blood flow.

7. Heart attack

It is the condition, when a part of heart muscles is suddenly damaged by an inadequate blood supply. It is also called **myocardial infarction.**

8. Cardiac arrest

It is a condition of complete stoppage of the heart beat i.e., sudden and complete loss of cardiac function.

BLOOD VESSELS

- In humans close circulatory system is present. In this system, blood flows in the close tubes which are called blood vessels.

- Three types of blood vessels are
  (A) Arteries (B) Veins (C) Capillaries

The wall of blood vessels is made up of three layers

- **Tunica externa:** It is outer most layer. It is made up of white fibrous connective tissue.

- **Tunica media:** It is thickest, middle layer. It is made up of circular unstriped muscles and elastic fibres.

- **Tunica interna:** It is inner layer made up of simple squamous epithelium.

(A) Arteries: These carry blood from the heart to the different body parts. The walls of arteries are thick, muscular, elastic and non-collapsible. Two elastic membranes are also present–

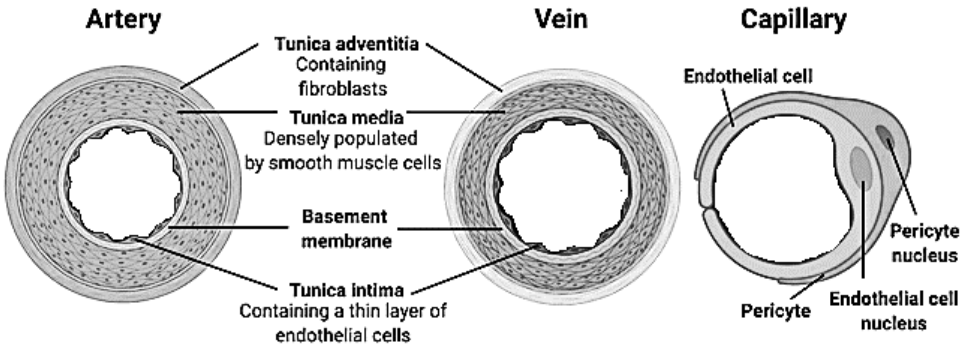
- **External elastic lamina –** between tunica externa and tunica media

- **Internal elastic lamina –** between tunica media and tunica interna
  After death arteries become empty but blood is present in the veins.

(B) Veins: They bring blood from the different parts of the body to the heart. The wall of veins is thin, less muscular and non-elastic.

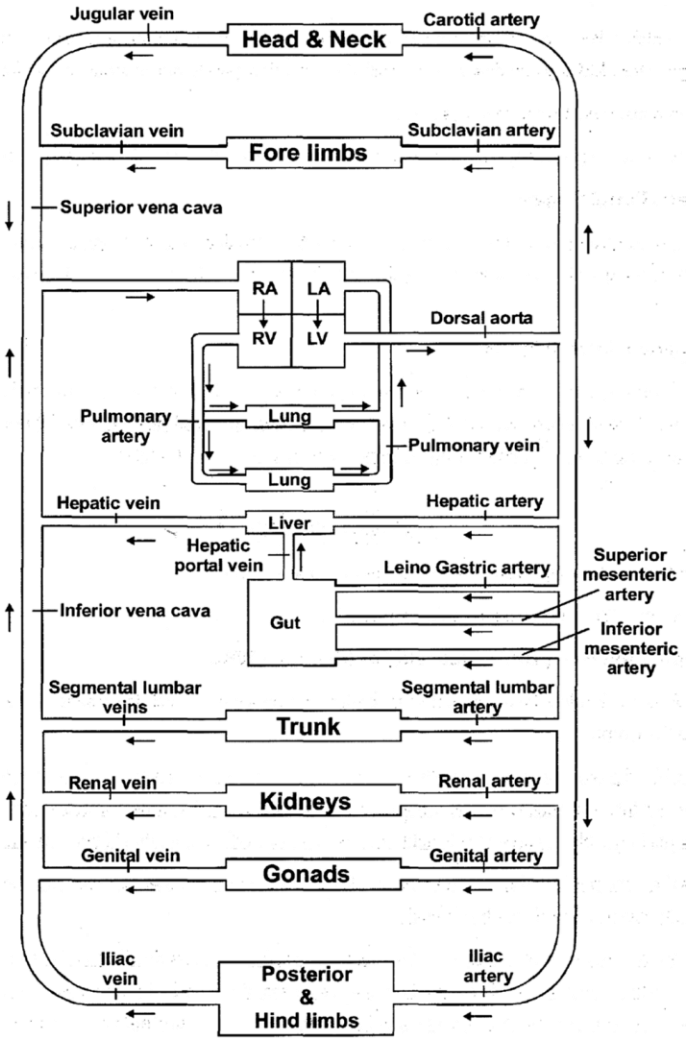
(C) Capillaries: The wall of capillary is made up of only endothelium. Its cells are flat and squamous.

VESSELS OF VESSELS: For supplying the essential materials to the cells of the wall of large blood vessels, a network of thin blood vessels is also found which is called "Vasa Vasorum/vessels of vessels".



Differences between arteries and veins			
Arteries		**Veins**	
1.	Arteries distribute blood from the heart to the different parts of the body.	**1.**	Veins collect blood from different parts of of the body and pour it into the heart.
2.	They are usually deep situated.	**2.**	They are usually superficially situated.
3.	The walls of the arteries are thick and muscular.	**3.**	The walls of the veins are thin and non-muscular.
4.	Arteries have no valves. (except arches/trunks)	**4.**	Veins have valves which prevent backward flow of blood.
5.	They have smaller lumen.	**5.**	The lumen of the veins is larger.
6.	In arteries blood flows with jerks.	**6.**	In veins blood flows smoothly.
7.	Arteries become empty after the death.	**7.**	Veins contain blood even after the death.
8.	Arteries carry oxygenated blood except the pulmonary arteries.	**8.**	Veins carry deoxygenated blood Except pulmonary veins.

Flow chart of Circulation of blood



(A) PORTAL SYSTEM

- In this system, the vein starts from capillaries and ends in capillaries.
- A portal vein collects venous blood from some part of body by a set of capillaries and distributes it to some other organ by another set of capillaries.
- A portal system consists of a portal vein and second set of blood capillaries and it is named after the name of the organ containing the second set of blood capillaries.

Types of portal system

1. Renal portal system

- In this system vein which collects blood from posterior parts of body and legs, enters into the kidney. This vein is called renal portal vein. Now this vein divides into capillaries and forms renal portal system. This system is found in lower vertebrates like amphibians, fishes.

- This system is absent in man and rabbit.

2. Heptaic portal system

- It is found in all vertebrates. In this system, vein which collects blood from digestive and absorptive parts of alimentary canal, enters into the **liver**; this is called hepatic portal vein. Now in liver it divides into capillaries and forms hepatic portal system.

3. Hypothalamo hypophyseal portal system

- This system occurs in mammalian brain. This is present between hypothalamus and anterior lobe of the pituitary gland. Hypophyseal portal vein carries blood from the hypothalamus of the brain to the anterior lobe of the pituitary gland. This portal system enables the hormones of hypothalamus to reach the anterior lobe of the pituitary gland.