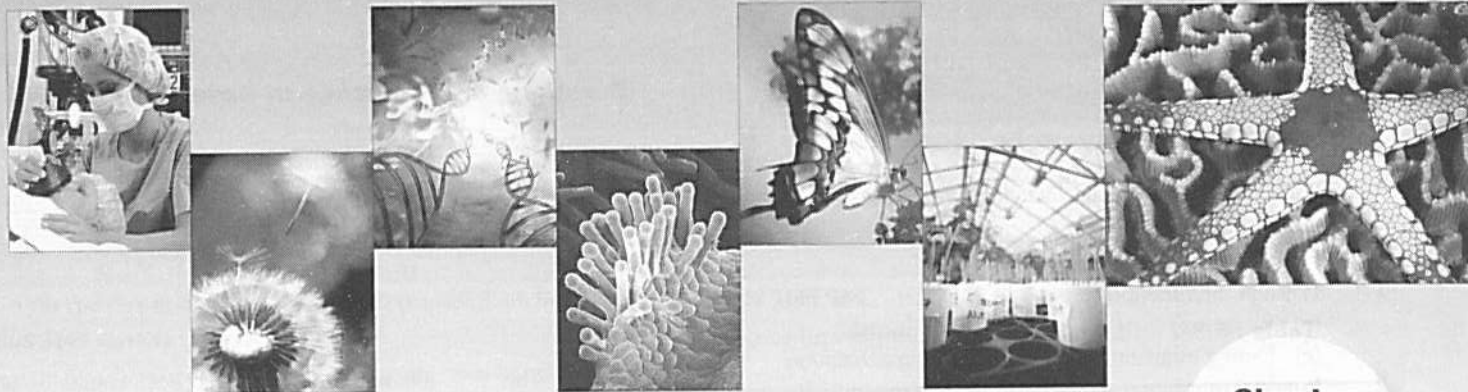




Chapter 5.3

Body Fluids and Circulation

This system is concerned with the circulation of body fluids to distribute various substances to various body parts.

Functions of Circulatory System

(1) Transport of various substances such as nutrients, waste products, respiratory gases, metabolic intermediates (Such as lactic acid from muscle to liver), vitamins, hormones etc.

(2) Regulation of body *pH* by means of buffer, body temperature homeostasis, water balance etc.

(3) Prevention of diseases by means of antibodies and antitoxins.

(4) Support or turgidity to certain organs like penis and nipples.

Types of Circulation

Circulatory system in various groups of animals can be classified as follows :

(1) **Intracellular circulation** : Occurs inside the individual cells where the distribution of substances is through cyclosis of cell cytoplasm. Example – Protozoans.

(2) **Extracellular circulation** : When the distribution of the substances occurs inside the body through extracellular or intracellular fluids. This is of following types –

(i) **Extra organismic circulation** : Canal system in porifera, water vascular system in Echinoderms and gastrovascular system in coelenterates.

(ii) **Intra-organismic circulation** : It involves circulation of body fluids. It is of following types –

(a) **Parenchymal circulation** : In platyhelminthes, the fluid filled spaces present in the mesodermal parenchyma tissue between body wall and internal organs are used in the distribution of substances.

(b) **Coelomic circulation** : Coelomic fluid is concerned with the transport of substances. Example – pseudocoelomic fluid in the roundworms and haemolymph in Arthropods.

(c) **Blood vascular system** : It contains blood and a pumping structure (heart) for circulation of materials inside the body. It is open circulatory system and closed circulatory system.

Table : 5.3-1 Differences between open and closed circulatory system

S.N.	Open circulatory system	Closed circulatory system
1.	In open circulatory system blood flows through large open spaces and channels called lacunae and sinuses among the tissues.	In closed circulatory system blood flows through a closed system of chambers called heart and blood vessels.
2.	Tissues are in direct contact with the blood.	Blood does not come in direct contact with tissue.
3.	Blood flow is very slow and blood has very low pressure.	Blood flow is quite rapid and blood has a high pressure.
4.	Exchange of gases and nutrients takes place directly between blood and tissues.	Nutrients and gases pass through the capillary wall to the tissue fluid from where they are passed on to the tissues.
5.	Less efficient as volume of blood flowing through a tissue cannot be controlled as blood flows out in open space.	More efficient as volume of blood can be regulated by the contraction and relaxation of the smooth muscles of the blood vessels.
6.	Open circulatory system is found in higher invertebrates like most arthropods such as prawn, insects, etc., and in some molluscs (snails, clams, oyster).	Closed circulatory system is found in echinoderms, some molluscs, (squids) annelids and all vertebrates.
7.	Respiratory pigment, if present, is dissolved in plasma; RBCs are not present.	Respiratory pigment is present and may be dissolved in plasma but is usually held in RBCs.



Blood circulation in vertebrates

Blood circulation was discovered by William Harvey. In case of vertebrates, blood circulation is of closed type, which can be grouped into two categories :

(1) Single circulation

(2) Double circulation

Table : 5.3-2 Differences between single and double circulation

S.N.	Single circulation	Double circulation
1.	Blood flows only once through the heart in a complete cycle. Auricle → Ventricle Tissues ← Gills	Blood flows in two circuit pulmonary and systemic. Pulmonary vein Right auricle → Left auricle → Venacava Lungs → Right ventricle → Pulmonary artery Left ventricle → Dorsal aorta → Tissues
2.	Heart pumps only deoxygenated blood, hence called Venous Heart.	Heart pumps both deoxygenated and oxygenated blood to lungs and body respectively, hence called arteriovenous heart.
3.	Blood is oxygenated in gills.	Blood is oxygenated in lungs.
4.	Less efficient as gill capillaries slow down the blood flow. So, the body receives blood at a low pressure which decreases the rate of O ₂ supply to the cells i.e. keeps the metabolic rate low.	More efficient as blood flows at higher pressure, especially in birds and mammals, which increases the rate of food and O ₂ supply to the cells and also rapid removal of wastes from them i.e. provides a higher metabolic rate.
5.	Found only in fishes, petromyzon.	Found in dipnoi, amphibians, reptiles, birds and mammals.

Double circulation in mammals can be divided into three parts :

(i) **Cardiac circulation** : The amount of blood present in the heart. Its value is 8%.

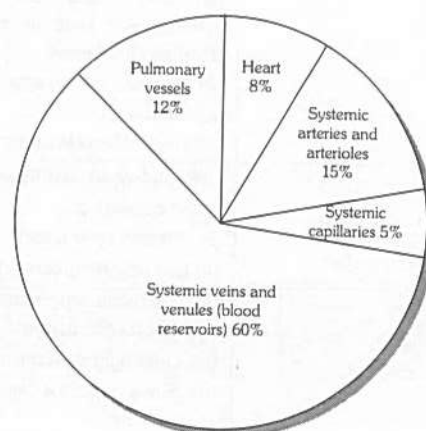
(ii) **Pulmonary or lesser circulation** : The amount of blood present in the surrounding of lungs and pulmonary blood vessels. Its value is 12%.

(iii) **Systemic or greater circulation** : The amount of blood which circulates in the rest part of the body. Its value is 80%. It can be divided into three parts –

Arterial circulation – 15%

Capillary circulation – 5%

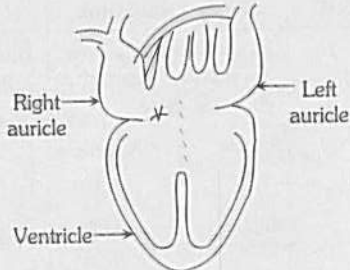
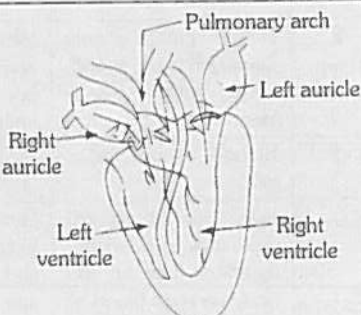
Venous circulation – 60%

**Fig : 5.3-1 Distribution of blood volume in different part of circulatory system****Heart**

The form, structure and function of heart exhibits much variation. The characteristics of heart of fishes, amphibians, reptiles, birds and mammals is presented in the following table.

Table : 5.3-3 Heart of vertebrates

S.No.	Class of vertebrates	Characteristics	Example	Diagram
1.	Pisces (= Branchial heart), Cyclostomata	Thick, muscular, made of cardiac muscles, has two chambers (i) auricle and (ii) ventricle. The heart is called venous heart since it pumps deoxygenated blood to gills for oxygenation. This blood goes directly from gills to visceral organs (single circuit circulation). A sinus venosus and conus arteriosus is present. Lung fishes have only one auricle and one ventricle.	Labeo Scoliodon	
2.	Amphibians, Lung fish	Heart consists of : (i) Two auricles (ii) Undivided ventricle (iii) Sinus venosus (iv) Truncus arteriosus (conus + proximal part of aorta) Right auricle receives blood from all the visceral organs (deoxygenated) via precaval and post	Frog Toad Neoceratodus or Dipnoi	

		caval. Pulmonary artery carries deoxygenated blood to lungs for oxygenation. This blood returns to left auricle via pulmonary vein (Double circuit circulation) (v) S.A. node in sinus venosus (vi) Truncus arteriosus divided into synangium, pylangium		
3.	Reptiles	Heart consists of : (i) Left and right auricle (ii) Incompletely divided ventricle (Ventricle in crocodiles, gavialis, and alligator is completely divided) (iii) Sinus venosus (iv) Conus arteriosus divided into right systemic, left systemic and pulmonary arch. (Double circulation) (v) Foramen panizzae at crossing of right-left systemic arch. (vi) Only SA node in right auricle	Lizards Snakes Turtles	
4.	Aves	Exhibit double circulation : Heart consists of (i) Left and right auricle (ii) Left and right ventricle (iii) Complete separation of arterial and venous circulation (iv) Only right systemic arch is present (v) Sinus venosus and truncus, arteriosus absent (vi) Two pace maker SA node and AV node (vii) Mitral valve present.	Pigeon	
5.	Mammals	Same as bird except that mammals have left systemic arch.	Rabbit, man	

Shape and position : Reddish, roughly conical, highly muscular, mesodermal hollow organ of the size of one's fist. Its average weight in males is about 300 gm. and in females about 250 gm. It lies behind the sternum in the mediastinum space of thoracic cavity in between the two lungs. The broader base faces upward and backward. The narrower apex is directed downward, forward and slightly towards left, lying between 5th and 6th ribs and rests on the diaphragm. The heart is about 12 cm (5 inch) long, 9 cm (3.5 inch) wide and 6 cm (2.2 inch) thick.

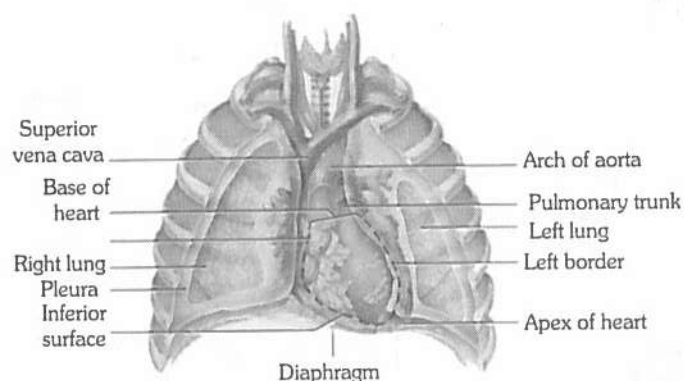
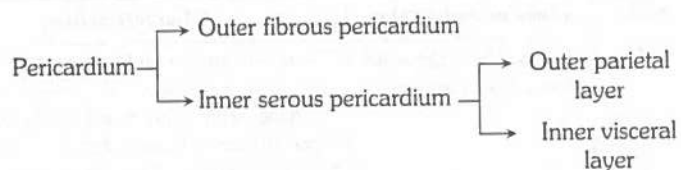


Fig : 5.3-2 Position of heart in our chest cavity

Protective covering : Heart is enclosed in a tough, 2 layered fibroserous sac, the pericardium. The outer layer is non-distensible fibrous pericardium and inner layer is thin serous pericardium which further consists of outer parietal layer (attached to fibrous pericardium) and inner visceral layer (adhered to the heart).



Between the parietal and visceral layers, occurs a narrow potential space, the pericardial cavity which is derived from coelom and is filled with serous pericardial fluid for frictionless movement and protection from shock and mechanical injury.

Histology : The heart wall consists of connective tissue, blood vessels and cardiac muscle fibres in 3 different layers – Epicardium, Myocardium and Endocardium.

(1) **Epicardium** : The outermost epicardium, also called visceral layer of the serous pericardium, is the thin, transparent outer layer of the wall. It is composed of mesothelium and connective tissue. Visceral pericardium, is joined to the myocardium by connective tissue.

(2) **Myocardium** : Middle, highly vascular layer, composed of cardiac muscle fibres are joined together by intercalated disc. The connective tissue in myocardium acts as cardiac skeleton. Myocardium is thickest where the endocardium is thinnest.

(3) **Endocardium** : Innermost layer lining the cavity of heart and consisting of endothelium of squamous cells resting on thin basement membrane of loose connective tissue.

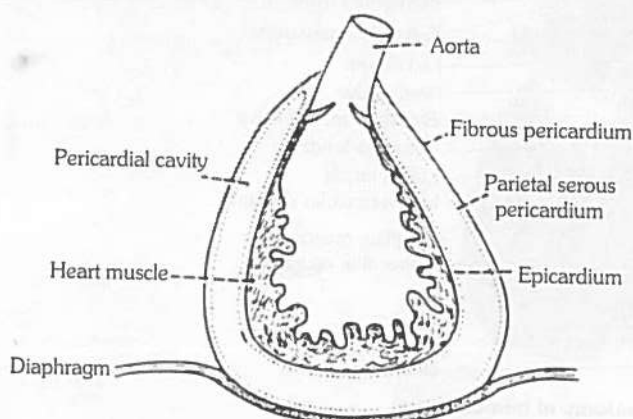


Fig : 5.3-3 Diagram to show the layers of the pericardium

External structure : Human heart is 4-chambered and is divided by septa into two halves – right and left. Each half has one darker, thin walled auricle in the broader upper region and one lighter, thick-walled ventricle in the narrower lower region.

Sinus venosus and conus/truncus/bulbus arteriosus are accessory chambers in the heart of lower vertebrates (fishes and amphibians). In rabbit, sinus venosus is formed in the embryo but later it becomes a part of wall of right auricle.

In frog, sinus venosus spreads upon most of the dorsal side of heart and conus arteriosus lies obliquely upon the ventral surface of right atrium.

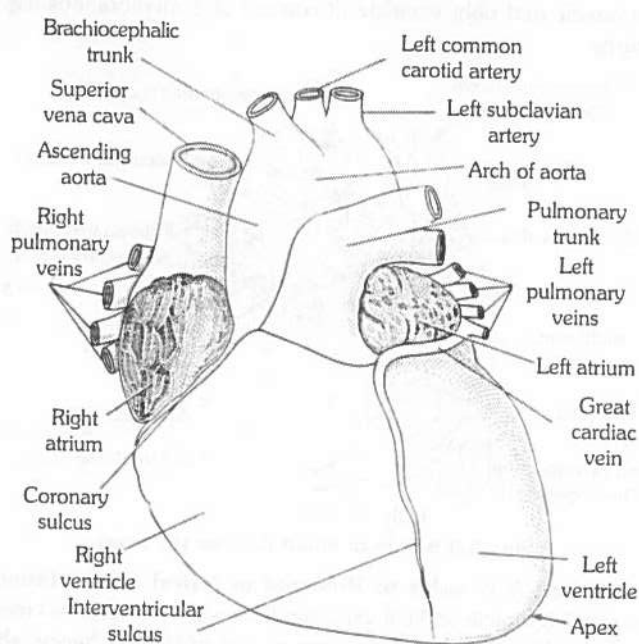


Fig : 5.3-4 External features of human heart

Internal structure

(1) **Auricles** : Atria are thin walled. They act as reservoirs for blood entering the heart. Right auricle is bigger than left auricle and both are separated by a myomembranous partition called Interatrial or interauricular septum. During embryonic stage, at the place of this septum, there are present septum primum and septum secundum having a gap (aperture) called foramen ovale between them. From the opening of inferior vena cava upto foramen ovale, there is a flap called Eustachian flap which prevents the blood in the foetal heart go to lungs because in foetal life, lungs are not functional purification of blood is done by placenta.

At the time of birth, there is closure of foramen ovale but there remains depression on posterior part of the right surface of interauricular septum in rabbit. In man this depression is present on both the side because of least regenerative power in human being. The depression towards right atrium is called fossa ovalis and depression towards left atrium is called fossa lunata.

The inner surface of auricles is smooth. A network of muscular ridges called musculi pectinati or trabeculi pectinati occurs internally in the region of the auricular appendages and give comb like appearance.

❑ **PFO (Patent Foramen Ovale) or septal defect** : In case there is no closure of foramen ovale, then disease is called PFO. In this condition, there is mixing of blood after birth which gives bluish appearance to the body called as Cyanosis. Such child is called Blue Baby.

(2) **Ventricles** : The right and left ventricles are demarcated by an interventricular septum which is obliquely curved towards right, so that the left ventricle is larger than right one. However, the cavity of left ventricle is relatively smaller and nearly circular because the myocardium of left ventricle is 3 times thicker than right ventricle whose cavity is larger and somewhat crescentic.

The walls of the ventricles are internally raised into a number of thick, muscular, column shaped projections called columnae carnae or trabecular carnae; and a few large muscular elevations called papillary muscles or musculi papillares which are 3 in right ventricle and 2 in left ventricle. These muscles act as anchors for chordae tendinae.

Numerous, strong, inelastic thread like tendons are present in the mammalian heart but absent in frog.

❑ **Regurgitation** : If there is weakening of papillary muscles or breaking of chordae tendinae, then AV valves revert into auricles. So, blood goes in opposite direction, it is called regurgitation. Sometimes, there is narrowing of valves. So, there remains gap between the valves which causes regurgitation.

❑ **Moderator band** : Right ventricle contains a prominent muscular trabeculum called moderator band which extends from the interventricular septum to anterior papillary muscle.

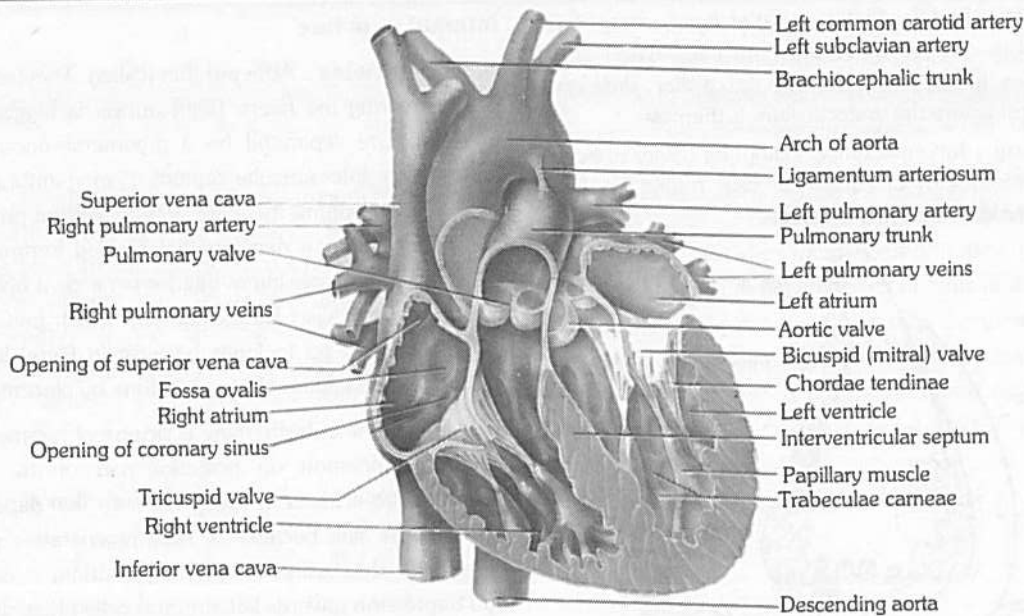


Fig : 5.3-5 Internal anatomy of human heart

Major blood vessels associated with heart : The blood vessels that enter or leave the heart are called Great Blood Vessels.

(1) **Superior vena cava or precaval :** Brings deoxygenated blood from head and upper parts of the body into the right auricle through an opening which is single in human and cat and two in rabbit as there are 2 precavals – right and left in rabbit.

(2) **Inferior vena cava or post caval :** Drains deoxygenated blood from middle and lower parts of the body into the right auricle through a single opening which is bordered by a membranous, falciform fold which is a remnant of the foetal valve of Eustachian.

(3) **Coronary sinus :** Returns deoxygenated blood from heart wall into right auricle through a single opening.

(4) **Pulmonary vein :** Four pulmonary veins, two from each lung, carry oxygenated blood from the lungs and open into the left auricle through four openings. In rabbit, the pulmonary veins open in the left auricle through 2 openings.

(5) **Pulmonary aorta/arch :** Arises from upper left corner of right ventricle through a single opening and divides into right and left pulmonary arteries which carry deoxygenated blood to the lungs for oxygenation.

(6) **Systemic aorta :** Arises from upper right corner of left ventricle through a single opening and has 3 regions – ascending aorta, arch of aorta and descending aorta. It distributes oxygenated blood to various body parts except lungs.

❑ **Ligamentum arteriosum :** During foetal life, because the lungs are non-functional hence blood of pulmonary aorta comes into systemic aorta through a small duct called ductus botalli or ductus arteriosus soon after birth, deposition of elastin fibre blocks this duct, forming a new structure called ligamentum botalli or ligamentum arteriosum.

❑ **PDA (Patent Ductus Arteriosus) :** If the ligamentum arteriosus remains open, the condition is called PDA. In this case, there is mixing of blood which leads to blue baby.

Valves : Various membranous structure in a hollow organ or passage that temporarily closes in order to permit flow of blood in one direction only.

(1) **Eustachian valve :** Present on the opening of inferior vena cava (post caval) in the right auricle in rabbit, whereas in human, the vestige of eustachian valve is present over the opening of post caval vein. It allows the passage of blood in right auricle.

(2) **Haversian valve :** Present in human but absent in rabbit. It is present over the opening of precaval vein and allows the passage of blood in right auricle.

(3) **Thebesian or coronary valve :** Present over the opening of coronary sinus in right auricle in mammals and allows the passage of blood in right auricle.

(4) **Right A.V. valve or Tricuspid valve :** Present between right auricle and right ventricle. It consists of 3 membranous flaps or cusps.

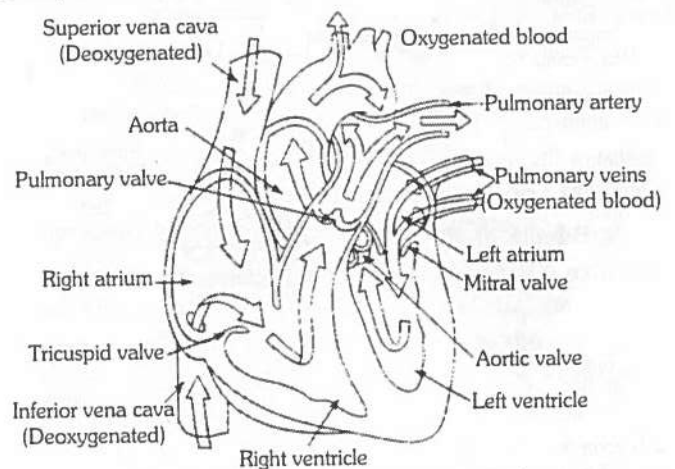


Fig : 5.3-6 Path of blood through the heart

(5) **Left A.V. valve or Bicuspid or Mitral valve :** Present between left auricle and left ventricle. It consists of 2 flaps or cusps. The bicuspid valve resembles mitre or topi of bishop, hence, also called as Mitral valve.

(6) **Semilunar valves** : At the base of pulmonary arch and systemic aorta, three membranous, pocket-shaped flaps called semilunar valves are present. They allow the passage of blood from ventricles to respective blood vessels, but prevent the return of blood.

Nodal tissue : The nodal tissue consists of the following –

(1) **Sinu-auricular or S.A. node** : Also called as pacemaker, node of Keith and Flack, heart of heart, brain of heart, pulsation centre. It is located in the right wall of right atrium below the opening of superior vena cava. This is the place where sinus venosus is incorporated in the wall of right atrium in the embryo. S.A. node is the main tissue of heart and has highest degree of autorhythmicity (generates beating impulse at the rate of 70-80 times/minute) but least conductivity. The rhythmic impulses produced are called as Sinus rhythmia. In frog S.A. node is present in sinus venosus.

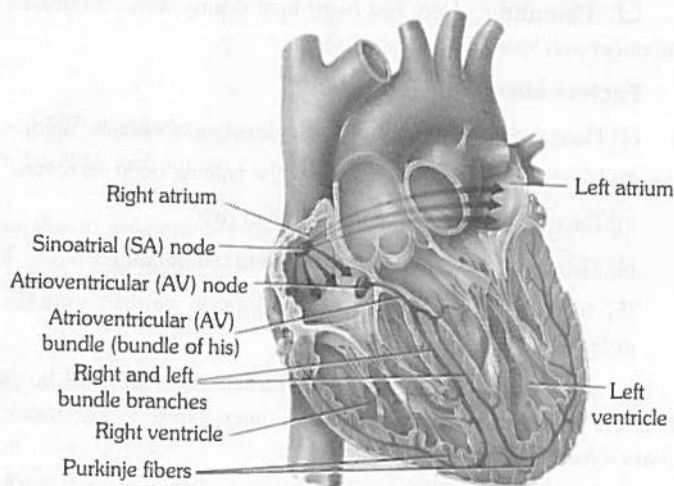


Fig : 5.3-7 Conducting system of rabbit's heart (ventral view)

(2) **Atrio-ventricular node or A.V. node** : Also called reserve pacemaker, node of Tawara and Aschoff. Discovered by Lewis Kent. It lies in the right atrium near the junction of interauricular and interventricular septum close to the opening of coronary sinus. It is concerned with the conduction of cardiac impulses generated by S.A. node, but it can also generate the impulse at the rate of 40-60/minute. These impulses produced are rhythmic and called nodal rhythmia. In frog, A.V. node is absent.

(3) **Bundle of His or A.V. bundle** : Discovered by His. It arises from A.V. node, descends in the interventricular septum and bifurcates into two branches innervating the wall of right and left ventricle respectively. The myocardium of atria and ventricles are discontinuous and this bundle is the only muscular connection between the two. It is concerned with the conduction of impulse from atria to the tip of ventricle but can also generate impulse at the rate of 35-40/minute. The impulses produced are non-rhythmic.

(4) **Purkinje fibres** : Numerous, modified muscle fibres which act as sympathetic nerve fibres. They arise from branches of bundle of His and provide impulse to myocardium of ventricles. They can also generate non-rhythmic impulse at a rate of 30-35/minute.

Working of nodal tissue : S.A. node spontaneously initiates a wave of contraction which is conducted along the tracts of special muscle fibres called internal pathways over both the auricles at a rate of 1m/sec. The impulse generated travels first in the right atrium than in left atrium. So, right atrium contracts first but the contraction ends simultaneously in both atria. As the musculatures of atria and ventricles are discontinuous and are separated by a septum of fibrous connective tissue, called annular pad in mammals, the wave of contraction is received by A.V. node from myocardium of atria and is provided to bundle of His. The impulses reach the A.V. node about 0.03 seconds after their origin from S.A. node. The A.V. node generates a fresh wave of contraction which passes over both the ventricles along the bundle of His and its ramifications at the rate of 1.5 to 4 m/sec. The Purkinje fibres bring about the contraction of ventricles from the apex of heart which passes quickly towards the origin of pulmonary and systemic arches forcing blood into them.

S.A. node not only acts as pacemaker but also establishes the basic rhythm at which the heart beats. In case of degeneration of S.A. node, A.V. node can generate impulse but it will lead to abnormal beating. The failure of atrial impulse to pass into ventricles for a few seconds to few hours is called ventricular escape or Stokes-Adams syndrome leading to delayed pick up of heart beat. In such conditions, artificial pacemaker (Lithium Battery) is placed underneath the patient's chest.

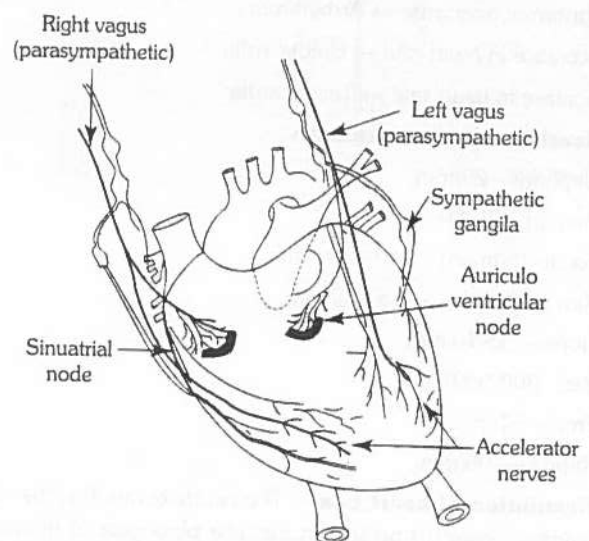


Fig : 5.3-8 Innervation of human heart by autonomic nerves

❑ **Ectopic pacemaker** : If any cardiac muscle other than the conducting tissue (nodes) generates impulse, then extra beats are heard. Such muscles are called Ectopic pacemaker.

In mammals, conducting system of the heart has S.A. node, A.V. node and complicated system of conducting fibres. But in frog, it has only S.A. node and system of conducting fibres is simple.

Heart beat : The spontaneous and rhythmic contraction and relaxation of the heart to pump out and receive blood to and from the body is called Heart beat. Depending upon the nature of control of the heart beat, hearts are of 2 types – Neurogenic and Myogenic or autorhythmic.

Table : 5.3-4 Differences between Neurogenic heart and Myogenic heart

S. No.	Neurogenic heart	Myogenic heart
1.	The heart beat is initiated by a ganglion situated near the heart.	The heart beat is initiated by a patch of modified heart muscle.
2.	The impulse of contraction originates from nervous system.	The impulse of contraction originates itself in the heart.
3.	The heart normally stops beating immediately after removal from the body. Therefore, heart transplantation is not possible.	The heart removed from the body continues to beat for some time. Therefore, heart transplantation is possible.
4.	Examples : Hearts of some annelids and most arthropods.	Examples : Hearts of molluscs and vertebrates.

Origin and conduction of heart beat : Initiation of heart beat is under special bundles of cardiac muscles called nodal tissue or autorhythmic cells. They act as pace maker so setting the rhythm for the entire heart and they form conducting system.

Heart rate : Heart beat/minute or number of cardiac cycles/minute. Females have higher heart rate than males.

Normal heart beat rate → Rhythmia

Abnormal heart rate → Arrhythmia

Decrease in heart rate → Bradycardia

Increase in heart rate → Tachycardia

Heart rate in some animals

Elephant – 29/min.

Human – 70-80/min.

Foetus (human) – 140-150 / min.

New born baby – 115-130/min.

Horse – 35-40/min.

Rat – 300-500/min.

Frog – 64/min.

Rabbit – 200/min.

Regulation of heart beat : The centre controlling the heart rate (cardiac centre) is present in medulla oblongata of brain and possess chemoreceptors sensitive for CO_2 , O_2 and also for blood pressure. This centre is under the influence of hypothalamus which is the controller of autonomic activities.

(1) **Nervous control :** Brain receives two sets of nerve fibres : Sympathetic and para sympathetic or vagal.

When there is increase in blood CO_2 , the sympathetic nerve fibres stimulate S.A. node by producing sympathin (adrenaline + noradrenaline). This compound induces impulse generation by inducing entry of Ca^{2+} into cardiac muscles. So, heart beat and force of contraction increase (Tachycardia). After action, sympathin is destroyed by sympathenase, COMT (catechol orthomethyl transferase) and MAO (Mono Amino Oxidase).

When there is increase in blood O_2 , the parasympathetic or vagal (10th cranial) nerve inhibits S.A. node by producing acetylcholine. This compound increases contraction time and hence, heart beat is decreased (Bradycardia). After action, acetyl choline is destroyed by enzyme acetyl choline esterase (AChE). This chemical regulation of heart beat on behalf of nerves was discovered by Otto Loewi.

❑ **Vagus escape :** Stimulation of vagus nerve decreases the heart rate but its continuous stimulation shows no further decrease. This phenomenon is called Vagus escape.

(2) **Hormonal control :** Hormones from adrenal medulla adrenaline and nor adrenaline accelerate the heart beat, the latter under normal conditions and the former at the time of emergency. Thyroxine hormone also increases the heart beat by increasing energy production.

❑ **Pounding :** Very fast heart beat during some conditions like anger and love.

Factors affecting heart rate

(1) Heart rate increases with increase in basal metabolic rate (BMR).

(2) Heart rate increases as the size of the animals body decreases.

(3) Decrease in pH also increases heart rate.

(4) Heart rate increases with increase in temperature.

(5) Increase in Na^+ ions in blood or in cardiac muscles, decrease heart rate.

(6) Increase in Ca^{2+} ions in blood increases heart beat but if they are injected in cardiac muscles, heart stops in contracted phase which is called Systolic Arrest.

(7) Injection of K^+ ions in heart muscles stop impulse generation. So, heart stops in diastolic or Relax phase.

(8) H^+ ions reduces force of contraction of heart.

(9) Increased inspiration, muscular exercise, low oxygen tension, injection of adrenaline, thyroxine, sympathin – all increase heart rate.

(10) Increased expiration, during sleep, injection of acetylcholine decrease heart rate.

(11) Stenosis – Narrowing of valve is called stenosis.

(12) Alkalosis – Decreases heart rate.

(13) Anoxia – (Absence of O_2 in tissue) Increases heart rates.

(14) CO_2 in more amount, decreases heart rate.

(15) CO_2 in moderate amount, increases heart rate.

(16) Epinephrine and nor-epinephrine increase heart rates.

(17) Thyroid hormone increases heart rate.

Cardiac cycle

The sequence of event which takes place from the beginning of one heart beat to the beginning of the next is called as cardiac cycle. Following events are repeated in a cyclic manner during each heart beat.

(1) **Auricular systole** : The atria contract due to wave of contraction stimulated by S.A. node contraction of auricles drives most of their blood into respective ventricles as the A.V. valves are open. There is no backflow of blood into the large veins as the contraction begins at the upper end and passes towards ventricles and moreover, the valves present at the opening of these veins close. Also, blood is already present in large veins which offers resistance to the blood that may return from the atria. At the end of a atrial systole, there starts the relaxation of auricles (auricular diastole) and contraction of ventricles (ventricular systole) simultaneously. Atrial systole takes 0.1 second while atrial diastole is of about 0.7 seconds.

(2) **Ventricular systole** : The ventricles begin to contract due to a wave of contraction stimulated by A.V. node. Due to ventricular systole, the pressure of blood in ventricles immediately rises above that in the auricles. With this pressure, the bicuspid and tricuspid valves close rapidly to prevent the backflow of blood. This closure of A.V. valves at the start of ventricular systole produces first heart sound called "Lubb" or Systolic sound. The semilunar valves are also close at this time. When the pressure of blood in the ventricles exceeds that in the great arteries, the semilunar valves open and blood enters into the great arteries. This marks the end of ventricular systole which takes about 0.3 seconds. Now the ventricles start relaxing (ventricular diastole which lasts for about 0.5 sec.)

(3) **Joint diastole** : The ventricles and auricles are in the diastolic phase simultaneously. As the ventricular diastole progresses, the pressure in the ventricles falls below that in the great arteries. So, to prevent backflow of blood from great arteries into ventricles, the semilunar valves close rapidly. This rapid closure of semilunar valves at the beginning of ventricular diastole produces second heart sound "Dup" or diastolic sound.

Heart Sounds

Heart sounds can be listened with the help of an instrument called STETHOSCOPE. It was invented by Laennec.

There are four heart sounds, designated as S_1 , S_2 , S_3 and S_4 .

First Heart Sound : S_1 is known as "LUBB" a long and louder sound produced by the closure of atrioventricular valves (tricuspid and bicuspid) at the beginning of ventricular system.

Second Heart Sound : S_2 is known as "DUP" a short and sharper sound created by the closure of semilunar valves towards the end of ventricular systole.

Third And Fourth Heart Sounds : S_3 and S_4 are usually very faint sounds and hence may not be audible. These sounds are associated with rapid ventricular filling (S_3) and atrial systole (S_4).

Heart sounds provides valuable information about working of valves. Defective or damaged heart valves lead to the backflow of blood either from ventricles to auricles or from aorta to ventricles. Such defects are detectable as abnormal hissing sound called 'MURMER' Defective valves may be replaced or repaired surgically.

The instrument used to magnify and record the heart sound is called PHONOCARDIOGRAM.

During joint diastole, blood from great veins and coronary sinus flows into the atria and some blood also passes from auricles into the respective relaxing ventricles due to less pressure in ventricles. This phase takes only 0.4 seconds and is also called as blood receiving period of heart. Thus a cardiac cycle is completed in 0.8 seconds.

Cardiac output : Volume of blood pumped from heart (left ventricle) into the systemic aorta in one minute is called cardiac output. It is also called minute volume. It is calculated as the product of stroke volume (amount of blood pumped by left ventricle each time it contracts) and rate of heart beat.

i.e. Cardiac output = Stroke volume $\times$ Rate of heart beat
 $= 70 \text{ ml} \times 75 \text{ times/minute} = 5250 \text{ ml/minute}$ or 5.25 litres/min.

Total amount of blood in human body is about 5 litres (7% of body weight). During mild exercise, the cardiac output rises to about 11 litres. During intense exercise, cardiac output rises to 19.5 litres/min., and heart beat may rise to 130 beat/minute. Cardiac output is directly proportional to the size of the organism, metabolic rate etc. but is inversely proportional to age.

(1) **Fractions of cardiac output** : Amount of pure blood going to an organ per minute is called as fraction of the organ.

(i) Cardiac fraction – 200 ml/min.

(ii) Hepatic fraction (maximum) – 1500 ml/min. (28% of blood as liver is the busiest organ of body and has maximum power of regeneration).

(iii) Renal fraction – 1300 ml/min (25% of blood)

(iv) Myofraction – 600-900 ml/min.

(v) Cephalic organs (brain) – 700-800 ml/min.

(vi) Remaining organs – Remaining blood.

(2) **Cardiac index** : Cardiac output per square metre of body surface area per minute. As area of normal young adult is 1.7 metre square, so, cardiac index is 3 litres/min/square metre.

(3) **Cardiac reserve** : Maximum amount of blood that can be pumped by left ventricle under the conditions of maximum needs. In this condition, heart beat can go upto 250 and stroke volume can go upto 100 ml per systole. Cardiac reserve is 25-30 litres which is about 5-6 times of cardiac output.

(4) **End diastolic volume (EDV)** : Amount of blood present in left ventricle at the end of diastole. It is the maximum volume of the cavity of left ventricle and is equal to 120-130 ml.

(5) **End systolic volume (ESV)** : Amount of blood present in left ventricle at the end of systole. It is the least volume of the cavity of left ventricle and is equal to 50-60 ml.

(6) **Stroke volume** : (70 ml) is equal to the difference between the end diastolic volume and end systolic volume.

$$SV = EDV - ESV$$

(7) **Venous return** : Amount of impure blood returning to right atrium per minute is called venous return and is equal to 5.25 litres.

Electrocardiogram (ECG)

A graphic record of electrical events occurring during a cardiac cycle is called Electrocardiogram. It was invented by Einthoven. The instrument used for recording the heart's electrical variations is called Electrocardiograph in which the potential differences of heart muscles are recorded by a galvanometer. In ECG, there are 2 types of waves :

(1) **Depolarisation waves** : They represent the generation of the potential difference. These waves appear only when both electrodes of galvanometer are in different fields. When both the electrodes are in same field, there is no deflection and wave drops down to base line.

(2) **Repolarisation waves** : They appear when depolarisation is over and the muscle fibre is returning to its original polarity. When both electrodes are in same polarity (means 100% repolarisation and 100% depolarisation), there is no deflection.

A normal ECG has 5 deflection waves – P, Q, R, S and T. Out of them – P, R and T waves are above the base line and are called positive waves. The Q and S waves are below base line and are called negative waves. The part of the base line between any 2 deflections is called Interval.

P wave : Indicates impulse of contraction generated by S.A. node and its spread in atria causing atrial depolarisation. The interval PQ represents atrial contraction and takes 0.1 second.

QRS complex : Indicates spread of impulse of contraction from A.V node to the wall of ventricles through bundle of His and purkinje fibres causing ventricular depolarisation. This complex also represents repolarization of S.A. node.

The RS of QRS wave and ST interval show ventricular contraction (0.3 seconds). QRS is related to ventricular systole.

T wave : Indicates repolarisation during ventricular relaxation.

Any abnormality in the working of heart alters the wave pattern of ECG. Thus, ECG is of great diagnostic value in cardiac diseases. ECG also indicates the rate of heart beat

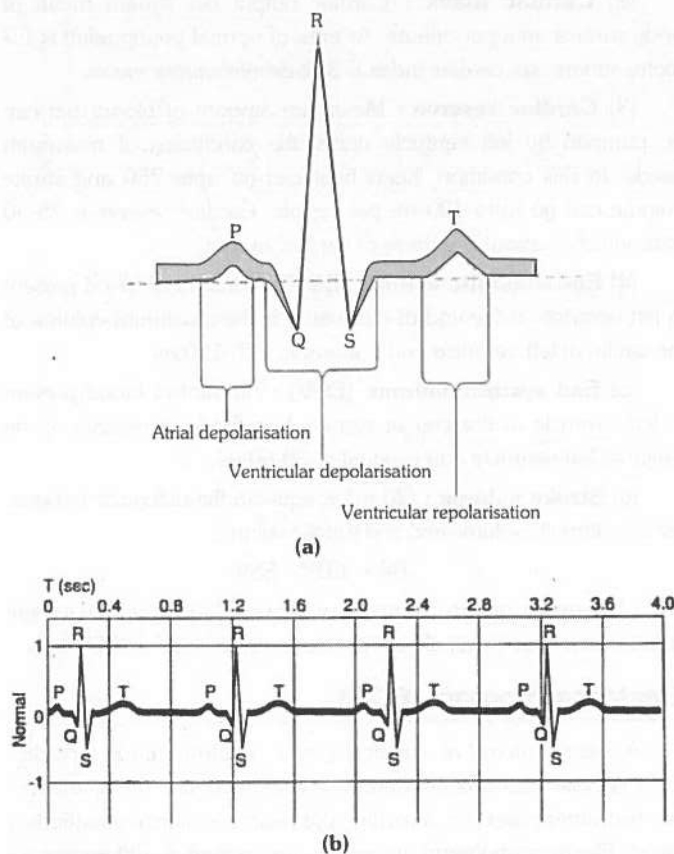


Fig : 5.3-9 (a) Normal ECG deflections, Depolarisation and repolarisation (b) Normal electrocardiogram

Blood vessels

The study of blood vessels is called Angiology. The blood vessels are of following types :

(1) **Arteries** : Thick walled, carrying oxygenated blood (deoxygenated in pulmonary artery) from heart to various parts of body. These blood vessels are grouped as Aorta which branches to form arteries which further divides into thinner branches called arterioles inside the organ. Average diameter of arteriole is $120 \mu\text{m}$. the arterioles further divide into smaller vessels called meta-arterioles ($70 \mu\text{m}$) which divide into capillaries. At the beginning of capillary, the arterioles posses circular muscles called precapillary sphincter which regulates flow of blood into the capillaries which is called vasomotion. Smooth muscles of arteries are innervated by sympathetic fibers, their stimulation control vasoconstriction and vasodilation. Smooth muscles of arteries and arterioles also limit bleeding from wounds by producing vascular spasm during cut. Arteries are of two types.

- (i) Conducting or elastic arteries
- (ii) Distributing or muscular arteries.

Elastic or conducting arteries receive blood from heart and do not provide it to any organ rather they provide blood to other arteries and are pressure reservoirs of blood.

Muscleless end of meta-arteriole is called thoroughfare channel or preferential channel.

The largest artery is dorsal / abdominal aorta (systemic aorta).

□ **Anastomosis** : If more than one arteries are supplying to one organ then branches of these arteries unite to form a network called Anastomosis. It provides many collateral or alternate pathways of blood supply. So, if there is blocking of any artery, it will not lead to necrosis.

(2) **Capillaries** : Smallest blood vessels, discovered by Marcello Malpighi. The wall is formed of single layer of endothelium resting on a basement membrane. Diameter of capillary is about 8μ . These are also called as exchange vessels as they are the site of exchange of material between blood and tissue because of least barrier in them. The capillaries can be grouped into two categories :

- (i) **Arteriolar capillary** : Which supplies nutrition, respiratory gases etc. to the body cells.
- (ii) **Veinular capillaries** : Which collect the metabolic wastes from the body cells.

Capillaries possess about 7% of total body blood and are present near almost all cells of body in the intercellular spaces. The tissues which are devoid of intercellular spaces are also devoid of capillary. They are called avascular tissues.

Capillaries are surrounded by cells of connective tissue called pericapillary cells. Some of these cells are contractile and phagocytic in nature and are called Rouget cells or pericytes.

Continuous capillaries are without fenestra/aperture, hence are less permeable. These are present in organs such as lungs, muscles, connective tissues and brain tissues.

Fenestrated capillaries possess apertures/fenestra and are found in those organs where there is maximum need of permeability such as endocrine glands, intestinal villi, cavities of brain, kidney, ciliary body of eye.

Sinusoids are irregularly dilated capillaries found in organs where there is decrease in flow rate such as liver, spleen, bone marrow, parathyroid, pituitary gland. In liver, sinusoids are branches of venules and open into venules while in other organs, they originate from arteriole and unite to form venules.

(3) **Veins** : These are thin walled, carrying deoxygenated blood (oxygenated in pulmonary vein) from tissues to the heart. Venules, smallest branches, unite to form veins which in turn unite to form vena cava. The largest vein is inferior vena cava/post caval. Varicose veins are stout, blood filled painful veins specially of the limbs due to defective watch pocket valves.

Histology of arteries and veins

(1) **Tunica externa or tunica adventitia** : Outermost, fibrous, made up of collagen rich connective tissue and less elastin fibres. The collagen fibres give strength to the blood vessels and prevent their overdilation.

(2) **Tunica media** : Middle, thickest, made up of smooth involuntary muscle fibres and elastin fibres. This layer is very much variable because number of elastin fibres and muscle fibres depend upon the position of blood vessels from the heart.

(3) **Tunica interna or tunica intima** : Innermost, thinnest, made up of inner, single layer of simple squamous epithelial cells called endothelium resting on a basement membrane and outer layer of elastic (yellow fibrous) connective tissue. The hollow space in the blood vessel is called lumen.

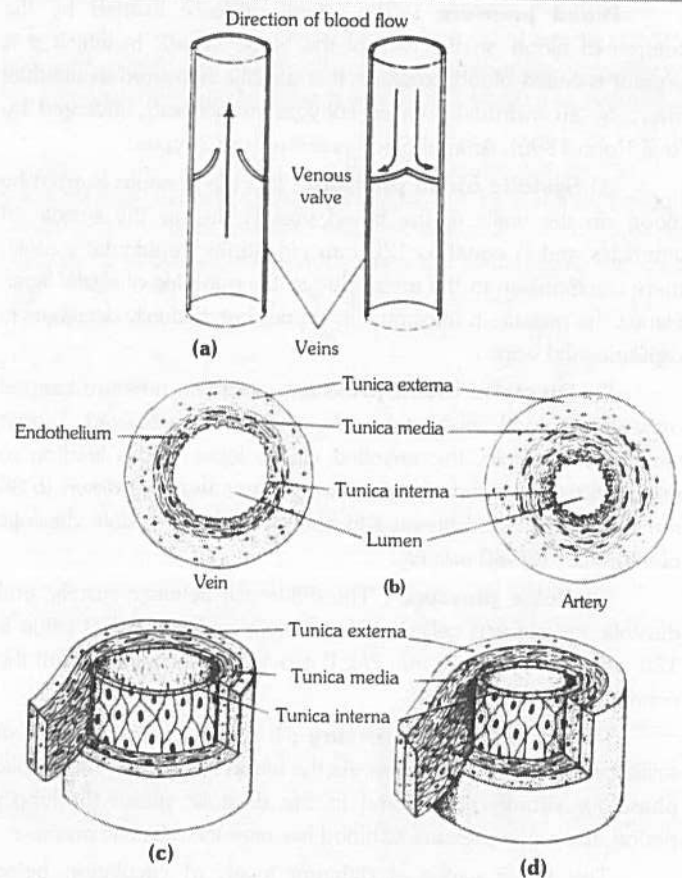


Fig : 5.3-10 (a) Venous valves, (b-d) Histology of the blood vessels

Table : 5.3-5 Differences between arteries and veins

S.No.	Characters	Arteries	Veins
(1)	Wall	Thick, more elastic, non collapsible.	Thin, less elastic, collapsible.
(2)	Tunica externa	Less developed, so less strong.	More developed, so more strong.
(3)	Tunica media	More muscular and has many elastic fibres.	Less muscular and only a few elastic fibres.
(4)	Tunica interna	Endothelial cells more elongated. Elastic membrane more developed.	Endothelial cells less flat. Elastic membrane less developed.
(5)	Lumen	Narrow	Wider
(6)	Position	Deep seated except wrist, neck etc.	Superficial
(7)	Valves	Without valves.	With valves to prevent back flow.
(8)	Direction of blood flow	From heart to body organs	From body organs to heart
(9)	Nature of blood	Oxygenated except pulmonary artery.	Deoxygenated except pulmonary vein
(10)	Blood pressure	More, generally 120/80 mm of Hg.	Less, generally 0 mm of Hg.
(11)	Speed of blood	Fast	Slow
(12)	After death	Becomes empty	Contain blood
(13)	Amount of blood	15% at any given time.	64% at any given time
(14)	Colour	Pink	Dark red
(15)	Distensibility	Less	More
(16)	Average Blood pressure	More	Less
(17)	Elastic-lamina	Present	Absent

Blood pressure : The lateral pressure exerted by the column of blood on the wall of the blood vessels in which it is present is called blood pressure. It is usually measured in brachial artery by an instrument called sphygmomanometer (invented by Riva-Rocci 1896). Arterial blood pressure is of 2 types :

(1) **Systolic blood pressure :** It is the pressure exerted by blood on the walls of the blood vessels due to the systole of ventricles and is equal to 120 mm Hg during ventricular systole, there is expansion in the artery due to the uncoiling of elastic layer. Hence, the pressure is maximum in arteries but gradually decreases in capillaries and veins.

(2) **Diastolic blood pressure :** It is the pressure exerted on walls of blood vessels when the ventricles are relaxed. During ventricular diastole, the uncoiled elastic layer recoils leading to normalization of artery. Hence, blood pressure drops down to 80 mm Hg. Thus, blood pressure in normal person is systolic/diastolic pressure i.e. 120/80 mm Hg.

(3) **Pulse pressure :** The difference between systolic and diastolic pressures is called pulse pressure and its normal value is $120 - 80 \text{ mm Hg} = 40 \text{ mm Hg}$. It provides information about the condition of arteries.

(4) **Mean arterial pressure :** It is the average pressure of systolic and diastolic pressures. As the blood remains in the systolic phase for shorter period and in the diastolic phase for longer period, the mean pressure of blood lies near the diastolic pressure.

This value varies at different levels of circulation being maximum (100 mm Hg) in the aorta and minimum (0 mm Hg) in the venae cavae under normal conditions.

Pulse : It is the pressure wave of distension and recoiling felt in the radial artery due to the contraction of left ventricle which force about 70-90 ml of blood in each cardiac cycle to aorta. This pressure wave of contraction travels down to the wall of the arteries and is called the pulse.

The pulse is measured in the radial artery in the wrist but can be felt in the temporal artery over the temporal bone or the dorsal pedis artery at the back of ankle. The pulse normally travels at the rate of 5-8 m/second.

Since each heart beat generates one pulse in the arteries so the pulse rate per minute indicates the rate of heart beat. So the normal pulse rate in a normal adult person is 72/minute.

The normal ratio of systolic pressure to diastolic pressure to pulse pressure is about 3 : 2 : 1.

Factors affecting blood pressure

(1) **Age :** With the advancing age, BP increases after the age of 60 years, it is calculated as $100 + \text{age of the person}$.

(2) **Cardiac output :** BP increases with the increase in cardiac output.

(3) **Elasticity of blood vessels :** BP is inversely related to the elasticity of the blood vessels.

(4) **Total peripheral resistance :** Constriction of the blood vessels increases BP whereas dilatation of the blood vessels decreases BP.

Hypotension : Low blood pressure with systolic below 110 mm Hg and diastolic below 70 mm Hg. It is caused by low metabolic rate, starvation, anaemia, chronic vasodilation of arterioles, lower pumping activity of heart, loss of blood in haemorrhage, valvular defects, nervous disorders and Addison's disease. It may cause fainting. Also due to lowering of oxytocin, Acetylcholine. ANP (Atrial Natriuretic Peptide) Low Ca^{++} , Low BMR.

Hypertension : Persistent high blood pressure with systolic more than 140 mm Hg and diastolic more than 90 mm Hg. It is caused by decrease in extensibility of the artery due to atherosclerosis and arteriosclerosis. Sclerosis means hardening and narrowing of blood vessels which may be due to the deposition of cholesterol or calcium or lipid or any other compound in the wall of the arteries and arterioles.

In atherosclerosis deposition is mainly in tunica interna of the blood vessels which prevents their dilation. The atherosclerosis is, infact, the beginning of thickening and hardening of blood vessels but later, the deposition of cholesterol and other compounds takes places in both tunica media and tunica interna leading to arteriosclerosis.

Hypertension caused by hormones (epinephrine, aldosterone, renin) is called secondary hypertension, other forms of hypertension are known as primary or essential hypertension.

Blood circulation in human

The physiology of blood circulation was first described by Sir William Harvey in 1628. The blood circulation in our body is divisible into 3 circuits –

(1) **Coronary circulation :** It involves blood supply to the heart wall and also drainage of the heart wall.

(i) **Coronary arteries :** One pair, arising from the aortic arch just above the semilunar valves. They break up into capillaries to supply oxygenated blood to the heart wall.

(ii) **Coronary veins :** Numerous, collecting deoxygenated blood from the heart wall and drains it into right auricle through coronary sinus which is formed by joining of most of the coronary veins. But some very fine coronary veins, called venae cordis minimae open directly in the right auricle by small sized openings called foramina of Thebesius.

(2) **Pulmonary circulation :** It includes circulation between heart and lungs. The right ventricle pumps deoxygenated blood into a single, thick vessel called pulmonary aorta which ascends upward and outside heart gets divided into longer, right and shorter, left pulmonary arteries running to the respective lungs where oxygenation of blood takes place. The oxygenated blood from lungs is returned to the left auricle by four pulmonary veins. Left auricle pumps this blood into the left ventricle.

(3) **Systemic circulation :** In this, circulation of blood occurs between heart and body organs. The left ventricle pumps the oxygenated blood into systemic arch which supplies it to the body organs other than lungs through a number of arteries. The deoxygenated blood from these organs is returned to the right auricle through two large veins (precaval and post caval). Right auricle pumps this blood into the right ventricle. Thus, the systemic circulation involves two circuits –



Arterial system

It involves aorta, arteries, arterioles and meta-arterioles. It supplies oxygenated blood to all parts of the body except lungs.

The left ventricle of the heart pumps the oxygenated blood into a single, question marked shaped, long vessel called left carotid-systemic aorta. It is the largest blood vessel of the body.

After ascending from the heart, the systemic aorta turns and descends down to the level of lower border of fourth lumbar vertebra. At its distal extremity, it bifurcates into right and left common iliac arteries. The systemic aorta has following parts –

(1) **Ascending aorta** : It gives off left and right coronary arteries.

Brachiocephalic (innominate) : Unpaired, largest branch of the aorta divides into right subclavian towards right side and right common carotid towards left side. Right subclavian gives off vertebral artery (supplies to head and part of right shoulder) and then enters into right arm, now called axillary artery or brachial artery, which divides into ulnar and radial arteries in the region of elbow. The right common carotid, enters into head and divides into external and internal carotids which supply the right parts of head by their branches.

Left common carotid : Unpaired artery, enters into head and divides into left external and internal carotids which supply the left part of the head by their tributaries. The external carotids of both sides provide blood to thyroid gland, tongue, throat, face, ear, scalp. The internal carotids of both sides supply to brain, eye, inner part of nose and forehead. These internal carotids go upward and enter skull through foramen magnum and unite at the base of brain along with the vertebral arteries of both sides. So, there is formation of a ring shaped artery called as “Circle of willis”. From this circle, many branches or arteries arise which go to different parts of brain.

In frog, the internal carotid has at its base, carotid labyrinth (spongy mass of non-contractile fibro-elastic tissue) which acts as a sensory organ to detect blood pressure in artery.

Left subclavian artery : Unpaired artery, it gives off a left vertebral artery (supplies to head and part of left shoulder) and then enters into left arm, now called left axillary artery or left brachial artery which divides into ulnar and radial arteries in the region of elbow.

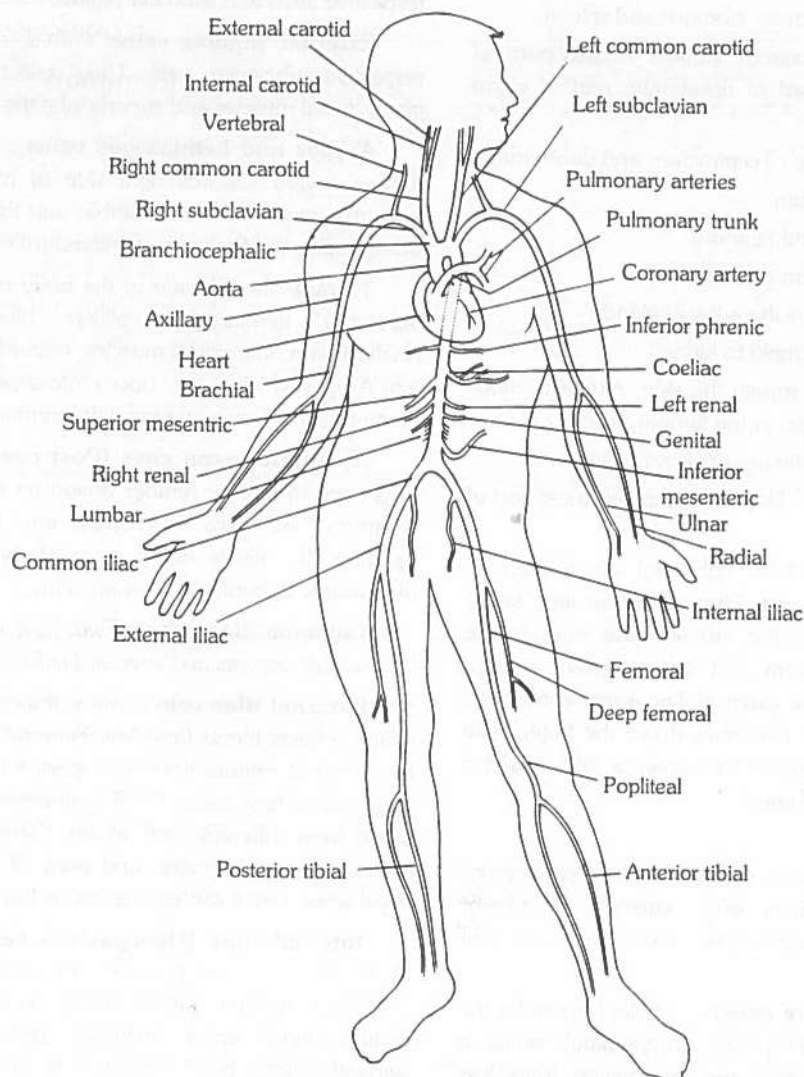


Fig : 5.3-11 Arterial system in human body

(2) **Descending aorta** : The aorta turns towards the back of heart and finally converts into dorsal aorta. The descending dorsal aorta is called thoracic aorta in thoracic region and abdominal aorta in abdominal region.

From thoracic segment of aorta : Several pairs of small arteries arise in this region to supply various parts such as pericardium (pericardial artery); lungs and bronchi (bronchial artery); oesophagus (oesophageal artery); mediastinal organs and thymus (mediastinal artery); intercostal muscles and mammary glands (intercostals and subcostal arteries); upper surface of diaphragm (superior phrenic artery).

From abdominal region of aorta : In the abdominal region, abdominal aorta gives off several pairs of arteries. Some of the major ones are as follows –

Inferior phrenic artery : Right and left to supply the lower surface of the diaphragm.

Coeliac artery : Unpaired, divides into three branches

(i) **Left gastric artery** : To stomach.

(ii) **Common hepatic artery** : To pylorus, pancreas, gall bladder, liver, cystic duct, hepatic ducts etc.

(iii) **Splenic artery** : To pancreas, stomach and spleen.

Superior mesenteric : Unpaired, supplies various parts of small intestine (except superior part of duodenum part of colon and caecum). Its sub branches are

(i) **Pancreo duodenal artery** : To pancreas and duodenum.

(ii) **Jejunal artery** : To jejunum.

(iii) **Iliac artery** : To ileum and jejunum.

(iv) **Iliocolic artery** : To ileum and colon.

Supra renal artery : Supplies the adrenal glands.

Renal arteries : One pair, supply to kidney.

Lumbar arteries : 4 pairs, supply the skin, muscles, joints, vertebrae, meninges, spinal cord etc. in the lumbar region.

Sacral artery : Supplies the tissues of sacral region.

Inferior mesenteric artery : Unpaired, supplies most part of colon, rectum and anal canal.

Common iliac arteries : Two, right and left, formed by bifurcation of aorta at its lower end. Each common iliac artery divides into external and internal iliac arteries. The internal iliac (hypogastric) artery supplies viscera and wall of pelvic region, perineum and gluteal regions. The external iliac artery enters into the leg now called femoral artery continues down the thigh, now called popliteal artery which bifurcates into anterior and posterior tibial arteries, at about the level of knee.

Venous system

It originates in tissues by union of capillaries and ends in the atrium of heart. It includes two major veins – superior and inferior vena cava which drain the deoxygenated blood into the right atrium.

(1) **Superior vena cava (pre caval)** : Single, formed by the union of right and left brachiocephalic (innominate) veins. It collects blood from head, neck, arms and chest region. It involves the following veins –

Brachiocephalic veins : Two, each is formed by the union of an outer subclavian vein and medial internal jugular vein. Each vein also receives blood from different thoracic parts of its sides through three main veins.

(i) **Internal thoracic vein** : From some muscles and mammary glands.

(ii) **Inferior thyroid vein** : From thyroid gland.

(iii) **Left superior intercostal vein** : From upper part of thorax.

Internal jugular vein : Two, right and left. Each one is formed by the union of numerous sinuses and veins of the cranial cavity, superior part of the face and some part of neck and collects blood from these regions.

Subclavian veins : Two, right and left, formed in the shoulder region by union of cephalic and axillary veins of respective sides.

(i) **Axillary veins** : Two, right and left, present in the respective arms and collect blood from these regions.

(ii) **Cephalic veins** : Two, right and left, collect blood from respective arms and shoulder region.

External jugular veins : Two, right and left, open into respective subclavian vein. They collect the blood from parotid gland, facial muscles and superficial parts of cranium.

Azygos and hemiazygos veins : Azygos vein originates in lumbar region towards right side of mediastinum and ascends upwards small veins from lumbar and thoracic parts of backbone, oesophagus, mediastinum, pericardium etc. empty into it.

Towards the left side of the body originates hemiazygos and accessory hemiazygos collects blood from oesophagus, mediastinum, intercostal muscles, mammary glands etc. and drains into Azygos which in turn opens into superior vena cava. Accessory hemiazygos drains blood into left innominate vein.

(2) **Inferior vena cava (Post caval)** : It is the largest vein, originated in inferior lumbar region by the union of right and left common iliac veins and opens into right atrium by separate opening. It collects blood from all body structures below the diaphragm. It involves following veins –

Common iliac veins : Two, right and left. Each one is formed by union of external and internal iliac veins.

External iliac vein : This is the continuation of femoral vein which collects blood from leg. Femoral vein in turn is formed by the union of anterior tibial vein, posterior tibial vein, popliteal vein, large saphenous vein, small saphenous vein, etc. which collect blood from different parts of leg. External iliac vein also collects blood from pubic region and parts of pelvis through number of small veins. Great saphenous vein is the longest vein of the body.

Internal iliac (Hypogastric) veins : Two, right and left. Each one is formed by union of number of small veins, which collect blood from pelvis, pelvic viscera, pelvic girdle, sacrum, rectum, ureter, urinary bladder, uterus, vagina, prostate glands, seminal vesicle, penis, scrotum etc. (i.e. number of reproductive organs).

Lumbar veins : Four pairs, which collect blood from muscles, skin and vertebrae of lumbar region and drains it into inferior vena cava.

Genital veins : In man, right testicular vein collects blood from male organs and inguinal regions and drains it into inferior vena cava. Left testicular vein drains the blood into left renal vein. In woman, the right ovarian vein drain blood from ovaries, uterus etc. and empties into inferior vena cava. The left ovarian vein opens into left renal vein.

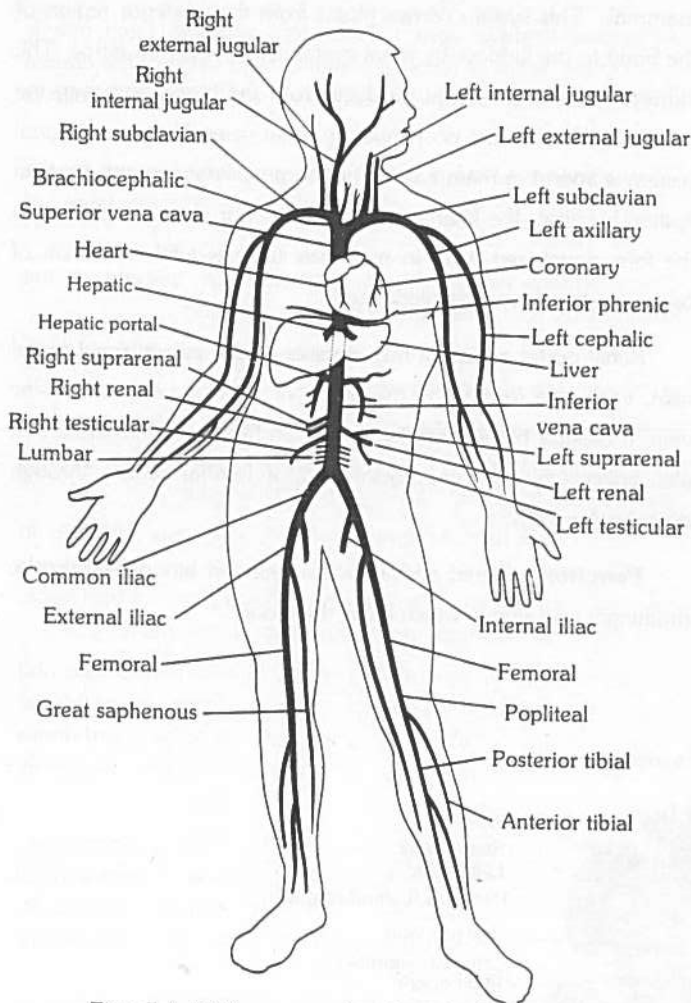


Fig : 5.3-12 Venous system in male human being

Renal veins : Two, right and left collect blood from respective kidneys and opens into inferior vena cava. The left renal vein is about three times longer than the right one.

Suprarenal vein : Two, right and left, collect blood from adrenal glands. Right one opens into inferior vena cava whereas left one opens into left renal vein.

Inferior phrenic veins : These veins drain the blood from lower surface of diaphragm. The right one ends in post caval. The left one is often doubled with its one branch ending in left renal or suprarenal vein and the other in post caval.

Hepatic veins : They drain blood from liver into the post caval. Urea is maximum in hepatic vein while it is minimum in renal vein.

Portal system

It is a part of venous circulation which is present between two groups of capillaries i.e. starts in capillaries and ends in capillaries. The vein which drains blood into organs other than heart is called portal vein.

Types of portal system : It is of following types :

(1) **Hypothalamo-hypophyseal portal system :** Present in higher vertebrates (amphibia, reptiles, birds and mammals). Blood from hypothalamus is collected by hypophyseal portal vein which ends in anterior lobe of pituitary gland. The superior hypophyseal artery which bring blood into circle of willis bifurcate outside the lobe; one branch supplies the lobe itself, but the other one supplies the hypothalamus. The vein that drain the blood from hypothalamus then runs into pars distalis and divide into capillaries. Thus this is a portal vein called hypothalamo-hypophyseal portal vein.

Function : This portal system enables the releasing factors and inhibiting factors from hypothalamus to reach upto anterior pituitary.

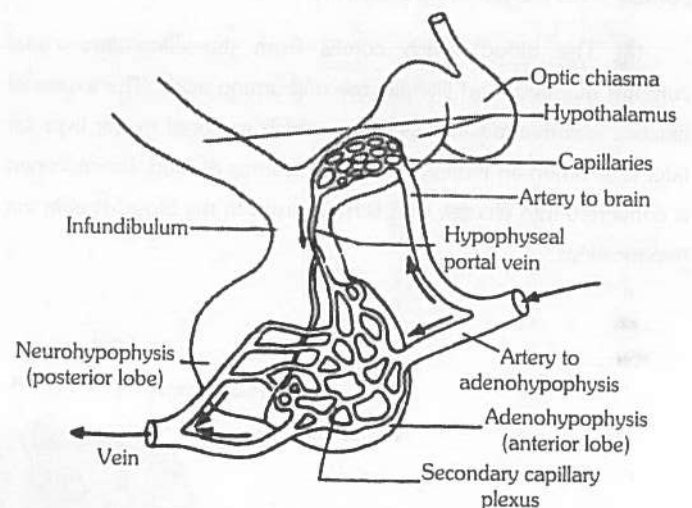


Fig : 5.3-13 Human hypothalamo-hypophyseal portal system

(2) **Hepatic portal system :** Found in all chordates. In mammals, there is a single vein called hepatic portal vein, formed by the union of six main veins, which drain venous blood from different parts of alimentary canal (digestive system) into the liver. These veins are :

(i) **Posterior or Inferior mesenteric vein :** Collect blood from rectal wall and anal region. This vein possess maximum diluted blood. Posterior mesenteric made up of by joining of 4 small veins that is rectal vein, sigmoid vein, left colonic vein and it opens into the splenic vein.

(ii) **Anterior or Superior mesenteric vein :** Collect blood from wall of colon, caecum and small intestine. This vein possesses largest concentration of nutrients (glucose, amino-acid and vitamins). This vein formed by the joining of right colonic vein, ileocolic vein and appendicular vein.

(iii) **Splenic vein** : Collect blood from spleen and pancreas, splenic vein possess free haemoglobin in large amount.

(iv) **Right gastric vein** : Receives blood from stomach.

(v) **Left gastric vein** : Receives blood from stomach and pancreas.

(vi) **Cystic vein** : Receives blood from gall bladder.

Posterior mesenteric vein open into splenic vein and splenic, anterior mesenteric, right gastric fused to form hepatic portal vein, which leads blood into the liver.

In amphibians (example – frog), hepatic portal system is formed of single hepatic portal vein and single anterior abdominal vein. The latter collects blood from leg region and drains it into the left lobe of liver.

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

(a) The blood which comes from the alimentary canal contains digested food like glucose and amino acids. The excess of glucose is converted into glycogen which is stored in the liver for later use. When an individual feels deficiency of food, the glycogen is converted into glucose and is transferred to the blood stream via hepatic veins.

(b) Harmful nitrogenous waste like ammonia is converted into urea which is later removed by kidneys. Thus the blood is detoxified (purified) of harmful nitrogenous waste.

(c) Liver produces blood proteins which are put into blood circulation.

(3) **Renal portal system** : It is well developed in fishes and amphibians, it is reduced in reptiles and birds and is absent in mammals. This system carries blood from the posterior region of the body to the kidneys by renal portal veins, hence its name. The kidneys remove the waste products from the blood and then the blood is passed to the post caval by renal veins. Why renal portal system is absent in mammals ? The mammals have no renal portal system because, the heart of mammals is four chambered. Due to the four chambered heart in mammals there is total separation of oxygenated and deoxygenated blood.

Renal portal system in frog consists of one pair of renal portal vein, each one formed by the union of femoral vein and sciatic vein. It collects blood from leg region and drains it into kidney. It also collects blood from dorsal part of lumbar region through dorsolumbar vein.

Function : Renal portal system helps in blood filtration by draining it into kidney which filters the blood

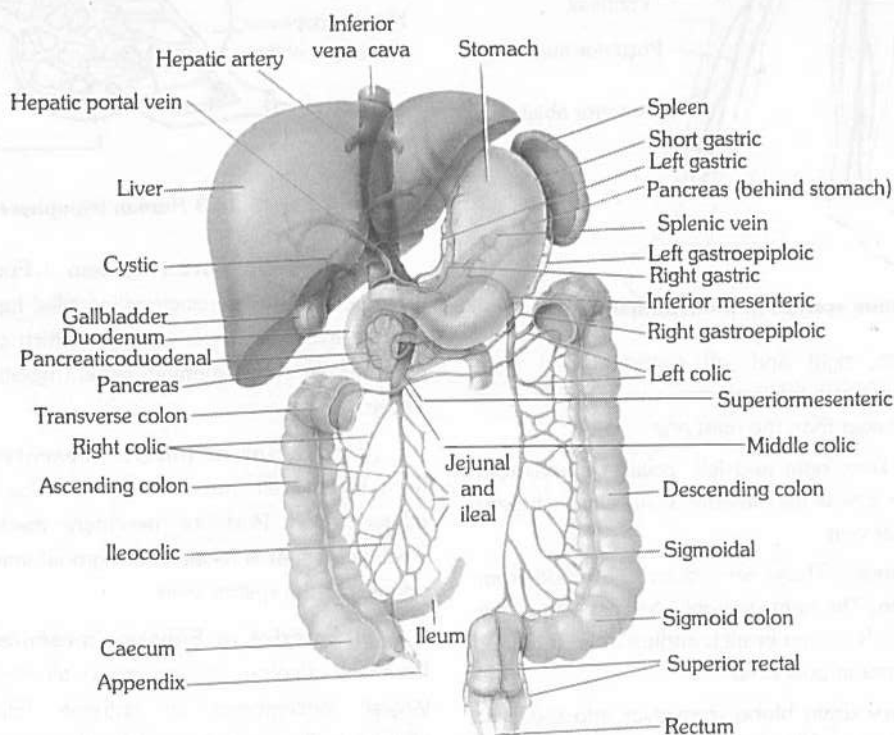


Fig : 5.3-14 Human hepatic portal system

Lymphatic system

It is a part of greater circulation which begins in the tissue fluid with lymphatic capillaries which are always terminally closed. This system terminates into venous system near heart. The main components of this system are :

(1) **Lymph** : Lymph can be defined as blood minus RBC's. In addition to the blood vascular system all vertebrate possess a lymphatic system. It is colourless or yellowish fluid present in the lymph vessels. It is a mobile connective tissue like blood and is formed by the filtration of blood. This process involves the diffusion of substances from blood capillaries into the interstitial space which is, thus, the primary site of lymph formation. Two forces bring about a steady filtration of plasma fluid into the tissue spaces : capillary pressure (30-35 mm Hg) and colloid osmotic pressure in tissue fluid (8 mm Hg). After absorption by veins, a small amount of CO_2 and waste material still remains in the tissue fluid which is absorbed in the lymphatic capillaries as lymph. So, we can say that lymph is modified tissue fluid.

Table : 5.3-6 Differences between lymph and blood

S.No.	Characters	Blood	Lymph
(1)	RBC	Present	Absent
(2)	Blood platelets	Present	Absent
(3)	WBC	Present, generally 7000/cu mm	Present, generally 500-75000/cu mm
(4)	Plasma	Present	Present
(5)	Albumin : globulin	Albumin > Globulin	Albumin > Globulin
(6)	Fibrinogen	More	Less
(7)	Coagulation property	More	Less
(8)	Direction of flow	Two way, heart to tissues and tissues to heart	One way, tissues to heart
(9)	Rate of flow	Fast	Slow
(10)	Glucose, urea and CO_2	Less	More

Hence, lymph can be represented as :

$\text{Lymph} = \text{Blood} - [\text{RBC} + \text{platelets} + \text{plasma proteins of high molecular weight}]$

Composition of lymph : Microscopic examination of lymph depicts that it contains a large number of leucocytes (mostly lymphocytes) ranging from 500 to 75,000 per cubic mm. No blood platelets present. The composition of the non cellular part of lymph (fasting) is as follows :

- (i) Water 94% (ii) Solids 6%

(a) **Proteins** : Protein content is roughly half of the plasma and varies from 2.0 – 4.5%. It varies according to the part of the body from which it is collected, i.e. in liver 6%, in limb 2%, in intestinal part 4%. The varieties of proteins are found – albumin, globulin and fibrinogen. In addition to this, traces of prothrombin, fibrinogen are also found.

(b) **Fats** : In fasting condition fat content is low but after a fatty diet it may be 5.0 – 15%.

(c) **Carbohydrates** : Sugar, 132.2 mg per 100 ml.

(d) **Other constituents** : Urea, creatinine, chlorides, phosphorus, calcium, enzymes and antibodies (120 ml./hour).

□ Normally the rate of lymph formation is equal to the rate of its return to the blood stream. But occasionally the rate of lymph formation exceeds its return to the blood stream which causes accumulation of fluid around the cells resulting in dropsy or oedema.

(2) **Lymphatic organs** : In human primary lymphatic (lymphoid) organs of the body are the Red bone marrow and Thymus gland. They are called primary lymphatic organs because they produce B and T cells the lymphocytes that carry out immune response. Haemopoietic stem cells in red bone marrow gives rise to B Cell and pre-T cells. Pre-T cells then migrate to thymus gland. Secondary lymphatic organs are the lymph nodes and spleen.

(i) **Spleen** : Spleen is mesodermal in origin. Spleen is the largest solid mass of reticulo-endothelial tissue in the body. In human it measures about 12 cm (5 inch) in length and is situated in the left hypochondriac regions between the stomach and diaphragm. Like lymph nodes, spleen has hilus, where splenic artery, vein and efferent lymphatic vessels pass through. Spleen never filter lymph, because it has no afferent lymphatic vessel. Histologically it is formed by following structure –

(a) **Capsule** : It is the outer covering of spleen formed of dense connective tissue and smooth muscles. The outer layer of the capsule is the serous coat formed of visceral peritoneum.

(b) **Trabeculae** : Narrow fold like septa or trabeculae extend inwards from the capsule, dividing the spleen tissue into several incomplete lobules. They provide support and convey blood vessels into the interior of spleen.

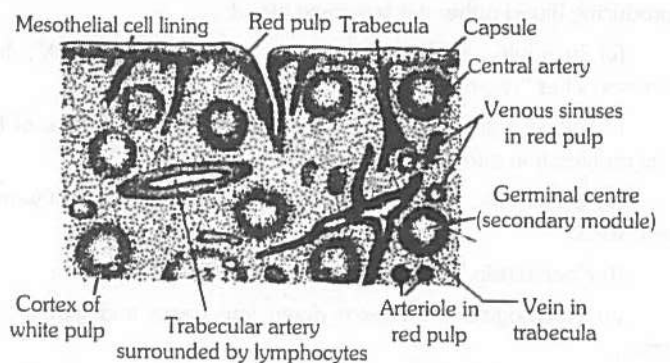


Fig : 5.3-15 Histological structure of spleen (Diagrammatic)

(c) **Splenic pulp** : The reticulo-endothelial tissue is called splenic pulp. It contains a denser network of blood capillaries, small sinuses and fine blood vessels. The meshes of this network are studded with numerous splenic cells, red, blood corpuscles, macrophages and lymphocytes. The splenic pulp is of two distinct types –

- (i) White pulp (ii) Red pulp

In mammal embryos the red pulp contains myelocytes, erythroblast and also megakaryocytes. These types of cells are not present in adult spleen except in certain pathological condition.

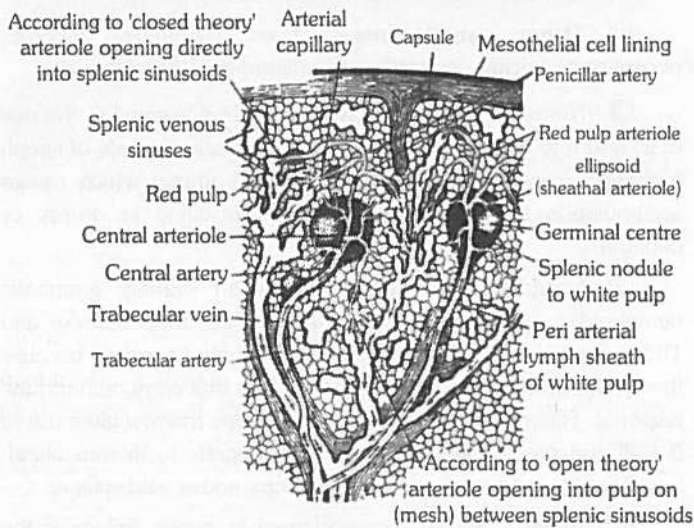


Fig : 5.3-16 Anatomy of circulation in a splenic lobule showing both closed circulation and open circulation (Diagrammatic)

Function : Although located close to the alimentary canal, the spleen has nothing to do with digestive system. It is, in fact, an important constituent of the reticuloendothelial system of body and performs the following functions:

(a) Its macrophages engulf (= phagocytize) and destroy worn-out blood corpuscles (RBC + platelets), dead and live pathogens, cell debris, pigment granules and other useless particulate materials, thus regularly cleaning the blood of its impurities.

(b) It is an active haemopoietic organ. In foetal life, the red pulp possesses myeloblast, erythroblast and megakaryocytes. Hence, in foetus, it produces blood. In adults, the red pulp possesses macrophages, plasma cells and lymphocytes. So, in adults, it is not producing blood rather it is screening blood.

(c) In adults, it also serves as a sort of "blood bank". Its sinuses act as "reservoirs of blood".

(d) White pulp of spleen functions in immunity as a site of B cell proliferation into antibody-producing plasma cells.

(e) Spleen also acts as Graveyard or Slaughter house of worn-out RBCs.

(f) Haemolysin is formed in spleen (Lysolecithin).

(g) Haemoglobin is broken down into haem and globin by spleen.

Besides all these functions, the primary function of spleen is that it assists liver and helps in maintaining the composition of blood.

(ii) **Thymus gland :** In human thymus is located in the mediastinum, between the lungs. The two thymic lobes divide into lobules by trabeculae. Each lobule consists of cortex and medulla. Cortex composed of tightly packed lymphocytes, epithelial cells, Macrophages. Pre-T cells migrate (via blood) from red bone marrow to thymus, where they proliferate and develop into mature T cells. Medulla consists of mostly of epithelial cells and

more widely scattered lymphocytes. Epithelial cells produce thymic hormone for maturation of T cells. Medulla also contains characteristic thymic (Hassall's) corpuscles, possibly, they are remnants of dying cells.

Lymphatic system in human

Lymph capillaries : Small, thin, lined by endothelium resting on a basement membrane and fine whose one end is blind and other end unites to form lymphatic ducts. These are present almost throughout the body but are absent in brain, eyeball, spinal cord, internal ear, bone marrow etc. Lymph capillaries in the region of small intestine in villi are called "lacteals" which collect chyle which is milky white in colour due to absorbed fat. Lacteals help in the absorption of digested fat.

Lymphatic ducts or vessels : Numerous, present in various parts of body. These vessels are like veins as they have all the three layers – tunica externa, tunica media and tunica interna, and are provided with watch pocket or semilunar valves but valves are more in number than veins. Valves are bicuspid.

Flow of lymph in lymphatics : Pulsations of lymph hearts in frog create sufficient force to maintain a steady flow of lymph in the lymphatic system. In mammals, the credit for maintaining onwards flow of lymph goes to (i) the "squeezing force" created by the skeletal muscles known as milking reaction (ii) the breathing movements of diaphragm and thoracic cage, (iii) mild peristalsis created by smooth muscles of the wall, of lymphatics themselves, and (iv) the pressure created by increasing amount of lymph in the lymphatics. Certain compounds like fats increase the rate of lymph flow and are called lymphagogues. Blocking of lymph flow causes oedema.

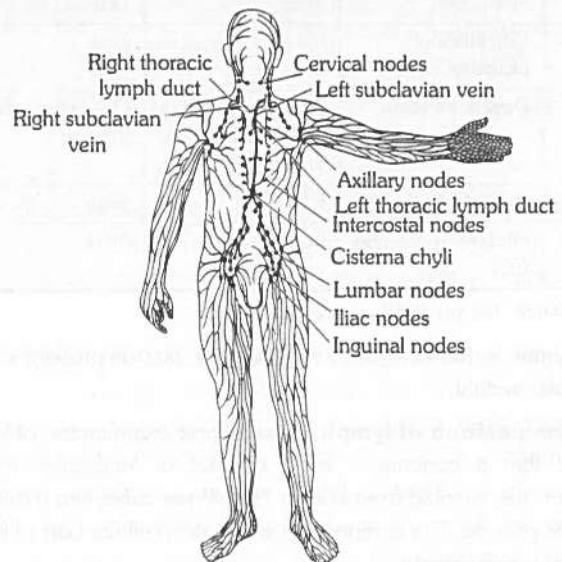


Fig : 5.3-17 Lymphatic system of mammals shown in man (ventral view)

Types of lymphatic ducts : Two main types :

(1) **Right lymphatic duct :** It is the smallest lymphatic duct with the length of approximately 1.25 cm. Its one end is blind and other one opens into right subclavian vein at the junction of right internal jugular vein. It collects lymph from one-fourth of the body (right part of head, neck, thoracic cavity and right arm).

(2) **Left lymphatic duct/thoracic duct** : It is the longest lymphatic duct with the length of approximately 38-45 cm. It originates from cisterna chyli and empties into left subclavian vein. It collects lymph from three-fourth part of the body i.e. complete posterior part through cisterna chyli, left part of head, neck, thoracic cavity and left arms.

Cisterna chyli/Receptaculum chyli : It is a dilated sac like structure present below the diaphragm in lumbar region at the level of second lumbar vertebra. It collects lymph from posterior part of body i.e. abdomen, pelvic region and hind limbs and drains it in the left lymphatic duct.

It shows inflation and deflation due to the movement of diaphragm which is a passive movement. Hence, it is also called as passive lymphatic artery. It is also called as second heart.

Lymph nodes or lymph glands : These are the masses of lymphatic tissue and connective tissue (reticular tissue) and are located on the capillaries either solitary or in cluster. Where they are present solitary and in few number, such tissues are called diffused lymphatic tissues and where they are in clusters, they are called tonsils.

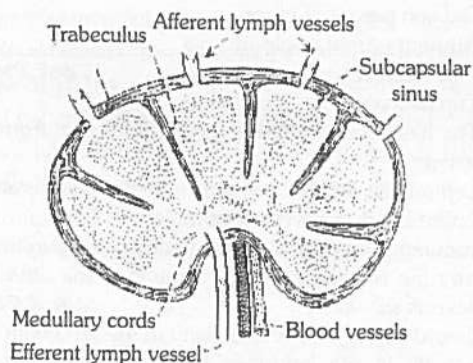


Fig : 5.3-18 Scheme to show some features of the structure of a lymph node

❑ **Lymphadenitis** : During infection, central part of follicle shows rapid division and formation of plasma cells. hence, this part is also called reaction centre. The inflammation of lymph nodes in such condition is called Lymphadenitis.

Some of the common lymph nodes are – Axillary nodes (in armpits), genital (Inguinal) nodes (in pubic region), cervical nodes (in neck region), intercostal nodes (in chest region), lumbar nodes (in lumbar region), iliac nodes (in pelvic region) and peyer's patches (in small intestine). Besides these lymphatic nodes, a number of them are also present near major blood vessels (arteries), specially dorsal aorta.

❑ **Tonsils** : Clusters of lymph nodes. They are very often called as policemen. Various tonsils are – Normal tonsils (in pharynx), adenoid tonsils (in nasopharynx), abdominal tonsils (in vermiform appendix) and policeman of intestine (in lamina propria of ileum). Adenoid tonsils are present upto 7 years of age, then they are degenerated. Their swelling is called adenoid. Inflammation of tonsils is called Tonsillitis.

❑ **Haemal lymph node** : In many animals some lymph nodes are found to possess red colour, due to the presence of blood in them. In man they are found in the retroperitoneal tissues and also in the mediastinum. Spleen may be regarded as the modified haemal lymph (haemolymph) node. Lymph nodes are located at intervals along its course.

Function of lymph nodes

(i) They produce and supply lymphocytes to the blood and as a supportive function the trabeculae carry blood vessels which supply the node.

(ii) They make screening of the lymph by means of phagocytic activity.

(iii) They serve a great defensive role against bacterial infections.

(iv) They temporarily stop the spread of cancer cells as those cells have to penetrate through the lymph vessels to the lymph nodes from where they spread in the body.

(v) They act as mechanical filters to resist the entrance of poisonous substances into circulation.

(vi) They carry out immunological responses. They help in elaboration of antibodies and in the development of immunity.

(vii) Lymph nodes produce γ -globulin.

T Tips & Tricks

- ✍ Lymphatic system in class amphibia is of open type.
- ✍ Lymph sinuses are the large spaces containing lymph. These are present in frog but absent in mammals.
- ✍ Lymph heart – The heart which collects lymph.
- ✍ In frog, lymph hearts are two pairs – an anterior pair and a posterior pair which collect lymph from respective regions. There are no lymph hearts in mammals.
- ✍ The process of lymph formation is called Transudation.
- ✍ Spleen is called “first reservoir” of blood while liver is called “second reservoir” of blood.
- ✍ Spleen, liver and kidneys – all are called filter apparatus of blood.
- ✍ Diseases where there is more destruction of RBCs such as malaria, banti disease, there is enlargement of spleen called as splenomegaly
- ✍ In AIDS, there occurs generalised swelling of all lymph nodes.
- ✍ Spleen is absent in cyclostomes.
- ✍ Cardiology – Study of heart.
- ✍ Frank-Starling law – The increase in strength of contraction as a result of stretching the walls of ventricle is known as starling's law of the heart.
- ✍ Largest sized heart is found in Blue whale and in elephant among the terrestrial animals.

- ✍ Papillary muscles of ventricles are found only in the heart of mammals.
- ✍ Valves in heart were first reported by Fabricius.
- ✍ World's first heart transplant was performed by Dr. Christian Barnard on 55-year old Louis Washkansky in Cape town, South Africa in the year 1967.
- ✍ India's first heart transplant was conducted by cardiac surgeon Dr. P. Venu Gopal in a 42-year old man Mr. Devi Ram on 3rd August, 1994 at AIIMS, Delhi
- ✍ Myocardial Ischaemia – Deficient blood supply to heart muscle leading to angina pectoris
- ✍ Angina pectoris – Severe but temporary heart pain of short duration which is usually felt in front of the chest and may pass into the arms specially left sided.
- ✍ Coronary thrombosis – Formation of blood clot in coronary arteries of heart causing death of tissue and leading to heart attack or MI.
- ✍ Coronary sclerosis – Narrowing of coronary arteries leading to severe chest pain (Angina pectoris).
- ✍ Rheumatic heart Disease (RHD) – Defects in heart valve due to toxins produced by throat infection caused by streptococcus leading to rheumatic fever and arthritis.
- ✍ Coronary angiography – X-ray of the arteries, supplying the heart, after injecting them with radio-opaque material.
- ✍ Vasa vasorum are blood vessels which supply blood to the walls of great blood vessels.
- ✍ Ringer's solution is solution of chlorides of sodium, potassium, and calcium, discovered by Ringer in 1887.
- ✍ Artificial pacemaker is an electronic device with lithium halide battery, it was first developed by Greatbach and Chardack (1960).
- ✍ Splenic vein with maximum free Hb.
- ✍ Both pulmonary Aorta and a pair of umbilical artery (Human foetus) carry deoxygenated blood.
- ✍ Nereis among annelids and amphioxus among chordates have no heart.
- ✍ Ampullary hearts are found in crustaceans, insects and cephalopods.
- ✍ Pulsating hearts are found in annelids and mollusca.
- ✍ The heart of cockroach contracts with the help of alary muscles at a rate of 50 times/minute.
- ✍ In Unio (fresh water mussel), rectum passes through the heart and the wastes are discharged into the pericardial cavity by Keber's organ (also called pericardial gland)
- ✍ Circulatory system develops from the mesoderm in vertebrates.
- ✍ **Gubernaculum cordis** : White fibrous band which attaches apex of lizard heart to pericardium.
- ✍ Blood pressure was first measured by Halls in 1732.
- ✍ ECG was invented by Einthoven (1906).
- ✍ Bundle of His was discovered by a German Physiologist William His Jr. (1893).

✍ **Plethysmograph** : Device for finding variations in size of a part due to variation in amount of blood passing through or contained in the part.

✍ **Wenckebach's Phenomenon** : A form of incomplete heart block in which there is progressive lengthening of P-R interval.

✍ **Diapedesis** : Passage of blood cells esp. leucocytes by amoeboid movements through the unruptured wall of a capillary vessel.

✍ S.A. node is the pacemaker and A.V. node is the pace setter of heart.



Ordinary Thinking

Objective Questions

Structure and function of heart

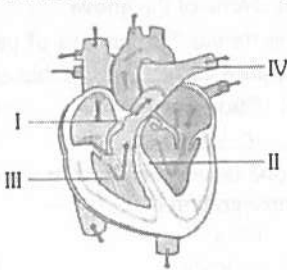
1. The blood returning to the heart from lungs via pulmonary vein has more [AIIMS 1992; MP PMT 1994]
 - (a) RBC per ml of blood
 - (c) Haemoglobin per ml of blood
 - (c) Oxygen per ml of blood
 - (d) Nutrient per ml of blood
2. Systemic heart refers to [CBSE PMT 2003]
 - (a) The two ventricles together in humans
 - (b) The heart that contracts under stimulation from nervous system
 - (c) Left auricle and left ventricle in higher vertebrates
 - (d) Entire heart in lower vertebrates
3. The problem of electrical discontinuity caused in the normal heart by the connective tissue separating the atria from the ventricles is solved by [J & K CET 2012]
 - (a) Coordinating electrical activity in the atria with electrical activity in the ventricles by connecting them via the bundle of His
 - (b) Having the A-V node function as a secondary pacemaker
 - (c) Having an ectopic pacemaker
 - (d) Coordinating electrical activity in the atria with electrical activity in the ventricles by connecting them via the vagus nerve
4. What is total diastolic time of ventricle in cardiac cycle [GUJCET 2015]

(a) 0.30 second	(b) 0.40 second
(c) 0.50 second	(d) 0.10 second
5. Which one of the following is a matching pair [AIIMS 2003, 08; AMU (Med.) 2012]
 - (a) Lub - sharp closure of AV valves at the beginning of ventricular systole
 - (b) Dup - sudden opening of semilunar valves at the beginning of ventricular diastole
 - (c) Pulsation of the radial artery-valves in the blood vessels
 - (d) Initiation of the heart beat Purkinje fibres
6. In the heart of mammals the bicuspid valve (mitral valve) is situated between [NCERT; Manipal 1995; BHU 1999; VITEEE 2003; MP PMT 2005, 06; AFMC 2009]
 - (a) Left auricle and left ventricle
 - (b) Post caval and right caval
 - (c) Right auricle and left auricle
 - (d) Right ventricle and pulmonary aorta



7. The auriculo-ventricular node in human heart was discovered by [JIPMER 1994]
(a) Hiss (b) Lewis
(c) Ringer (d) William Harvey
8. Ventricular diastole occurs due to a/an [AIIMS 2012]
(a) Organ system (b) Cell organelle
(c) Tissue (d) Organ
9. Nature of valves in the heart is [CPMT 1992]
(a) Membranous (b) Muscular
(c) Tendinous (d) Ligamentous
10. Which of the following is the correct statement about the circulatory system of cockroach [CPMT 2001]
(a) It is closed type of circulatory system
(b) It is a complicated type of circulatory system
(c) It takes place without the participation of tissue
(d) It has 13 chambered heart and in each segment one pair of ostia are present
11. The T-wave in an ECG represents [KCET 2015]
(a) Depolarisation of ventricles
(b) Electrical excitation of atria
(c) Beginning of systole
(d) Return of the ventricles from excited state
12. The volume of blood that enters into the aorta with each ventricular systole is called [KCET 2012]
(a) Cardiac cycle (b) Stroke volume
(c) Cardiac output (d) Vital capacity
13. Epinephrine is secreted by [AFMC 2008; Kerala PMT 2012]
(a) Adrenal medulla and increases the heart rate
(b) Adrenal medulla and decreases the heart rate
(c) Adrenal cortex and increases the heart rate
(d) Adrenal cortex and decreases the heart rate
14. Heart beat can be initiated by [NCERT; CBSE PMT 1999, 2002; AFMC 2000; Odisha JEE 2004; KCET 2012]
Or
The cardiac pacemaker in a patient fails to function normally. The doctors find that an artificial pacemaker is to be grafted in him. It is likely that it will be grafted at the site of [CBSE PMT 2004]
(a) Sino-auricular node (b) Atrio-ventricular node
(c) Sodium ion (d) Purkinje's fibres
15. The other term for heart attack is [BHU 2012]
(a) Coronary thrombosis (b) Myocardial infarction
(c) Cardiac arrest (d) Ischaemia
16. Read the statements regarding the cardiac system and choose the right option
A. Human heart is an ectodermal derivative
B. Mitral valve guards the opening between the right atrium and left ventricle
C. SAN is located on the left upper corner of the right atrium
D. $\text{Stroke volume} \times \text{Heart rate} = \text{Cardiac output}$ [NCERT; BHU 2004; AMU (Med) 2005; Kerala PMT 2012]
(a) A alone is correct
(b) A and B alone are correct
(c) B and C alone are correct
(d) D alone is correct
(e) B and D above are correct
17. Oxygenated blood is carried by [AFMC 1995, 2000, 10; MP PMT 1998]
Or
Blood vessels carrying blood from lungs to heart [MP PMT 1994; MHCET 2000; JIPMER 2002]
(a) Pulmonary vein (b) Pulmonary artery
(c) Renal vein (d) Hepatic portal vein
18. Purkinje's fibres are special types of [BHU 1995, 2000; MP PMT 2012]
(a) Muscle fibres located in heart
(b) Nerve fibres located in cerebrum
(c) Connective tissue fibres joining one bone to another bone
(d) Sensory fibres extending from retina into optic nerve
19. The tricuspid valve is present at the origin of [CBSE PMT 1993]
(a) Carotid arch (b) Pulmonary arch
(c) Truncus arteriosus (d) Systemic arch
20. The atrio-ventricular valves of the heart is prevented from turning inside out by tough strands of connective tissue is called as [CBSE PMT 1993]
(a) Tendinous cords (b) Tricuspid
(c) Pocket valve (d) Mitral valve
21. The pericardium and the pericardial fluid help in [DPMT 1993]
(a) Protecting the heart from friction, shocks and keeps it moist
(b) Pumping the blood
(c) Receiving the blood from various parts of the body
(d) None of the above
22. The thread like tendons of papillary muscles inserted upon the flaps of tricuspid and bicuspid valves are [AIIMS 2009]
(a) Chordae tendinae (b) Yellow elastin fibres
(c) Reticulate fibres (d) Collagen fibres
23. Blood leaving liver and moving to the heart has usually high concentration of [CPMT 2005]
(a) Urea (b) Bile
(c) Glucose (d) Erythrocytes
24. Circulatory system does not help in [Odisha JEE 2012]
(a) Transport of respiratory gases
(b) Transport of hormones
(c) Transport of food materials
(d) Transfer of impulses
25. The volume of blood each ventricle pumps out during a cardiac cycle is about [Kerala PMT 2011]
(a) 70 ml (b) 5000 ml
(c) 7 l (d) 1200 ml
(e) 40 ml
26. Which one of the statement is correct with reference to the circulation of blood in a mammal
(a) Left auricle receives oxygenated blood from the lungs
(b) Pulmonary artery returns oxygenated blood from the lungs to the left auricle
(c) Pulmonary vein carries venous blood from right auricle to lungs
(d) Venous blood is returned to the left auricle



27. The typical Lubb-Dup sounds heard in the heart beat of a healthy person are due to [CBSE PMT 1994; KCET 1994; MP PMT 2011; WB JEE 2012; AIPMT 2015]
 (a) Closing of the tricuspid and bicuspid valve
 (b) Blood flow through the aorta
 (c) Closing of the tricuspid and semilunar valves
 (d) Closing of the semilunar valves
28. The increase in blood flow to heart stimulates secretion of [MHCET 2015]
 (a) Renin (b) Oxytocin
 (c) Antidiuretic hormone (d) Atrial natriuretic factor
29. Pace maker (S.A. Node) of the heart is situated [NCERT; MP PMT 1994, 95; BVP 2000; AIIMS 2004; Pb PMT 2004; Wardha 2005; DPMT 2006]
 (a) In wall of right atrium close to eustachian valve
 (b) On intra-auricular septum
 (c) On inter-ventricular septum
 (d) In wall of left atrium close to the opening of pulmonary veins
30. During systole [NCERT; MP PMT 1994]
 (a) Auricles and ventricles contract simultaneously
 (b) Auricles and ventricles contract separately
 (c) Only auricles contract
 (d) Only ventricles contract
31. Right auricle of mammalian heart receives blood from [MP PMT 1994, 96]
 (a) Sinus venosus (b) Pulmonary veins
 (c) Precavals (d) Pre and postcavals
32. During ventricular diastole [MP PMT 1994; PET (Pharmacy) 2013]
 (a) The auricles relax (b) The heart contracts
 (c) The heart pumps blood (d) The ventricles relax
33. The following figure shows human heart. Which labelled structure represents the bundle of His [NCERT]
- 
- (a) IV
 (b) III
 (c) II
 (d) I
34. In humans, blood passes from the post caval to the diastolic right atrium of heart due to [CBSE PMT 2008]
 (a) Stimulation of the sino auricular node
 (b) Pressure difference between the post caval and atrium
 (c) Pushing open of the venous valves
 (d) Suction pull
35. Open circulatory system is present in [NCERT; KCET 1999; Kerala PMT 2008]
 (A) Arthropods (Insects) (B) Annelids
 (C) Chordates (D) Molluscs
 (a) C only (b) C and B
 (c) A and B (d) D only
 (e) A and D
36. Blood enters the heart because muscles of the [Odisha JEE 2009]
 (a) Atrium contracts (b) Atrium relaxes
 (c) Ventricle relaxes (d) Ventricle contracts
37. The function of vagus nerve innervating the heart is to [DUMET 2009]
 (a) Initiate the heart beat (b) Reduce the heart beat
 (c) Accelerate the heart beat (d) Maintain constant heart beat
38. An oval depression called fossa ovalis is seen on [Kerala PMT 2009]
 (a) Inter atrial septum
 (b) Inter ventricular septum
 (c) Right auriculo-ventricular septum
 (d) Left auriculo-ventricular septum
 (e) Papillary muscles
39. Which of the following statements is related to Starling's law of heart [WB JEE 2008]
 (a) Greater the stroke volume greater is the heart rate
 (b) Greater the initial length of the cardiac muscle fibre, more is the force of contraction of heart
 (c) Greater the minute volume, greater is the heart rate
 (d) Lesser the length of cardiac muscle fibre greater is the force of contraction of heart
40. Heart beats are accelerated by [AFMC 1994]
 (a) Cranial nerves and acetylcholine
 (b) Sympathetic nerves and acetylcholine
 (c) Cranial nerves and adrenaline
 (d) Sympathetic nerves and epinephrine
41. JG cells, under low glomerular blood flow, release [Kerala PMT 2008]
 (a) Angiotensin I (b) Angiotensin II
 (c) Renin (d) Aldosterone
 (e) ADH
42. The triangular sac like structure which receives blood through the vena cava in frog is [Kerala PMT 2012]
 Or
 Which of the following structure is absent in rabbit's heart [RPMT 1995]
 (a) Ventricle (b) Sinus venosus
 (c) Hepatic portal system (d) Conus arteriosus
 (e) Left auricle
43. Which of the following parts of heart first receives deoxygenated blood [BHU 2008]
 Or
 Tricuspid valve is present in [Odisha JEE 2010]
 (a) Right ventricle (b) Left auricle
 (c) Right auricle (d) Left ventricle
44. The duration of cardiac cycle is [NCERT; J & K CET 2008; WB JEE 2009, 10; BHU 2012]
 (a) 0.8 sec (b) 0.8 μ sec
 (c) 0.08 sec (d) 0.008 sec
45. 'Bundle of His' is a part of which one of the following organs in humans [NCERT; CBSE PMT (Pre.) 2011]
 (a) Pancreas (b) Brain
 (c) Heart (d) Kidney
46. First heart sound occurs at [RPMT 1999; CBSE PMT 2000; BHU 2008]
 (a) Opening of semilunar valve (b) Closing of semilunar valve
 (c) Onset of auricular systole (d) Sudden closure of A.V. valves
47. An artificial pace-maker is implanted subcutaneously and connected to the heart in patients [AIIMS 2004, 07]
 (a) Having 90% blockage of the three main coronary arteries
 (b) Having a very high blood pressure
 (c) With irregularity in the heart rhythm
 (d) Suffering from arteriosclerosis
48. When the heart beat increases the condition is called
 (a) Bradycardia (b) Tachycardia
 (c) Leucopenia (d) Cardiac arrest
49. If due to some injury the chordae tendinae of the tricuspid valve of the human heart is partially non-functional, what will be the immediate effect [CBSE PMT (Pre.) 2010]
 (a) The flow of blood into the pulmonary artery will be reduced
 (b) The flow of blood into the aorta will be slowed down
 (c) The 'pacemaker' will stop working
 (d) The blood will tend to flow back into the left atrium



50. Human heart is enclosed in a double walled sac called [HP PMT 2005]

(a) Peritone (b) Pericardium
(c) Pericardial sinus (d) Perineural sinus

51. 'Heart of Heart' is [NCERT; BHU 2005, 08]

Or

Pace maker of the heart is

[CPMT 1995, 98; BHU 2006; WB JEE 2011]

(a) SA node (b) AV node
(c) Bundle of His (d) Purkinje fibres

52. Spiral valve is present in [MH CET 2000]

(a) Right auricle (b) Left auricle
(c) Right ventricle (d) Truncus arteriosus

53. Which one is the correct route through which pulse making impulse travels in the heart [NCERT; KCET 1994, 2004, 05; CBSE PMT 1995; Kerala PMT 2007; WB JEE 2011]

(a) SA node → Purkinje fibres → Bundle of His → AV node → Heart muscles
(b) AV node → SA node → Purkinje fibres → Bundle of His → Heart muscles
(c) AV node → Bundle of His → SA node → Purkinje fibres → Heart muscles
(d) SA node → AV node → Bundle of His → Purkinje fibres → Heart muscles

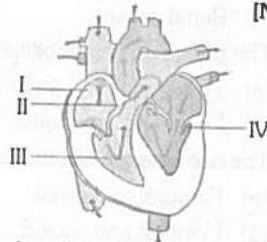
54. The given diagram shows the human heart. Which site represents the generation of action potential in human heart [NCERT]

(a) IV

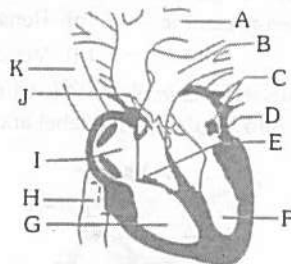
(b) III

(c) II

(d) I



55. See the figure of the vertical section of human heart given below certain parts have been indicated by letters. Select the correct answer in which these letters have been correctly paired with parts they indicate [NCERT]



- (a) A - Aorta; B - Superior vena cava, C - Inferior vena cava; D - Left ventricle; E - Semilunar valves; F - Left auricle; G - Right auricle; H - Pulmonary artery; I - Right ventricle; J - Tricuspid valves; K - Pulmonary vein
(b) A - Aorta; B - Superior vena cava, C - Inferior vena cava; D - Right ventricle; E - Tricuspid and Mitral valves; F - Right auricle; G - Left auricle; H - Pulmonary vein; I - Left ventricle; J - Semilunar valves; K - Pulmonary artery
(c) A - Aorta; B - Pulmonary artery, C - Pulmonary vein; D - Left auricle; E - Tricuspid and Mitral valves; F - Left ventricle; G - Right ventricle; H - Inferior vena cava; I - Right auricle; J - Semi lunar valves; K - Superior vena cava
(d) A - Aorta; B - Pulmonary vein, C - Pulmonary arteries; D - Left ventricle; E - Semilunar valves; F - Left auricle; G - Right auricle; H - Superior vena cava; I - Right ventricle; J - Tricuspid valves; K - Inferior vena cava

56. Which of the following statements is false [Manipal 1995]

(a) Blood from the right side of the heart is carried to the lungs by the pulmonary artery
(b) The term *pleura* refers the double layered covering of the kidney
(c) Pancreas is both an exocrine and endocrine gland
(d) Scurvy is caused by the deficiency of vitamin C

57. The pace-setter in the heart is called [CBSE PMT 1994]

(a) Purkinje fibres
(b) Sino-arterial node (SAN)
(c) Papillary muscle
(d) Atrio-ventricular node (AVN)

58. Largest heart is found in [AFMC 1996]

(a) Elephant (b) Giraffe
(c) Crocodile (d) Lion

59. Average cardiac output is [MP PMT 1996; WB JEE 2012]

(a) 4 litres per minute (b) 6.3 litres per minute
(c) 5.3 litres per minute (d) 7.3 litres per minute

60. Alary muscle is associated with [CPMT 2002; RPMT 2005]

(a) Heart and circulation
(b) Malpighian tubules and excretion
(c) Trachea and respiration
(d) None of the above

61. Which diagram shows the correct blood circulation [NCERT; GUJCET 2014]



Diagram 1



Diagram 2



Diagram 3



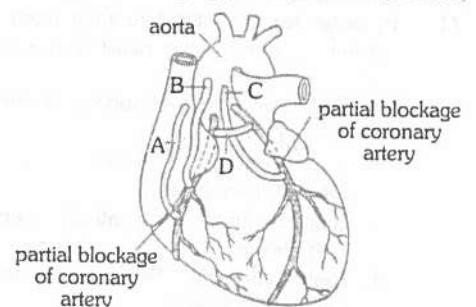
Diagram 4

- (a) Diagram 1 (b) Diagram 2
(c) Diagram 3 (d) Diagram 4

62. The chamber of human heart, which has thickest wall [JIPMER 1994; Kerala PMT 2004; WB JEE 2010]

(a) Right atrium (b) Left atrium
(c) Right ventricle (d) Left ventricle
(e) None of these

63. Which tube in the given figure of a heart correctly represents the result of a successful coronary bypass operation [NCERT]



- (a) C
(b) B
(c) D
(d) A

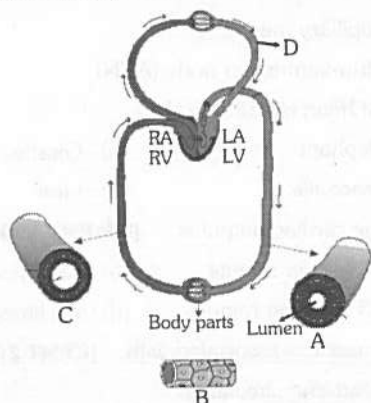
64. The given figure indicates three stages in the cardiac cycle



Choose the correct sequence

[NCERT]

- (a) 3, 1, 2 (b) 2, 1, 3
(c) 1, 2, 3 (d) 2, 3, 1
65. Figure shows blood circulation in humans with labels A to D. Select the option which gives correct identification of label and functions of the part



[NEET (Karnataka) 2013]

- (a) B – Capillary – thin without muscle layers and well two cell thick
(b) C – Vein – thin walled and blood flows in jerks/spurts
(c) D – Pulmonary vein – takes oxygenated blood to heart $PO_2 = 95 \text{ mm Hg}$
(d) A – Artery – thick walled and blood flows evenly
66. The wall of heart is made up of [MP PMT 1997]
(a) Epicardium (b) Myocardium
(c) Endocardium (d) All of the above
67. Heart beats are affected by [MP PMT 1998]
(a) Carbon dioxide (b) Oxygen
(c) Vagus nerve (d) All the above
68. Heart beat originates from [NCERT; CMC Vellore 1993; MP PMT 1998; CBSE PMT 2002]
(a) Pacemaker (b) Cardiac muscles
(c) Left atrium (d) Right ventricle
69. In the evolution of animals a heart to pump the blood is found for the first time in [Kerala CET 2003]
(a) Annelids (b) Roundworms
(c) Arthropods (d) Flat worms
70. Which of the following is different from others in absence of muscular coat [CPMT 1999; JIPMER 2001]
(a) Veins (b) Arteries
(c) Capillaries (d) Arterioles
71. In order for the blood to flow from right ventricle to left ventricle in mammalian heart, it must flow through [DUMET 2010]
(a) Right ventricle, pulmonary arteries, Lungs, Pulmonary veins, Left atrium
(b) Right ventricle, Pulmonary veins, Lungs, Pulmonary arteries, Left atrium
(c) Right ventricle, Right atrium, Lungs, Pulmonary veins, Left atrium
(d) Right ventricle, Systemic aorta, Lungs, Pulmonary veins, Left atrium

72. The heart of a crocodile consists of [KCET 2002; RPMT 2002; AIEEE Pharmacy 2003; BVP 2004]

- (a) A single auricle and two ventricles
(b) Two auricles and a single ventricle
(c) Two auricles and two ventricles
(d) A single auricle and a single ventricle

73. The post-caval is constituted by [Pune CET 1998]

- (a) Renal, gonadal and hepatic
(b) Renal and gonadal
(c) Gonadal and hepatic
(d) Hepatic and renal

74. The pre-caval vein is formed of [Pune CET 1998]

- (a) External jugular and innominate
(b) Innominate and subclavian
(c) External jugular, innominate and subclavian
(d) External jugular and subclavian

75. The post-caval vein collects blood from [Pune CET 1998]

- (a) Hind limbs
(b) Hind limbs and organs of the body cavity
(c) Body cavity organs
(d) Renal organs

76. The pre-caval veins collect blood from [Pune CET 1998]

- (a) Trunk and hind limbs (b) Fore limbs and hind limbs
(c) Head and fore limbs (d) Head and hind limbs

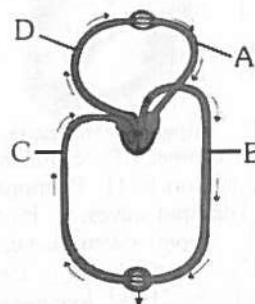
77. The two branches of the iliac artery are [Pune CET 1998]

- (a) Femoral and renal
(b) Femoral and sciatic
(c) Vesiculo-epigastric and femoral
(d) Renal and sciatic

78. The unpaired systemic branch is [Pune CET 1998]

- (a) Coeliaco-mesenteric (b) Renal artery
(c) Iliac (d) Vesiculo-epigastric

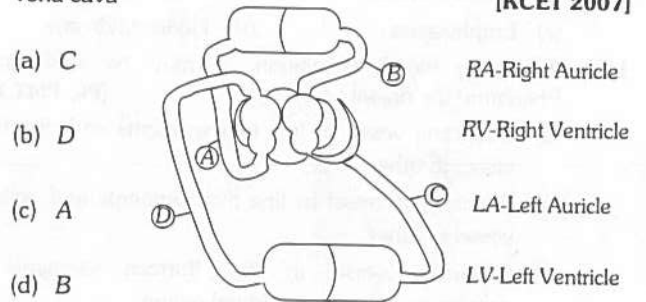
79. Figure shows schematic plan of blood circulation in humans with labels A to D, Identify the label and give its function/s



[NEET 2013]

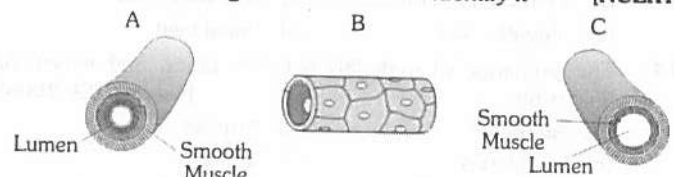
- (a) D-Dorsal aorta-takes blood from heart to body parts, $PO_2 = 95 \text{ mm Hg}$
(b) A-Pulmonary vein-takes impure blood from body parts, $PO_2 = 60 \text{ mm Hg}$
(c) B-Pulmonary artery-takes blood from heart to lungs, $PO_2 = 90 \text{ mm Hg}$
(d) C-Vena Cava-takes blood from body parts the right auricle, $PCO_2 = 45 \text{ mm Hg}$

80. Inter-auricular septum in the embryonic stages has a/an [AFMC 1997]
 (a) Foramen ovale (b) Fenestra ovalis
 (c) Fenestra rotunda (d) Inter-auricular aperture
81. Bundle of His is a network of [NCERT; CBSE PMT 2003; MP PMT 2004, 07]
 (a) Nerve fibres found throughout the heart
 (b) Muscle fibres distributed throughout the heart walls
 (c) Muscle fibres found only in the ventricle wall
 (d) Nerve fibres distributed in ventricles
82. Which is correct about veins [BHU 2000]
 (a) Valves are absent
 (b) Carry blood towards heart
 (c) Always carry oxygenated blood
 (d) Always carry deoxygenated blood
83. In frog heart, there are cardiac muscles which consist of fibres called [BHU 2006]
 (a) Purkinje fibres (b) Myonemes
 (c) Telodendria (d) Columnae carnae
84. What is correct about sinus venosus [MP PMT 2000]
 (a) It is situated on dorsal surface of rabbit heart
 (b) It is situated ventrally in frog heart
 (c) It sends blood to dorsal aorta
 (d) It opens into right auricle
85. In amphibia, the heart has [AFMC 2001]
 (a) Two auricles and two ventricle
 (b) Two auricles and one ventricle
 (c) One auricle and two ventricles
 (d) One auricle and one ventricle
86. Atherosclerosis refers to the ailment of [MP PMT 2001]
 (a) Lungs (b) Heart
 (c) Kidney (d) Liver
87. In rabbit oxygenated blood flows from [RPMT 2001]
 (a) Left auricle to left ventricle during auricular systole
 (b) Right auricle to right ventricle during ventricular systole
 (c) Right ventricle to aorta during ventricular systole
 (d) Pulmonary vein to left auricle during auricular systole
88. The innervation of heart is primarily meant for [MP PMT 2013]
 (a) Initiation of heart beat (b) Regulation of heart beat
 (c) Activation of pace maker (d) Release of acetylcholine
89. Impulse originating from sinu-atrial node are transmitted to the [JIPMER 2002]
 (a) Atrio-ventricular node (b) Bundle of His
 (c) Pacemaker (d) Purkinje system
90. Below normal heart beat is called [AFMC 2002]
 (a) Bradycardia (b) Tachycardia
 (c) Hyperpiesis (d) All of these
91. Heart of elephant is [CPMT 2002; DPMT 2004, 05]
 (a) Neurogenic (b) Myogenic
 (c) Both (a) and (b) (d) None of these
92. Thoracic duct in humans is associated with [BHU 2002]
 (a) Aorta (b) Hepatic duct
 (c) Purkinje fibre (d) Innominate vein
93. How many double circulations are normally completed by the human heart, in one minute [NCERT; KCET 2006]
 (a) Eight (b) Sixteen
 (c) Seventy two (d) Thirty six
94. The blood vascular system of mammals is known as double vascular system because [AFMC 1995]
 (a) A group of veins carry oxygenated and other group conduct deoxygenated blood
 (b) Oxygenated blood runs from heart to different organs by one set of veins while deoxygenated blood runs from heart to lung by another set
 (c) The two different systems never meet
 (d) All of the above
95. In connection with circulatory system, valves are present [CBSE PMT 1995]
 (a) Not only in heart and blood vessels of vertebrates and invertebrates, but in vertebrate lymphatics as well
 (b) Vertebrate heart only
 (c) Vertebrate heart and invertebrate hearts only
 (d) Vertebrate hearts, invertebrate hearts and their blood vessels
96. In the below given diagram which blood vessel represents vena cava [KCET 2007]



Blood vessel

1. The study of blood vessels is termed as [MHCET 2015]
 (a) Angiology (b) Cardiology
 (c) Haematology (d) Histology
2. Serotonin in the blood [CBSE PMT 1992]
 (a) Relaxes blood vessels (b) Prevents clotting of blood
 (c) Helps in clotting of blood (d) Constricts blood vessels
3. The thickening of walls of arteries is called [BHU 2012]
 (a) Arteriosclerosis (b) Arthritis
 (c) Aneurysm (d) Both (b) and (c)
4. The pulse beat is measured by the
 (a) Artery (b) Capillary
 (c) Vein (d) None
5. Carotid artery carries [MP PMT 1995; AFMC 2005]
 (a) Impure blood from brain
 (b) Oxygenated blood to anterior region of body or to brain
 (c) Impure blood to kidney
 (d) Oxygenated blood to heart
6. See the following blood vessels and identify it [NCERT]



	A	B	C
(a)	Vein	Capillary	Artery
(b)	Artery	Capillary	Vein
(c)	Capillary	Artery	Vein
(d)	Artery	Vein	Capillary

7. Which artery is absent in frog [MP PMT 2000]
Or

The diaphragm is supplied with blood by

[CPMT 1992; RPMT 1995; MP PMT 1995]

- (a) Cardiac artery (b) Phrenic artery
(c) Lingual artery (d) Lumbar artery
8. The blood vessel which supplies oxygenated blood to cardiac tissue is [WB JEE 2012]
(a) Coronary artery (b) Coronary vein
(c) Coronary sinus (d) Pulmonary vein
9. Blocking of arteries due to deposition of fats and calcium is called [MH CET 2002; Kerala PMT 2009]

Or

Which one of following is not related with bone disorder

[WB JEE 2016]

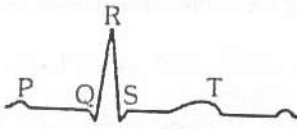
- (a) Arteriosclerosis (b) Atherosclerosis
(c) Emphysema (d) Heart syndrome
10. Regarding blood circulation, it may be said that in *Pheretima* the dorsal vessel is a [Pb. PMT 1999]
(a) Collecting vessel in first two segments and distributing vessel in other
(b) Distributing vessel in first five segments and collecting vessel in other
(c) Collecting vessel in first thirteen segments and distributing vessel in intestinal region
(d) Distributing vessel in first thirteen segments and collecting vessel in intestinal region
11. Arteries are best defined as the vessels which [NCERT; Odisha JEE 2009; CBSE PMT (Pre.) 2011]
(a) Carry blood from one visceral organ to another visceral organ
(b) Supply oxygenated blood to the different organs
(c) Carry blood away from the heart to different organs
(d) Break up into capillaries which reunite to form a vein
12. Fastest distribution of some injectible material/medicine and with no risk of any kind can be achieved by injecting it into the [NCERT; CBSE PMT (Mains) 2010]
(a) Muscles (b) Arteries
(c) Veins (d) Lymph vessels
13. Which of the following vein has least amount of urea [CPMT 1992, 93; HPMT 2005]
(a) Pulmonary vein (b) Hepatic portal vein
(c) Hepatic vein (d) Renal vein
14. The exchange of materials between blood and interstitial fluid is by [Odisha JEE 2009]
(a) Arterioles (b) Arteries
(c) Capillaries (d) Veins
15. Which one of the following is incorrect for 'atherosclerosis' [WB JEE 2012]
(a) Constriction of arterial lumen reduces the blood flow
(b) Loss of dilation ability of the arterial wall and its rupture
(c) Cholesterol deposition at the inner wall of the artery
(d) Proliferation of the vascular muscles

16. In closed circulatory system blood is enclosed by [Odisha JEE 2009]
(a) Tubes (b) Ducts
(c) Valves (d) Vessels

17. The structure of which of the following consist of a layer of single cell thickness [GUJCET 2007]
(a) Blood capillary (b) Artery
(c) Venule (d) Arteriole

Blood pressure, ECG

1. In a standard ECG which one of the following alphabets is the correct representation of the respective of the human heart [NCERT; Kerala PMT 2007; CBSE PMT 2009]
(a) R – repolarisation of ventricles
(b) S – start of systole
(c) T – end of diastole
(d) P – depolarization of the atria
2. Sphygmomanometer measure [BHU 1999; AIIMS 2000; DPMT 2003; Odisha JEE 2010]
(a) Nerve conduction rate (b) Heart beat rate
(c) Blood pressure (d) Pulse rate
3. Increase in blood pressure is due to [Odisha JEE 2011]
(a) Hypertension (b) Hypotension
(c) Hyperglycemia (d) Hypochromia
4. ECG records [NCERT; BVP 2003]
(a) Electric current of the body
(b) Potential differences
(c) Pulse rate
(d) Quantity of blood pumped per minute
5. QRST is related with [MP PMT 2011]
(a) Ventricular contraction or depolarization
(b) Auricular contraction
(c) Auricular relaxation
(d) Cardiac cycle
6. Choose the correct statement [Kerala PMT 2012]
(a) The T-wave in an ECG represents excitation of ventricles
(b) The sum of P and T waves in a given time period can determine the heart beat rate of an individual
(c) The end of the P-wave marks the end of the systole
(d) In a standard ECG, a person is connected to the machine with three electrical leads
(e) In a normal ECG, the highest peak is represented by 'S'
7. Fall in blood pressure due to loss of blood is soon restored because the [AIEEE Pharmacy 2003]
(a) Blood vessels dilate
(b) Blood cells decrease in number
(c) Heart beat is increased
(d) Heart beat is decreased
8. If the heart sound recording and ECG recordings are superimposed then the first heart sound would occur [AMU (Med.) 2009]
(a) At the P wave
(b) Just after the P wave
(c) Just before the QRS complex
(d) Just after the QRS complex

9. Blood pressure in the mammalian aorta is maximum during [AIPMT (Cancelled) 2015]
 (a) Diastole of the right ventricle
 (b) Systole of the left ventricle
 (c) Diastole of the right atrium
 (d) Systole of the left atrium
10. In a typical heart, if EDV is 120ml of blood and ESV is 50ml of blood, the stroke volume (SV) is [NCERT; KCET 2011]
 (a) $120 - 50 = 70\text{ml}$ (b) $120 + 50 = 70\text{ml}$
 (c) $120 \times 50 = 6000\text{ml}$ (d) $120 + 50 = 2.4\text{ml}$
11. The carotid labyrinth of frog is concerned with the control of [MH CET 2000]
 (a) Temperature (b) Blood sugar
 (c) Blood pressure (d) Blood composition
12. Blood pressure increases and heart rate decreases in response to [AIIMS 2001]
 (a) Exercise (b) Haemorrhage
 (c) Exposure to high altitude (d) Increased intracranial pressure
13. Which one of the following statement is correct regarding blood pressure [NCERT; CBSE PMT (Pre.) 2011]
 (a) 190/110 mmHg may harm vital organs like brain and kidney
 (b) 130/90 mmHg is considered high and requires treatment
 (c) 100/55 mmHg is considered and ideal blood pressure
 (d) 105/50 mmHg makes one very active
14. Deficiency of which of the following causes obesity, low plasma Na^+ , high K^+ and increased blood pressure [CPMT 1999; JIPMER 2001]
 (a) Growth hormone (b) Adrenaline
 (c) Cortisol (d) Thyroxine
15. During systole of ventricle [MP PMT 1995]
 (a) Blood enters the heart (b) Blood leaves the heart
 (c) Blood leaves the ventricle (d) Blood enters lungs
16. We feel sleepy just after taking meals because [CPMT 1996]
 (a) Blood pressure increases (b) Blood pressure decreases
 (c) Body weight increases (d) We feel lethargic
17. During diastole [MP PMT 1996]
 (a) Blood enters lungs (b) Blood leaves the ventricle
 (c) Blood leaves the heart (d) Blood enters the heart
18. If the systolic pressure is 120 mm Hg and diastolic pressure is 80 mm Hg, the pulse pressure is [MHCET 2006; WB JEE 2010; KCET 2010]
 (a) $120 \times 80 = 9600\text{ mm Hg}$ (b) $120 + 80 = 200\text{ mm Hg}$
 (c) $120 - 80 = 40\text{ mm Hg}$ (d) $\frac{120}{80} = 1.5\text{ mm Hg}$
19. The diagram given here is the standard ECG of a normal person. The P-wave represents the
- 
- [CBSE PMT (Mains) 2011; NEET 2013]
 (a) End of systole
 (b) Contraction of both the atria
 (c) Initiation of the ventricular contraction
 (d) Beginning of the systole
20. Blood pressure in the pulmonary artery is [NEET (Phase - I) 2016]
 (a) Same as that in the aorta
 (b) More than that in the carotid
 (c) More than that in the pulmonary vein
 (d) Less than that in the venae cavae
21. A decrease in blood pressure/volume will not cause the release of [NEET 2017]
 (a) Renin (b) Atrial natriuretic Factor
 (c) Aldosterone (d) ADH

Lymphatic system

1. Lymph (nodes) glands form [MP PMT 1999]
 (a) Hormones (b) Lymphs
 (c) Antigens (d) Antibodies
2. Which of the following is first to receive lymphatic duct from legs [GUJCET 2007]
 (a) Left subclavian vein (b) Right subclavian vein
 (c) Right lymphatic duct (d) Thoracic lymphatic duct
3. Lymph is colourless because [MP PMT 1999]
 (a) WBC are absent (b) WBC are present
 (c) Haemoglobin is absent (d) RBC are absent
4. Which organ is considered as "Graveyard of RBC" where most of them are destroyed by macrophages [NCERT; AFMC 2001; AMU (Med.) 2006; CBSE PMT (Mains) 2012]

Or

Which of the following organs can be called as a sort of "blood bank"

- (a) Red bone marrow (b) Spleen
 (c) Kidney (d) Intestine
5. Which of the following is not a major organ of lymphatic system [MP PMT 2010; AFMC 2012]
 (a) Lymph nodes (b) Thymus
 (c) Kidney (d) Spleen
6. An antibody is a [MP PMT 1996; BVP 2003]
 (a) Molecule that specifically inactivates an antigen
 (b) WBC which invades bacteria
 (c) Secretion of mammalian RBC
 (d) Component of blood
7. Antigens are present [CBSE PMT 1995]
 (a) Inside nucleus (b) On cell surface
 (c) Inside cytoplasm (d) On nuclear membrane
8. Function of human spleen is to
 (a) Control the pulse rate (b) Secrete hormone
 (c) Stimulate heart (d) Control blood volume
9. T-Lymphocytes originate from [MP PMT 2001; WB JEE 2009]
 (a) Thymus (b) Bone marrow
 (c) Liver (d) None of these
10. Lymphoid tissue is found in [CPMT 2000; BHU 2006]
 (a) Thymus (b) Tonsils
 (c) Lymph nodes (d) All of these
11. If the spleen is removed from the body of an adult man then
 (a) Antibody production will be less
 (b) RBC production will be lowered
 (c) WBC production will be lowered
 (d) Filtration of dead RBC will stop

12. Red pulp and white pulp are found in [CBSE PMT 1991]
 (a) Bone (b) Spleen
 (c) Tooth (d) Skeletal Muscle
13. Spleen is [CBSE PMT 2001; BVP 2001]
 (a) Haemopoietic (b) Lymphoid
 (c) Reproductive (d) Celluloid
14. The principle function of the lymph node in the man is
 (a) Destruction of old RBC
 (b) Destruction of old WBC
 (c) Collection and destruction of pathogens in the blood
 (d) Production of WBC
15. The lymph serves to [CBSE PMT 1995; BHU 2004]
 (a) Transport O_2 to the brain
 (b) Transport CO_2 to the lungs
 (c) Return the interstitial fluid to the blood
 (d) Return the WBCs and the RBCs to the lymph nodes
16. Humoral antibodies are produced by
 (a) B – cells (b) T – cells
 (c) Globulins (d) Plasma cells
17. If thymus gland of an infant is removed which of the following will not form [CPMT 1993]
 (a) T – lymphocytes (b) β – lymphocytes
 (c) Erythrocytes (d) Granulocytes
18. Which vertebrate organ receives only oxygenated blood [KCET 2001]
 (a) Gill (b) Lung
 (c) Spleen (d) Liver
19. Lymph vessels are united to form [BHU 2001]
 (a) Lymph heart (b) Cisterna chyle
 (c) Thoracic duct (d) Jugular vein
20. Immunoglobulins are produced by [CBSE PMT 1996]
 (a) Lymphocytes (b) Spleen
 (c) Leucocytes (d) Monocytes

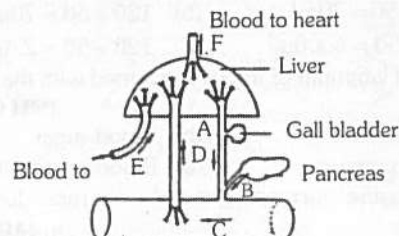
Portal system

1. A portal system is a system in which
 (a) A vein starts from an organ and ends up in heart
 (b) An artery breaks up in an organ and restarts by the union of its capillaries
 (c) The blood from the gut is brought into the kidney before it is poured into posterior venacava
 (d) A vein breaks up in an organ into capillaries and restarts by their union as a new vein in the same organ
2. A vein that collects blood from one network of capillaries and transports it directly to a second capillary network in another region of the body, without returning to the heart is called [Odisha JEE 2010; WB JEE 2012]
 (a) Coronary vein (b) Pulmonary vein
 (c) Portal vein (d) Carotid vein
3. Hepatic portal system starts from [NCERT]
 (a) Digestive system to liver (b) Kidney to liver
 (c) Liver to heart (d) Liver to kidney
4. Which of the following vessel in rabbit starts with capillaries and ends in capillaries [RPMT 2002]
 (a) Pulmonary artery (b) Renal vein
 (c) Hepatic portal vein (d) Renal artery

Or

Which one of the following vein breaks up into capillaries [MP PMT 1992]
 (a) Pulmonary artery (b) Renal vein
 (c) Hepatic portal vein (d) Renal artery

5. Blood circulation that starts in capillaries and ends in capillaries is called [NCERT; J & K CET 2010]
 (a) Portal circulation (b) Hepatic circulation
 (c) Cardiac circulation (d) None
6. The diagram below show how things get to and from the liver. They are labelled as A, B, C, D, E and F. Which one of the following labellings is the correct one [Kerala PMT 2004]



- (a) A is the hepatic portal vein and E is the hepatic vein
 (b) C is the intestine and F is the hepatic portal vein
 (c) D is the hepatic portal vein and F is the hepatic vein
 (d) B is pancreatic artery and E is the hepatic artery
 (e) D is the hepatic portal vein and E is the hepatic vein
7. Which of the following carries glucose from digestive tract to liver [CBSE PMT 1999; BHU 2001]
 (a) Hepatic artery (b) Hepatic portal vein
 (c) Pulmonary vein (d) None of these
8. The renal portal system is made of [Pune CET 1998]
 (a) Femoral, renal portal veins
 (b) Sciatic, renal portal veins
 (c) Renal portal veins
 (d) Femoral, sciatic, renal portal veins
9. The hepatic portal vein drains blood to liver from [NEET 2017]
 (a) Heart (b) Stomach
 (c) Kidneys (d) Intestine

NCERT

Exemplar Questions

1. Mark, among the following a cell which does not exhibit phagocytotic activity [NCERT]
 (a) Monocytes (b) Neutrophil
 (c) Basophil (d) Macrophage
2. One of the common symptoms observed in people infected with Dengue fever is [NCERT]
 (a) Significant decrease in RBC count
 (b) Significant decrease in WBC count
 (c) Significant decrease in platelets count
 (d) Significant increase in platelets count
3. Which among the followings is correct during each cardiac cycle [NCERT]
 (a) The volume of blood pumped out by the Rt and Lt ventricles is same
 (b) The volume of blood pumped out by the Rt and Lt ventricles is different
 (c) The volume of blood received by each atrium is different
 (d) The volume of blood received by the aorta and pulmonary artery is different

4. Cardiac activity could be moderated by the autonomous neural system. Tick the correct answer [NCERT]
 (a) The parasympathetic system stimulates heart rate and stroke volume
 (b) The sympathetic system stimulates heart rate and stroke volume
 (c) The parasympathetic system decreases the heart rate but increase stroke volume
 (d) The sympathetic system decreases the heart rate but increase stroke volume
5. Mark the pair of substances among the following which is essential for coagulation of blood [NCERT]
 (a) Heparin and calcium ions
 (b) Calcium ions and platelet factors
 (c) Oxalates and citrates
 (d) Platelet factors and heparin
6. ECG depicts the depolarization and repolarisation processes during the cardiac cycle. In the ECG of a normal healthy individual one of the following waves is not represented [NCERT]
 (a) Depolarisation of atria (b) Repolarisation of atria
 (c) Depolarisation of ventricles (d) Repolarisation of ventricles
7. The cells involved in inflammatory reactions are [NCERT]
 (a) Basophils (b) Neutrophils
 (c) Eosinophils (d) Lymphocytes
8. The second heart sound (dubb) is associated with the closure of [NCERT]
 (a) Tricuspid valve
 (b) Semilunar valves
 (c) Bicuspid valve
 (d) Tricuspid and bicuspid valves
9. Which of the following correctly explains a phase/event in cardiac cycle in a standard electrocardiogram [NCERT]
 (a) QRS complex indicates atrial contraction
 (b) QRS complex indicates ventricular contraction
 (c) Time between S and T represents atrial systole
 (d) P-wave indicates beginning of ventricular contraction
10. Which of the following statements is incorrect [NCERT]
 (a) A person of 'O' blood group has anti 'A' and anti 'B' antibodies in his blood plasma
 (b) A person of 'B' blood group can't donate blood to a person of 'A' blood group
 (c) Blood group is designated on the basis of the presence of antibodies in the blood plasma
 (d) A person of AB blood group is universal recipient
11. What would be the cardiac output of a person having 72 heart beats per minute and a stroke volume of 50 ml [NCERT]
 (a) 360 mL (b) 3600 mL
 (c) 7200 mL (d) 5000 mL
12. Match the terms given under Column 'A' with their functions given under Column 'B' and select the answer from the options given below
- | Column 'A' | Column 'B' |
|---------------------|---|
| A. Lymphatic system | i. Carries oxygenated blood |
| B. Pulmonary vein | ii. Immune Response |
| C. Thrombocytes | iii. To drain back the tissue fluid to the circulatory system |
| D. Lymphocytes | iv. Coagulation of blood |
- Options [NCERT]
 (a) A-ii, B-i, C-iii, D-iv (b) A-iii, B-i, C-iv, D-ii
 (c) A-iii, B-i, C-ii, D-iv (d) A-ii, B-i, C-iii, D-iv

13. Read the following statements and choose the correct option [NCERT]

Statement 1 : Atria receive blood from all parts of the body which subsequently flows to ventricles.

Statement 2 : Action potential generated at sino-atrial node passes from atria to ventricles.

- (a) Action mentioned in Statement 1 is dependent on action mentioned in Statement 2
 (b) Action mentioned in Statement 2 is dependent on action mentioned in Statement 1
 (c) Action mentioned in Statements 1 and 2 are independent of each other
 (d) Action mentioned in Statements 1 and 2 are synchronous

Critical Thinking

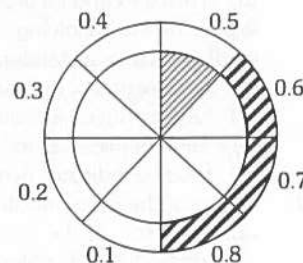
Objective Questions

1. Blood of *Periplaneta* does not carry oxygen because [RPMT 2001]
 (a) O_2 is transported by respiratory tubules
 (b) Its respiration is anaerobic
 (c) There is no cells in its blood
 (d) *Periplaneta* does not has any blood vessel
2. A vein differs from the artery in having [CBSE PMT 1993; MP PMT 1993, 94; Pb. PMT 2000]
 (a) Narrow lumen
 (b) Strong cuticular and muscular wall
 (c) Valves to control direction of flow
 (d) Dark pigmented wall
3. Which of the following diagram of cardiac cycle is possible in case of human heart, if the shaded and nonshaded sectors represents different events (systole or diastole) [NCERT]
-
- (a) (b) (c) (d)
4. pH of blood in artery and vein is
 (a) Same
 (b) More in artery and less in vein
 (c) More in vein and less in artery
 (d) Not definite
5. Largest blood vessel in body is [MP PMT 1993; MHCET 2000]
 (a) Carotid artery (b) Dorsal aorta
 (c) Phrenic artery (d) Coronary artery
6. All arteries carry oxygenated blood except [MP PMT 2001; AFMC 2003]
 (a) Systemic (b) Hepatic
 (c) Pulmonary (d) Cardiac



7. Choose the correct proportion with respect to the distribution of blood in the body of man. [Kerala PMT 2004]
- 5% to heart muscles, 15% to brain, 25% to liver, 25% kidney, 15% to bones, 15% to other organs
 - 20% to heart muscles, 10% to brain, 10% to liver, 25% to kidney, 10% to bones, 25% to other organs
 - 10% to heart muscles, 10% to brain, 10% to liver, 40% to kidney, 15% to bones, 15% to other organs
 - 5% to heart muscles, 20% to brain, 20% to liver, 15% to kidney, 5% to bones, 35% to other organs
 - 1% to heart muscles, 20% to brain, 30% to liver, 40% to kidney, 5% to bones, 40% to other organs
8. Given below are four statements (A-D) regarding human blood circulatory system
- Arteries are thick-walled and have narrow lumen as compared to veins
 - Angina is acute chest pain when the blood circulation to the brain is reduced
 - Persons with blood group AB can donate blood to any person with any blood group under ABO system
 - Calcium ions play a very important role in blood clotting
- Which two of the above statements are correct
- [NCERT; CBSE PMT (Mains) 2010]
- (A) and (D)
 - (A) and (B)
 - (B) and (C)
 - (C) and (D)
9. Heaviness with severe chest pain which may disappear with rest indicates [MHCET 2015]
- Angina pectoris
 - Atherosclerosis
 - Arteriosclerosis
 - Hyperthyroidism
10. In haemoglobin iron is present in [CBSE PMT 1992]
- Ferrous form
 - Ferric form
 - Metallic form
 - Any form
11. Mixing up of arterial and venous blood does not take place in a heart having [AIIMS 1992]
- Two chambers
 - Four chambers
 - Three chambers
 - None of the above
12. When the right ventricle contracts the blood goes into [CBSE PMT 1992]
- Aorta
 - Brain
 - Pulmonary artery
 - None
13. Trilobed valve present between right atrium and ventricle in mammalian heart is [NCERT; CBSE PMT 1993; AFMC 2008; Kerala PMT 2008]
- Triac
 - Triad
 - Tricuspid or besian
 - Trigeminal
14. Stimulation of the vagus nerve will make the heart beat
- Faster
 - 70 times/minute
 - Slower
 - Normal
15. The rate of heart beat per minute is highest in case of
- Elephant
 - Whale
 - Man
 - Mouse
16. Which one of the following animals has two separate circulatory pathways [AIPMT 2015]
- Lizard
 - Whale
 - Shark
 - Frog

17. Which one represents pulmonary circulation [NCERT; Kerala PMT 2002]
- In auricle (oxygenated blood) – lungs (deoxygenated blood) – Right auricle
 - Left auricle (deoxygenated blood) – lungs (oxygenated blood) – Right auricle
 - Left auricle (oxygenated blood) – lungs (deoxygenated blood) – Left auricle
 - Right auricle (deoxygenated blood) – lungs (oxygenated blood) – Left auricle
18. Mammals have biconcave RBC. The physiological use for it is [NCERT]
- To decrease the surface area
 - To increase the surface area
 - To be packed like coins
 - None of the above
19. Systole refers to the contraction of [BHU 2002]
- SA node
 - AV node
 - Major arteries
 - Atria and ventricles
20. Which set is correct [CBSE PMT 2001]
- Sebum – Analgesic
 - Vitamin – Nicotine
 - Corpuscallosum – Graffian follicle
 - Bundle of His – Purkinje fibre
21. In rabbit, function of spleen is [CPMT 1995]
- Blood purification
 - Respiration
 - Excretion
 - None of the above
22. See the following Cardiac Cycle. For how much duration does joint systole occur in the given cardiac cycle [NCERT]
- 0.4 seconds
 - 0.7 seconds
 - 0.3 seconds
 - None



Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :

- If both the assertion and the reason are true and the reason is a correct explanation of the assertion
 - If both the assertion and reason are true but the reason is not a correct explanation of the assertion
 - If the assertion is true but the reason is false
 - If both the assertion and reason are false
 - If the assertion is false but reason is true
1. Assertion : Heart valves resemble swing doors in action.
Reason : Valves are present in the heart chamber, at the opening of the heart into large arteries and veins.
2. Assertion : WBCs accumulate at the site of wounds by diapedesis.
Reason : It is the squeezing of leucocytes from the endothelium. [AIIMS 2002]



3. Assertion : Saline water is not given to patients of hypertension.
Reason : Saline water can cause vomiting and may drop blood pressure suddenly causing cardiac arrest. [AIIMS 2000]
4. Assertion : EEG is of immense diagnostic value in the cardiac diseases.
Reason : Defects in cardiac functions can be reflected in changes in the pattern of electrical potentials recorded in the EEG.
5. Assertion : An artificial pacemaker can replace the sinoatrial node of heart.
Reason : This is because, an artificial pacemaker is capable of stimulating the heart electrically to maintain its beats.
6. Assertion : Electrocardiogram is record of electrical activity of the heart which shows certain waves called P, Q, R, S and T waves.
Reason : It gives important information concerning the spread of excitation to the different parts of heart and it is of value in the diagnosis of cases of abnormal cardiac rhythm and myocardial damage. [AIIMS 2000]
7. Assertion : Blood pressure is arterial blood pressure.
Reason : It is measured by sphygmomanometer. [AIIMS 2000]
8. Assertion : Heart of fish contains only deoxygenated blood.
Reason : Oxygenated blood do not return back to the heart in fishes.
9. Assertion : Blood flows at a very slow velocity in the lacunae and sinuses of prawn.
Reason : This happens because of the absence of heart in the prawn.
10. Assertion : The muscle fibres of SA node possess the lowest rhythmicity among all cardiac muscle fibres.
Reason : Due to this fact, it can initiate excitatory waves at the highest rate [AIIMS 1997]

Answers

Structure and function of heart

1	c	2	c	3	a	4	b	5	a
6	a	7	b	8	c	9	a	10	d
11	d	12	b	13	a	14	a	15	b
16	d	17	a	18	a	19	b	20	a
21	a	22	a	23	a	24	d	25	a
26	a	27	c	28	d	29	a	30	b
31	d	32	d	33	c	34	b	35	e
36	b	37	b	38	a	39	b	40	d
41	c	42	b	43	c	44	a	45	c
46	d	47	c	48	b	49	a	50	b

51	a	52	d	53	d	54	d	55	c
56	b	57	d	58	a	59	c	60	a
61	c	62	d	63	a	64	b	65	c
66	d	67	d	68	a	69	a	70	c
71	a	72	c	73	a	74	c	75	b
76	c	77	c	78	a	79	d	80	a
81	c	82	b	83	a	84	d	85	b
86	b	87	a	88	b	89	a	90	a
91	b	92	d	93	c	94	d	95	a
96	b								

Blood vessel

1	a	2	d	3	a	4	a	5	b
6	b	7	b	8	a	9	b	10	d
11	c	12	c	13	d	14	c	15	b
16	d	17	a						

Blood pressure, ECG

1	d	2	c	3	a	4	b	5	a
6	d	7	c	8	d	9	b	10	a
11	c	12	d	13	a	14	c	15	c
16	a	17	d	18	c	19	b	20	c
21	b								

Lymphatic system

1	d	2	d	3	c	4	b	5	c
6	a	7	b	8	d	9	b	10	d
11	d	12	b	13	b	14	c	15	c
16	a	17	a	18	c	19	c	20	a

Portal system

1	d	2	c	3	a	4	c	5	a
6	c	7	b	8	d	9	d		

NCERT Exemplar Questions

1	c	2	c	3	a	4	b	5	b
6	b	7	a	8	b	9	b	10	c
11	b	12	b	13	b				

Critical Thinking Questions

1	a	2	c	3	b	4	b	5	b
6	c	7	d	8	a	9	b	10	a
11	b	12	c	13	c	14	c	15	d
16	b	17	d	18	b	19	d	20	d
21	a	22	a						



Assertion and Reason

1	b	2	b	3	c	4	d	5	a
6	a	7	b	8	a	9	c	10	e

AS

Answers and Solutions

Structure and function of heart

5. (a) Lubb is the first, low pitched heart sound produced due to the closure of bicuspid and tricuspid valves at the start of ventricular systole.
6. (a) The bicuspid valve is a valve consisting of two membranous flap or cups situated between the atrium and ventricle of the left side of the heart in mammals.
10. (d) The heart of cockroach is pulsatile and formed of 13 inverted funnel-shaped segmental chamber, each chamber (except last one) has a pair of apertures called ostia which open into the pericardial sinus.
16. (d) The amount of blood flowing from the heart over a given period of time is known as the cardiac output. It depends upon the heart rate and stroke volume.
Cardiac output = stroke volume $\times$ heart rate
17. (a) The left atrium receives oxygenated blood from the lungs through four of pulmonary veins.
18. (a) Within the lateral walls of ventricles and help in conduction of cardiac impulse.
21. (a) Pericardium (Protective covering) and pericardial fluid protects the heart from shocks, mechanical injuries and keeps it moist and also allows free movements of the heart.
22. (a) The chordae tendineae or heart strings are cord like tendons that connect the papillary muscles to the tricuspid valve and the mitral valve in the heart. The chordae tendineae prevents the flaps from being everted upto the right atrium, these cord like tendons hold in position other flaps such as bicuspid or mitral valve.
27. (c) First sound is 'lubb' a long and booming sound (related by the closure of tricuspid valve and second sound is 'dupp' a short and due to closure of semi lunar valves.
29. (a) Pace maker (SA node) which lies in the wall of the right atrium near the opening of the superior vena cava.
35. (e) Open circulatory system occurs in invertebrate animals such as arthropods (e.g. insects, spiders, crabs and lobsters) and some molluscs (e.g. snails, oysters and clams).
42. (b) Sinus venosus is the first chamber of the heart in fish, amphibia and reptiles. In fish it receives blood from the cuverian ducts and hepatic veins and leads into the single auricle. In amphibians and reptiles it receives blood from the three venae cavae and leads to the right auricle. Birds and mammals have no sinus venosus.
45. (c) 'Bundle of His' is a part of conducting system of human heart.
46. (d) The AV-valves close due to sharp rise of intraventricular pressure, their closure produces first heart sound LUBB.
47. (c) When irregularity in the heart rhythm occurs, normal heart rhythm can be restored and maintained by surgically implanting an artificial pace maker, a device that sends out small electrical current to stimulate the heart to contract.
52. (d) Spiral valve is a valve present in truncus arteriosus of amphibian heart guiding flow of different type of blood in three aortic arches.
56. (b) *Pleura* is a membrane in which the lungs of a vertebrate are suspended from the wall of the thorax i.e., it is the covering of the lungs.
57. (d) AV-node delays the impulse of contraction before transmitting it to the ventricles. Thus sets the time interval between the contraction of auricles and ventricles.
59. (c) Cardiac output = stroke volume $\times$ ventricular systole/minute
= 70 ml $\times$ 72 (min) = 5040 ml/min
= about 5.5 litres.
60. (a) Alary muscles are a pair of triangular fan like muscles in the floor of pericardial sinus of cockroach. The respiratory movements of abdomen and contraction of alary muscles increase the pumping force of the cockroach's heart.
62. (d) The wall of ventricles are thicker than those of auricles. Thickest wall is found in the left ventricle.
66. (d) The wall of heart has three layer : epicardium, myocardium and endocardium.
68. (a) Cardiac impulse (Heart beat) normally originate from the pace maker (S.A. node).
69. (a) In earthworm, an annelid, 4 pairs of thick, muscular, pulsatile hearts are present.
70. (c) Capillary has no muscular wall. Its wall is made of a single layer of endothelial cell.
75. (b) Inferior vena cava (post caval) collect blood from lower part of trunk and hind limbs.
76. (c) Superior vena cava (pre caval) collect blood from head, fore limbs and upper part of chest.
80. (a) In the right atrium adjoining the internal septum, an oval depression the fossa ovalis.
81. (c) Bundle of His is a network of muscle fibres found in between two ventricles.
82. (b) Veins bring blood from the body to the heart.
84. (d) Right auricle receives deoxygenated blood from the body via sinus venosus in the lower vertebrates.
86. (b) Atherosclerosis is narrowing of arteries and arterioles due to deposition of fats on their lining.
87. (a) During auricular systole, the auricles contract and drain most of their blood into the respective ventricles.
89. (a) Transmission of impulse occurs as
S-A node $\rightarrow$ A-V node $\rightarrow$ Bundle of His $\rightarrow$ Purkinje system.
91. (b) Since the impulse originates in the heart it self by a patch of modified heart muscle without requiring any external stimulation.
92. (d) Thoracic duct is a dorsal longitudinal lymphatic vessel which begins below diaphragm, ascends in front of vertebral column and drains into innominate vein at the base of neck.
96. (b) In the given diagram 'D' represent the vena cava. Vena cava is either of the two large veins that carry deoxygenated blood into the right atrium.



Blood vessel

2. (d) Because serotonin is a vaso-constrictor.
4. (a) Pulse can be detected in superficial artery like radial artery of wrist and temporal artery.
7. (b) A pair of phrenic arteries arise from the aorta and supply the diaphragm. Phrenic artery present in human but absent in frog.
9. (b) Blocking of arteries due to deposition of fat and calcium is called Atherosclerosis. Emphysema is a chronic obstructive lung disease.
10. (d) In the region behind 13th segment, blood laden with digested nutrients and O_2 is collected in the dorsal vessel while in anterior region of body, some of this blood is supplied by dorsal vessel to various parts.
11. (c) Arteries are best defined as vessels which carry blood away from the heart to different organs.
12. (c) Intravenous injection is given for rapid distribution of drugs/substance. Intramuscular injection is given for producing local effect.
13. (d) Least concentration of urea is found in renal vein. This is because urea is excreted through urine formed in kidney.

Blood pressure, ECG

2. (c) Blood pressure is measured in mm of mercury by an instrument known as sphygmomanometer. The instrument was invented by an Italian Doctor Riva-Rocci in 1896.
4. (b) ECG is the record of changes in electrical potential of heart during one beat.
5. (a) It is also called ventricular complex.
9. (b) Upon systole of left ventricle blood is pushed in aorta, which creates systolic blood pressure which is 120 mm Hg.
12. (d) With the increase in intra cranial pressure, the cerebral blood flow is reduced. This increased pressure also stimulates the vasomotor centre and increases systemic blood pressure.
13. (a) Hypertension occurs if the blood pressure is 190/110. This can harm the vital organ like brain and kidneys.
15. (c) Systole is the muscular contraction of the heart or of any chamber of it. Commonly, it is used to refer to the ventricles of human heart. During this stage the openings for CSA and PT are open, so the blood leaves the ventricles.
16. (a) Blood is diverted towards alimentary canal. Therefore the pressure of blood falls in brain.
21. (b) Except ANF which is released by Wall of atrium, rest three increase blood pressure and GFR by various methods. ANF will further decrease blood pressure.

Lymphatic system

2. (d) Essentially all the lymph from the lower part of the body even most of that from the legs flows up the thoracic duct and empties into the venous system at the juncture of left internal jugular vein and subclavian vein.

3. (c) Colour of blood is due to presence of haemoglobin in RBCs since RBCs are absent in lymph so lymph is colourless.
4. (b) Old RBCs are destroyed along with pathogens by phagocytosis carried out by macrophages. Thus, spleen acts as graveyard of RBCs.
6. (a) An antibody is a molecule that specifically inactivates an antigen.
7. (b) Antigen are present on cell surface and cause the formation of antibodies specifically reacting with them.
8. (d) So spleen is also called the blood reservoir of human body.
9. (b) Haemopoietic stem cells differentiate into T-and B-lymphocytes in the bone marrow T- cells then migrate to thymus gland for their proliferation.
16. (a) Humoral or Antibody mediated immune system is formed or proteinous defensive chemicals called antibodies which are produce by B lymphocyte and circulate in the plasma of blood and lymph and protect the body from bacteria and virus.
17. (a) Surgical removal of thymus gland of new born shall result in the failure to produce T lymphocytes.
19. (c) Lymphatic vessels unite to form two main vessels called thoracic duct and right lymphatic duct.

Portal system

3. (a) Hepatic portal system starts from digestive system and finishes in liver.
4. (c) Hepatic portal vein in Rabbit starts with capillaries and ends in capillaries.
5. (a) Blood circulation that starts in capillaries and ends in capillaries is called portal circulation.
7. (b) Hepatic portal vein carries blood rich in absorbed food material such as glucose and amino acid from intestine to liver.
8. (d) Renal portal system is found in frog in which femoral, sciatic and renal portal veins are include.

Critical Thinking Questions

1. (a) Blood of cockroach lacks respiratory pigment. Hence, O_2 is carried by the respiratory tubules.
2. (c) Vein contain valves to prevent back flow of blood.
4. (b) Because in vein presence of CO_2 decreases the pH.
5. (b) Largest blood vessel in the body is carotid systemic or dorsal aorta, It is a question marked shaped long vessel, that arise from left ventricle of the heart.
8. (a) Angina is due to reduced blood supply to heart wall. Person with blood group AB is universal receipient.
10. (a) In haemoglobin iron is present in ferrous (Fe^{++}) state.
12. (c) During ventricular systole. The pressure increases in the ventricles, thus forcing the oxygenated blood from left ventricle into systemic aorta and deoxygenated blood from right ventricle into pulmonary aorta.
14. (c) Stimulation of vagus nerve decreases the heart rate but its continuous stimulation shows no further decrease.



15. (d) Under the normal conditions heart rate has an inverse relation with the size of the animal.
16. (b) Whale is a mammal and has 4 chambered heart with 2 atria and 2 ventricles, oxygenated and deoxygenated blood flow on separate sides.
17. (d) Because pace maker of the heart is capable of initiating and regulating the heart beat.
18. (b) To allow relatively quick saturation and dissaturation with O_2 and CO_2 .
19. (d) Systole refers to contraction of atria (atrial systole) which propels blood into ventricles and contraction of ventricles (ventricular systole) expels blood into aorta and pulmonary artery.
21. (a) Macrophages of spleen engulf and destroy wornout blood corpuscles, dead and live pathogens, cell Lebris, Pigment gramules and other useless particulate materials, thus regularly cleaning the blood of its impurities.
5. (a) An artificial pacemaker is a therapeutic instrument which is implanted in the heart of patients to generate the heart beat. A pacemaker is used when the normal heart rate of 72-80 drops down to abnormally low levels like 30-40 due to diseases or operations and threatens the life of the patient. Sometime, the SA node may become damaged or defective. It then fails to generate cardiac impulses at the normal rate. The heart beats become abnormally slow and irregular, and ventricles fail to pump the required amount of blood. This is remedied by the surgical grafting of artificial pacemaker instrument in the chest of the patient. The artificial pacemaker stimulates the heart electrically at regular intervals to maintain its beats. Thus it replaces the SA node as the originator of the cardiac impulse.
6. (a) ECG consists of P-wave, QRS wave and T-wave. ECG gives important information concerning the spread of excitation to the different parts of heart and in the diagnosis of abnormal cardiac rhythm and myocardial damage.
7. (b) Blood pressure is the arterial blood pressure taken in left brachial artery and the instrument used to measure blood pressure is sphygmomanometer.
8. (a) The heart is a pumping organ for blood circulation which consists of chambers communicating with each other. In fishes the heart is two-chambered, consisting of an auricle and a ventricle. An accessory chamber called sinus venosus is also present which serves as a reservoir and opens anteriorly into auricle through the sino – atrial aperture. Fish heart contains and pumps only deoxygenated blood because after getting oxygenated from gills, the blood doesn't return back to the heart. Instead, it is supplied directly to the various parts of the body.
9. (c) Lacunae and sinuses are the open spaces and channels present in the tissues of prawn. Prawn possesses a heart which pumps the oxygenated blood into some arteries. These arteries directly open into the lacunae and sinuses. The tissues are thus in direct contact with blood. A sufficiently high blood pressure, however, cannot be maintained in the open lacunae and sinuses inspite of the pumping action of the heart. So, blood flows at a very slow velocity in the lacunae and sinuses.
10. (e) SA node and AV node are the contraction node. SA node possess the highest rhythmicity among all cardiac muscle fibres and can initiate excitory wave at highest rate.

Assertion and reason

1. (b) The valves present in heart when pushed by blood in the right direction, the flaps of the valve swing apart and allow the blood to flow through, but when pushed in the opposite direction, the flaps close sharply to block the passage through the valve. Thus these valves resemble swing doors in action. Hence the valves of the heart maintain unidirectional flow of blood and prevent it's regurgitation in the opposite direction.
2. (b) During the wound, germs are removed by the process of phagocytosis by WBC. WBCs accumulate at the site of wound by diapedesis. It is the squeezing of leucocytes out from the endothelium of capillaries to fight against foreign agent.
3. (c) Saline water is not given to a patient of hypertension because it may cause rise in blood pressure which may be fatal to patient.
4. (d) As the cardiac impulse spreads over the cardiac chambers and causes their contractions, electrical changes sweep over the cardiac chambers in a specific sequence. These changes in the electrical potential over the heart can be recorded by fixing leads on two arms, the left leg and the chest, and connecting them to an apparatus called electrocardiograph. The record is called electrocardiogram (ECG). An electrocardiogram is the recording of the various events of the cardiac cycle. Defects in cardiac functions or structures are reflected in changes in the pattern of electrical potentials recorded in the ECG. The ECG is, therefore of immense diagnostic value in cardiac diseases. On the other hand, EEG is an index of the brain functions. EEG or electroencephalogram represents the spontaneous electrical activity of the brain as recorded from the electrodes placed on the scalp. EEG wave pattern obtained shows certain characterstic features of the brain like the frequency amplitude of the signals of brain. Thus any deviation from the normal caused either by brain disease or change in the physiological state of the brain can be easily detected by EEG.



Body Fluids and Circulation

Self Evaluation Test

- Lack of pulmonary surfactant produces [AMU (Med.) 2009]
 - Asthma
 - Emphysema
 - Cystic fibrosis
 - Respiratory distress syndrome
- Myogenic heart is found in [MH CET 2000]
 - Man
 - Fishes
 - Earthworm
 - Cockroach
- If blood cells are eliminated from the blood, the liquid left is [MP PMT 1993, 98]
 - Serum
 - Plasma
 - Lymph
 - Synovial fluid
- The heart beat increases at the time of interview due to [NCERT; AIIMS 1999; BHU 2012]
 - Corticotrophic hormone
 - Hyper secretion of renin
 - Secretion of adrenaline
 - Antidiuretic hormone secretion
- Blood vessels that contain valves are called [CBSE PMT 1993]
 - Arteries
 - Veins
 - Capillaries
 - All the above
- Match the blood vessels of human heart listed under Column-I with the functions given under Column-II; Choose the answer which gives the correct combination of the alphabets of the two columns

Column-I (Blood vessel)		Column-II (Function)	
A.	Superior vena cava	p.	Carries deoxygenated blood to lungs
B.	Inferior vena cava	q.	Carries oxygenated blood to lungs
C.	Pulmonary artery	r.	Brings deoxygenated blood from lower parts of the body to the right atrium
D.	Pulmonary vein	s.	Brings oxygenated blood to the left atrium
		t.	Brings deoxygenated blood from upper parts of the body into the right atrium

[NCERT; KCET 1999; AIIMS 2009]

 - A = t, B = p, C = r, D = q
 - A = t, B = r, C = p, D = s
 - A = s, B = t, C = r, D = p
 - A = t, B = p, C = q, D = r
- Valves are found in veins to check the backflow of blood flowing under
 - Low pressure
 - High pressure
 - No pressure
 - Very high pressure
- A four chambered heart is not found in [KCET 2004]
 - Mammals
 - Birds
 - Snake
 - Crocodile
- To which organ does femoral artery supply blood [Odisha JEE 2005]
 - Dorsal part of thigh
 - All parts of hind limb
 - Ventral part of hind limb
 - Rectum
- Blood returns from lungs to heart through
 - Right auricle
 - Right ventricle
 - Left ventricle
 - Left auricle
- Although much CO_2 is carried in the blood, yet blood does not becomes acidic. This is because [CBSE PMT 1995]
 - In CO_2 transport, blood buffers play an important role
 - CO_2 combines with water to form H_2CO_3 which is neutralised by H_2CO_3
 - CO_2 is continuously diffused through the tissues and is not allowed to accumulate
 - CO_2 is absorbed by leucocytes
- Chordae tendinae are found in [NCERT; CBSE PMT 1993; Kerala PMT 2010; MP PMT 2013]
 - Ventricle of heart
 - Atria of heart
 - Joints
 - Ventricle of brain
- Arteries are [CPMT 1996; DPMT 2006]
 - Thin-walled and blood flows under diminished pressure
 - Thick-walled and blood flows under high pressure
 - Thin-walled and blood flows under high pressure
 - Thick-walled and blood flows under diminished pressure
- Which one of the following doctors performed the first heart transplant
 - Hargovind Khurana
 - Christian Barnard
 - Watson
 - William Harvey
- Innominate is
 - A nerve and artery
 - A muscle and artery
 - Skeleton part and artery
 - A nerve and vein
- Neurogenic heart is characteristic of [CBSE PMT 1995; MP PMT 2013]
 - Lower vertebrates
 - Humans
 - Rat
 - Rabbit
- Bicuspid valve is also called as [BCECE 1995; MP PMT 2004]
 - Mitral valve
 - Eustachian valve
 - Pulmonary valve
 - Ventricular valve
 - None of the above



18. An adult human with average health has systolic and diastolic pressures as [NCERT; CBSE PMT 1998; MH CET 2000; KCET 2000, 01; BVP 2002; HPMT 2005; WB JEE 2009]
- 80 mm Hg and 88 mm Hg
 - 70 mm Hg and 120 mm Hg
 - 120 mm Hg and 80 mm Hg
 - 50 mm Hg and 80 mm Hg
19. Papillary muscles are found in mammalian [MP PMT 2009]
- Auricles
 - Ventricles
 - Pinna
 - Eyes

AS Answers and Solutions

1	b	2	a	3	b	4	c	5	b
6	b	7	a	8	c	9	a	10	d
11	a	12	a	13	b	14	b	15	c
16	a	17	a	18	c	19	b		

2. (a) Myogenic heart is found in molluscs and vertebrates.
3. (b) The blood is composed of a faintly yellow transparent fluid known as the plasma and floating in this fluid are numerous cells or corpuscles of different kinds. Thus
Blood – Blood cells = Plasma.

4. (c) Adrenaline increases the heart beat normally during active and stress conditions.
8. (c) Four chambered heart is found only in mammals and birds except some reptiles such as crocodiles, gavialis and alligators.
9. (a) The general distribution of the femoral arteries is to the lower abdominal wall, groin, external genitals and muscles of the dorsal part of the thigh.
11. (a) Its due to buffer action of blood.
12. (a) Chordae tendinae are numerous, strong inelastic thread like tendons present in the ventricles of the mammalian heart.
13. (b) Arteries are thick walled, carrying oxygenated blood from heart to various parts of body at high pressure.
14. (b) The first human heart transplant was performed on 3rd December, 1967 by a team of 30 doctors headed by Prof. Christian Barnard on 55 years old Louis Washkansky at the Groote Schuur Hospital, Cape Town, South Africa. Inspite of the operation by a leading surgeon Washkansky died on 21st December, 1967.
16. (a) Neurogenic heart stops beating on cutting nerve supply.
17. (a) The bicuspid valve between the left atrium and the left ventricle of mammalian heart is known as mitral valve.
18. (c) In a normal human being, the systolic and diastolic blood pressures are respectively 120 mm Hg and 80 mm Hg.

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