CIRCULATORY SYSTEM

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

5.1 Functions of Circulatory System.

- Transport of various substances such as nutrients, waste products, respiratory gases, metabolic intermediates (Such as lactic acid from muscle to liver), vitamins hormones etc.
- Regulation of body *pH* by means of buffer, body temperature homeostasis, water balance etc.
- Prevention of disease by means of antibodies and antitoxins.
- Support or turgidity to certain organs like penis and nipples.

5.2 Types of Circulation.

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

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

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

(a) **Extra organismic circulation :** When the water of the external environment circulate through body. This is also called as water circulation system. Example – canal system in porifera, water vascular system in Echinoderms and gastrovascular system in coelenterates.

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

(1) **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.

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

(3) **Blood vascular system :** It contains blood and a pumping structure (heart) for circulation of materials inside the body. It is of following types –

(i) Open circulatory system

(ii) Closed circulatory system

Differences between open and closed circulatory system

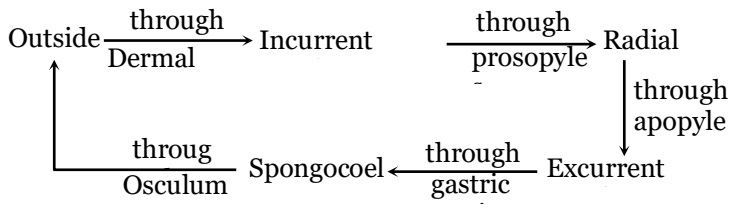
Open circulatory system	Closed circulatory system
(1) In open circulatory system blood flows through large open spaces and channels called lacunae and sinuses among the tissues.	(1) In closed circulatory system blood flows through a closed system of chambers called heart and blood vessels.
(2) Tissues are in direct contact with the blood.	(2) Blood does not come in direct contact with tissue.
(3) Blood flow is very slow and blood has very low pressure.	(3) Blood flow is quite rapid and blood has a high pressure.
(4) Exchange of gases and nutrients takes place directly between blood and tissues.	(4) 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.	(5) 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.	(6) closed circulatory system is found in echinoderms, some molluscs, annelids and all vertebrates.
(7) Respiratory pigment, if present, is dissolved in plasma; RBCs are not present.	(7) Respiratory pigment is present and may be dissolved in plasma but is usually held in RBCs.

5.3 Circulatory system in multicellular animals

(i) **In protozoans :** Distribution of nutrients takes place by cyclosis (streaming movement) of cytoplasm.

(ii) **In poriferans :** The vascular system of poriferans is the canal system. A simplest canal system involves ostia (mouth), spongocoel and on osculum (Anus).

Route followed by water current in sponges :



(iii) **In coelenterates :** Hydra has a single large internal cavity called coelenteron or gastrovascular cavity. It has single opening the mouth. It also extends into the hollow tentacles. It lacks a mesodermal epithelial covering (peritoneum) and a coelomic fluid. It is concerned with first extracellular and then intracellular digestion of food.

(iv) **In platyhelminthes :** Vascular system is absent but circulation occurs with the help of parenchyma hence called parenchymal circulation. Example – Fasciola hepatica.

(v) **In annelids :** Vascular system in annelids is a closed circulatory or blood vascular system which comprises four parts : blood, blood glands, blood vessels and hearts.

(a) **Blood :** Red, due to respiratory pigment haemoglobin dissolved in plasma. The blood cells are colourless and nucleated like the leucocytes of vertebrates.

(b) **Blood glands :** Reddish bodies present on alimentary canal in segments 4, 5 and 6 and are thought to produce blood corpuscles and haemoglobin.

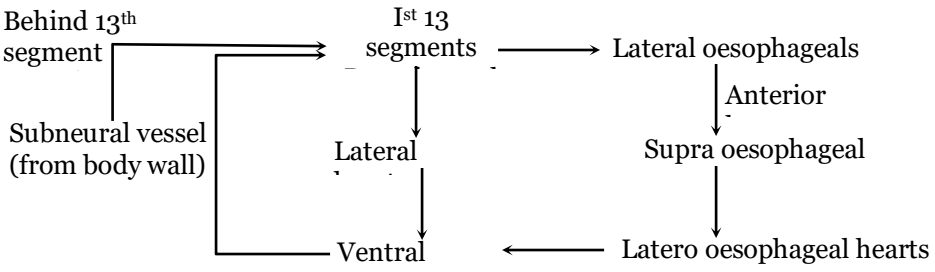
(c) **Blood vessels :** Lack endothelium. The arrangement of blood vessels in first 13 segments is different from that is rest of the body. Ist 13 segments have five longitudinal vessels – dorsal, ventral, a pair of lateral oesophageal and a supraoesophageal vessel. Behind 13th segment has 3 longitudinal vessels – dorsal, ventral and subneural.

(d) **Hearts :** Four pairs, one pair in each of 7th, 9th, 12th and 13th segment. Two anterior pairs receiving blood from dorsal vessel only are called lateral hearts and two posterior pairs receiving blood from dorsal vessel as well as supra oesophageal vessel are called latero-oesophageal hearts. All hearts possess muscular pulsafile walls to pump blood into ventral vessel. Valves present to prevent back flow of blood.

- **Anterior loops :** 2 pairs, one pair in each of the 10th and 11th segment, carry blood from lateral oesophageal vessel to supra oesophageal vessel.

- **Lymph glands :** Two, small, whitish, located on each side of the dorsal blood vessel in each of the segments 26 and those behind it. They produce phagocytic cells which are occasionally liberated into the coelomic fluid to phagocytise harmful bacteria and other invaders.

<u>Circulation in earthworm</u> :



Ventral vessel : Distributing vessel.

Subneural vessel : Collecting vessel.

Lateral oesophageal : Collecting vessel.

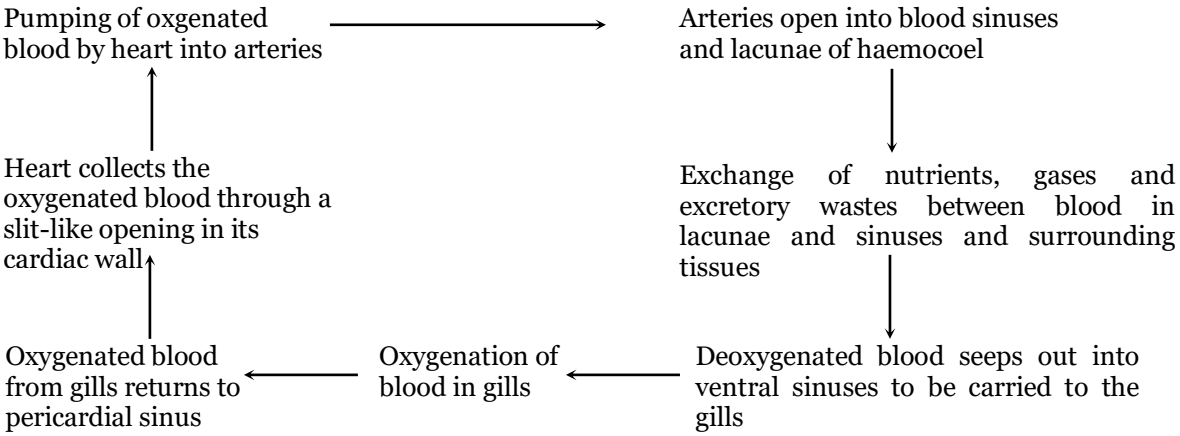
Supra oesophageal : Collecting vessel.

Dorsal vessel : Distributing in 1st 13 segments and collecting in the region behind 13th segment.

(vi) **In arthropoda :** Blood vascular system in arthropods is 'Open type' or "Lacunar type".

(a) **Prawn :** Blood vascular system of prawn includes pericardium, heart, arteries, blood lacunar/sinuses, blood channels and blood. Blood is colourless with phagocytic leucocytes and respiratory pigment haemocyanin dissolved in plasma. The blood has remarkable clotting properties. Heart is a muscular, triangular organ without auricle and ventricle but with ostia for inflow of blood into heart and arteries. Five of the arteries arise from the anterior end and one from the posterior end of heart. The prawn's heart always contains oxygenated blood only and hence, also called as Arterial heart.

Circulation of blood in prawn :



(b) **Cockroach :** Cockroach has an open circulatory system. The body cavity is called haemocoel filled with a fluid haemolymph. The heart lies in the pericardial sinus of haemocoel. The heart is 13 chambered, tubular dorsal vessel, pulsatile with an anterior aorta. Each chamber is inverted funnel, shaped provided with valved lateral apertures called ostia. The heart is supported by 13 pairs of triangular fan like alary muscles. The blood sinuses are dorsal pericardial sinus, middle perivisceral sinus and the ventral perinural sinus or sternal sinus. These sinuses are separated from each other by dorsal diaphragm and ventral diaphragm. Blood or haemolymph is colourless contains haemcytes but is without respiratory pigment as it plays no role in respiration.

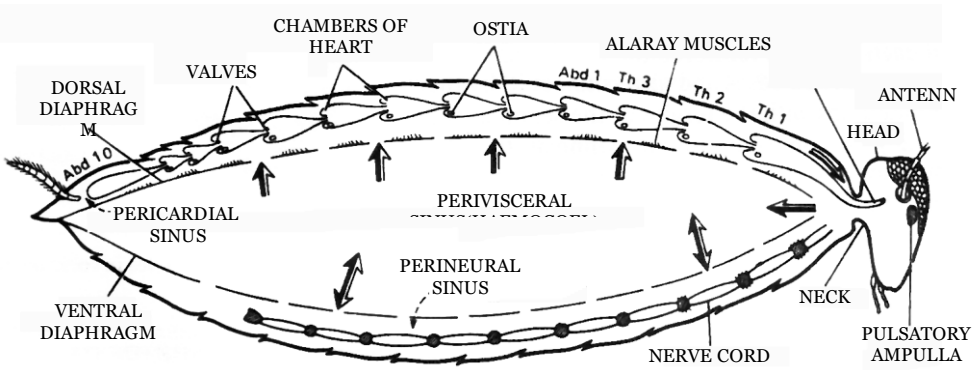
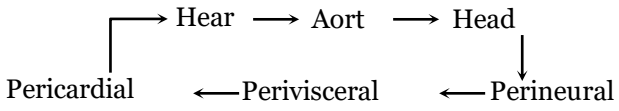


Fig. – Blood vascular system of cockroach (Diagrammatic)

Circulation of blood in cockroach :



(vii) **In echinoderms :** A true blood vascular system is absent. It is represented by a haemal system which is enclosed within a perihaemal system. haemal system includes oral haemal ring (a sinus), radical haemal sinuses or strands (present in the arms), axial glands, heart, brown glands (present within axial sinus of perihaemal system) and aboral haemal ring, from which arise, five pairs of genital haemal strands.

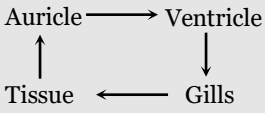
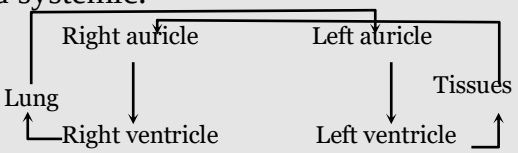
Important Tips

- Annelids are the first metazoans to have a well developed circulatory system.
- 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 molluscs.
- 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).

(viii) **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 :

(a) Single circulation (b) Double circulation

Differences between single and double circulation

Single circulation	Double circulation
(1) Blood flows only once through the heart in a complete cycle. 	(1) Blood flows in two circuit pulmonary and systemic. 
(2) Heart pumps only deoxygenated blood, hence called Venous Heart.	(2) Heart pumps both deoxygenated and oxygenated blood to lungs and body respectively, hence called arteriovenous heart.
(3) Blood is oxygenated in gills.	(3) 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.	(4) 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 cell and also rapid removal of wastes from them *i.e.* provides

	a higher metabolic rate.
(5) Found only in fishes.	(5) Found in amphibians, reptiles, birds and mammals.

Double circulation in mammals can be divided into three parts :

(1) **Cardiac circulation :** The amount of blood present in the heart. Its value is 7%.

(2) **Pulmonary or lesser circulation :** The amount of blood present in the surrounding of lungs and pulmonary blood vessels. Its value is 9%.

(3) **Systemic or greater circulation :** The amount of blood which circulates in the rest part of the body. Its value is 84%. It can be divided into three parts –

Arterial circulation – 15%

Capillary circulation – 5%

Venous circulation – 64%

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.

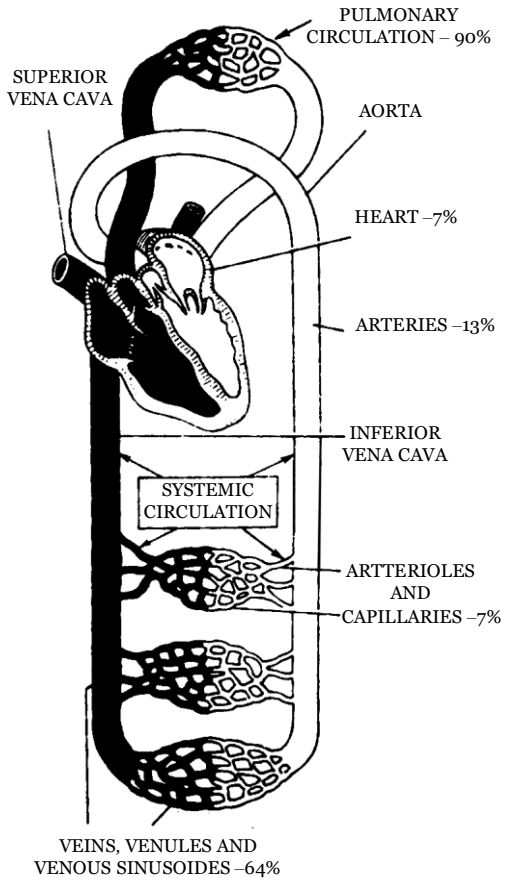
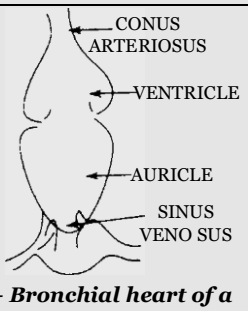
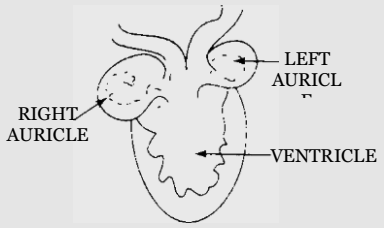
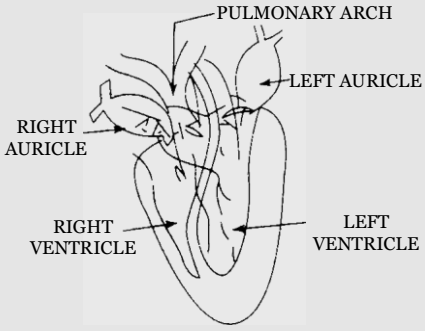


Fig. – Distribution of blood volume in different parts of circulatory system

Heart of vertebrates

Class of vertebrates	Characteristics	Example	Diagram
(1) Pisces (= Branchial heart)	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 2 auricles and 1 ventricle.	Labeo Scoliodon Neocerato dus	 ***Fig. – Bronchial heart of a fish*** ***ex. Labeo and scoliodon***

(2) Amphibians	Heart consists of (a) Two auricles (b) Undivided ventricle (c) Sinus venosus (d) Truncus arteriosus (conus + proximal part of aorta) Right auricle receives blood from all the visceral organs (deoxygenated) via precaval and post caval. Pulmonary artery carries deoxygenated blood to lungs for oxygenation. This blood returns to left auricle via pulmonary vein (Double circuit circulation)	Frog Toad	 ***Fig. – Amphibian heart***
(3) Reptiles	Heart consists of : (a) Left and right auricle (b) Incompletely divided ventricle (Ventricle in crocodiles gavialis and alligator is completely divided) (c) Sinus venosus (d) Conus arteriosus divided into right systemic, left systemic and pulmonary arch.	Lizards Snakes Turtles	 ***Fig. – Reptilian heart***
(4) Aves	Exhibit double circulation Heart consists of (a) Left and right auricle (b) Left and right ventricle (c) Complete separation of arterial and venous circulation (d) Only right systemic arch is present (e) Sinus venosus and truncus arterisious absent	Pigeon	 ***Fig. – Pigeon heart***

(5) Mammals	Same as bird except that mammals have left systemic arch.	Rabbit, man	

Important Tips

- Circulatory system develops from the mesoderm in vertebrates.
- Heart in fishes is 2-chambered, venous and branchial. Lung fishes have 3-chambered heart.
- **Foramen of pannizae :** Aperture between two systemic arches in reptiles.
- **Gubernaculum cordis :** White fibrous band which attaches apex of lizard heart to pericardium.
- Reptiles have incompletely 4-chambered heart except crocodiles, gavialis and alligators which have completely 4-chambered heart.
- **Branchial heart :** Where purification of blood occurs in gills. Example – Fishes, tadpole (larva), some amphibians.
- **Pulmonary heart :** Where oxygenation of blood takes place in lungs. Example – Some amphibians, reptiles, birds and mammals.

5.4 Heart

(i) **Shape and position :** Reddish, roughly conical, highly muscular, mesodermal hollow organ of the size of one's first. 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 5^{th} and 6^{th} ribs and rests on the diaphragm.

(ii) **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).

Pericardium → Outer fibrous
Pericardium → Inner serous pericardium → Outer parietal
Pericardium → Inner serous pericardium → Inner visceral

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.

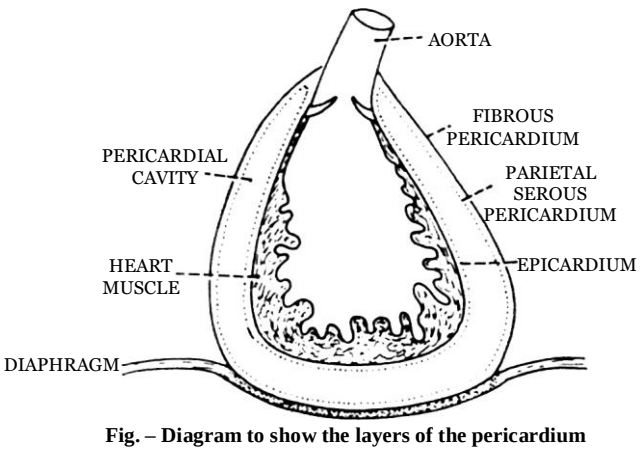


Fig. – Diagram to show the layers of the pericardium

(iii) **Histology :** The heart wall consists of connective tissue, blood vessels and cardiac muscle

fibres in 3 different layers – Epicardium, Myocardium and Endocardium.

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

(b) **Myocardium :** Middle, highly vascular layer, composed of cardiac muscle fibres joined together by intercalated disc. The connective tissue in myocardium acts as cardiac skeleton. Endocardium is thickest where the myocarduim is thinnest and *vice-versa*.

(c) **Epicardium :** Visceral pericardium, joined to myocardium by connective tissue.

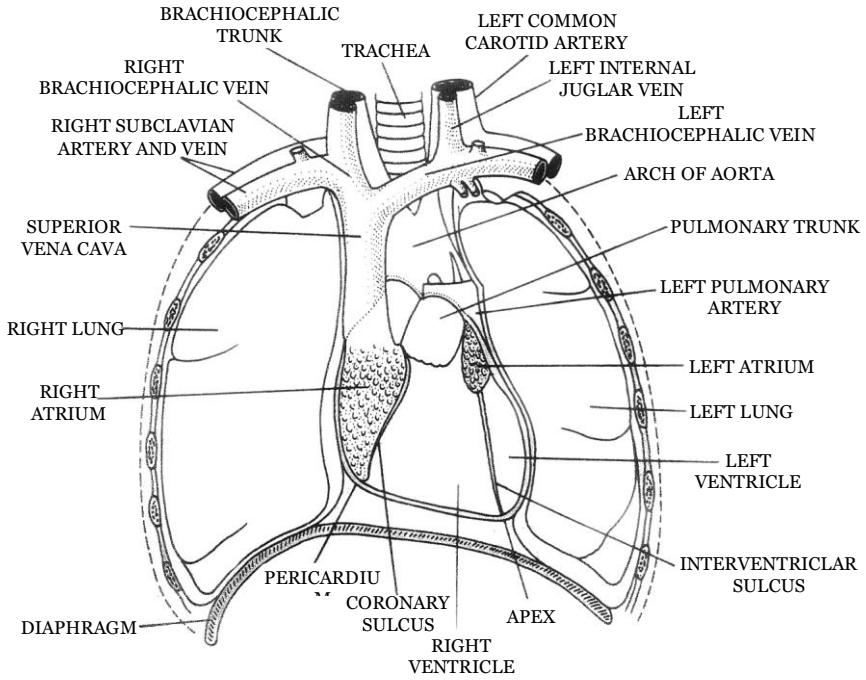


Fig. – Position of heart in our chest cavity

(iv) **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.

(a) **Auricles (Atria) :** Two in no., demarcated externally from ventricles by irregular groove called coronary sulcus and from each other by interatrial sulcus. When atria contract, small curtain like flaps called auricular appendages or appendices project from sides of auricles and overhang the corresponding ventricles.

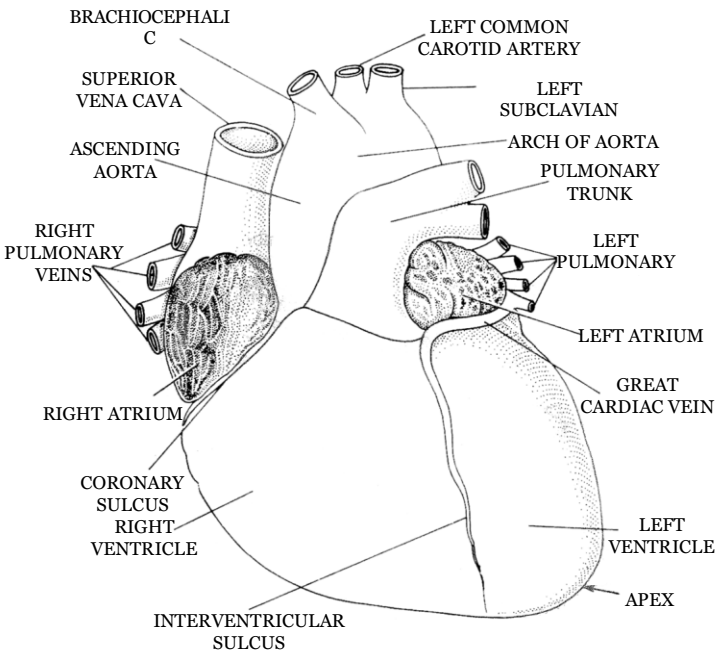


Fig. – External features of human heart

(b) **Ventricles :** Two in no. demarcated externally from each other by an oblique groove called interventricular sulcus which contains coronary blood vessels. The right ventricle does not reach apex.

(c) **Sinus venosus and conus arteriosus :** 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.

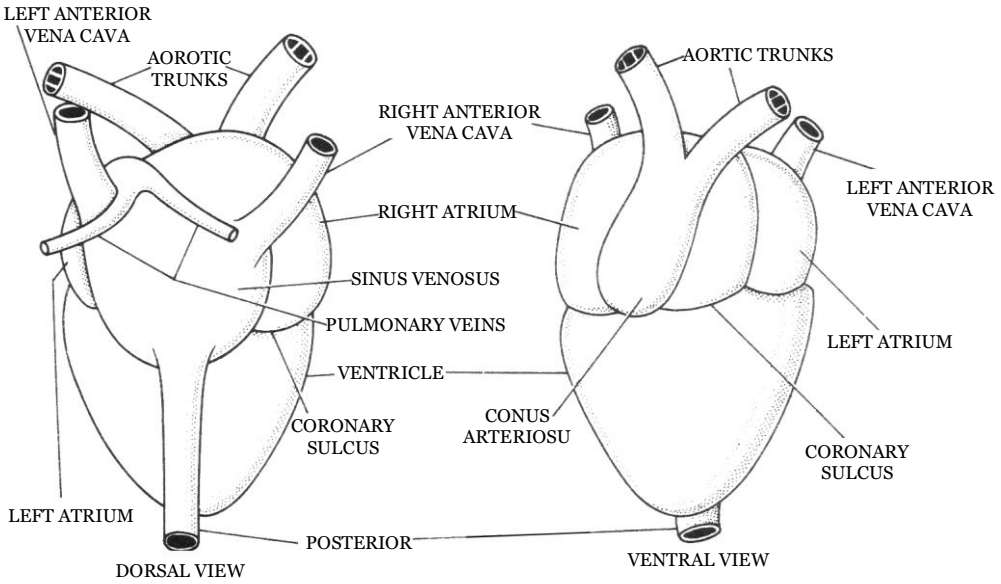


Fig. – Dorsal and ventral of frog's

(v) **Internal structure**

(a) **Auricles :** Atria are thin walled. They act as reserviors 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 secondum having a gap (aperture) called foramen ovalis between them. From the opening of inferior vena cava upto foramen ovalis, 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.

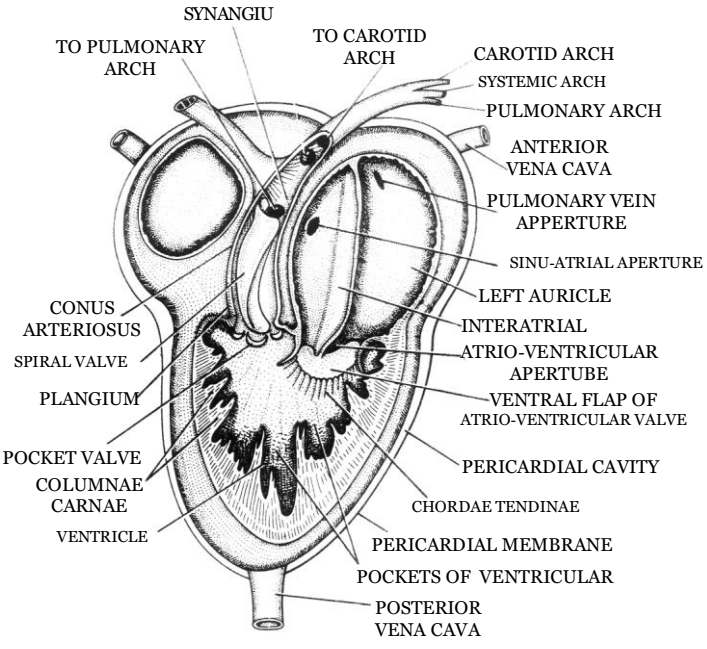


Fig. – Horizontal longitudinal section (H.L.S.) of frog's heart (ventral view)

At the time of birth, there is closure of

foramen ovalis 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.

PFO (Patient Foramen Ovalis) or septal defect : In case there is no closure of foramen ovalis, 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.

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.

(ii) **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 ventricleis 3 times thicker than right ventricle whose cavity is larger and somewhat crescentic.

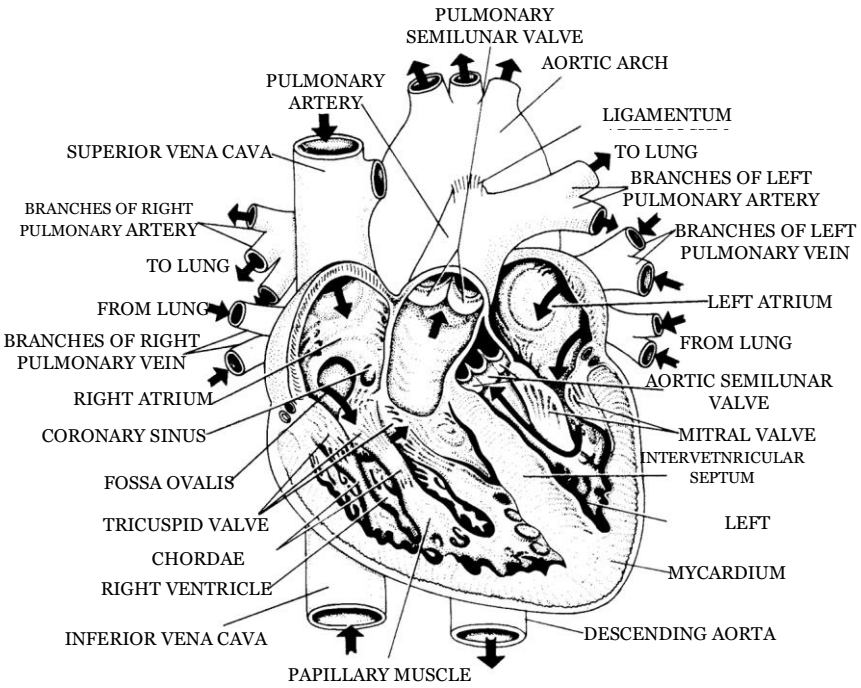


Fig. – Internal anatomy of human

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 musculli papillares which are 3 in right ventricle and 2 in left ventricle. These muscles act as anchors for chordae tendinae.

Chordae tendinae : Numerous, strong, inelastic thread like tendons present in the mammalian heart but absent in frog. One end of these threads is attached to the cusps of *A.V.* valves and the other end to the papillary muscles of the ventricles. These muscles contract during ventricular systole and pull the valves downwards, thus, preventing their everting into atria. The chordae tendinae hold the valves in place.

Regurgitation : If there is weeakening 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.

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

(a) **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. In frog, right and left precavals open into sinus venosus.

(b) **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. In frog, post caval opens into sinus venosus.

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

(d) **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.

(e) **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.

(f) **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 arteriosus : 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 arteriosus.

PDA (Patient 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 : The valves present in the mammalian heart are tendinous cords.

(a) **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.

(b) **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.

(c) **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.

(d) **Atrio-ventricular valves :** Auricles open into the respective ventricles through wide passages called auriculo ventricular apertures or *A.V.* apertures which are guarded by one-way *A.V.* valves or parachute valves and are located dorsally or posteriorly. There are 2 types of valves in mammals.

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

(2) **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.

The upper edges of the flaps are attached to the margins of the A.V. apertures while the lower edges project freely into the ventricles. The free edges of these flaps are connected by chordae tendinae to he papillary muscles of the ventricles. These valves allow the passage of blood from auricles into ventricles but prevent backflow.

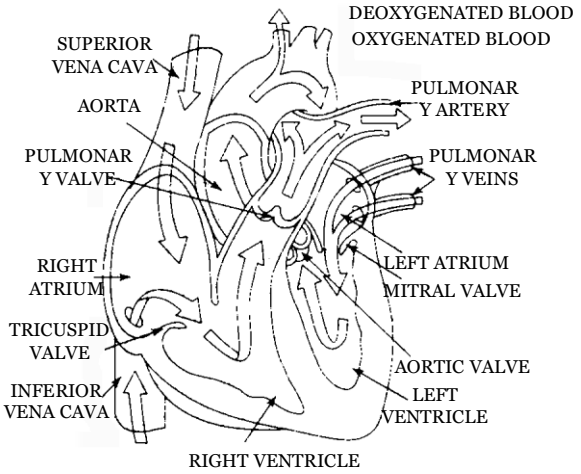


Fig. – Path of blood through the heart

In frog, the A.V. valves are semilunar type and not of cuspid type. There is single row of A.V. valves due to single ventricle.

(e) **Semilunar valves :** At the base of pulmonary arch and systemic aorta, three membranous, pocket-shaped flaps called semilunar valves are present which are set in a ring with their cavities directed away from the ventricles. They allow the passage of blood from ventricles to respective blood vessels, but prevent the return of blood.

Sinus of valsalva : When the semilunar valves open towards aorta, there remains gap between the flaps and the wall of aorta. This gap is called sinus of valsalva. When ventricles relax, blood is filled in this sinus and is called Drooping of blood.

Corpora Arantii : Thick nodules present on the edges of the flaps of semilunar valves which prevent the reverting of these valves into the ventricles.

(viii) **Physiology of heart :** The heart pumps blood to all parts of the body. The deoxygenated blood is drained into right auricle through superior and inferior venae cavae and coronary sinus whereas the pulmonary veins carry oxygenated blood from lungs to the left auricle. This is called as Auricular circulation. About 70% of the auricular blood passes into the ventricles during diastole. This phase is called diastasis. The rest of 30% of blood passes into the ventricles due to auricular systole (contraction). In this way, blood reaches the ventricles and is called ventricular filling. During ventricular systole (which starts first in left ventricle than in right ventricle), 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. The systemic arch distributes the oxygenated blood to all the body parts except lungs while pulmonary aorta carries the deoxygenated blood to lungs for oxygenation.

During foetal life, heart receives and pumps mixed blood and hence, it can be compared with transitional heart, the eustachian flap, in the foetus directs the blood of right atrium towards left atrium through foramen ovalis. From left atrium, blood reaches left ventricle from which the systemic aorta arise. An iliac artery arise from this aorta from the internal branches of illiac artery, two umbilical arteries arise which come out of body through naval and reach placenta where exchange of gases takes place. A single umbilical vein arises from placenta and enters the foetal body through naval and reaches the liver to give some blood to it and some blood to inferior vena cava. Inferior vena cava

already possess impure blood. So, there is mixing of blood. In foetus, pure blood is there only in umbilical vein (allantoic vein). Umbilical cord is a tube possessing a jelly like connective tissue (Wharton jelly) along with two umbilical arteries and one umbilical vein.

(a) **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.

Differences between Neurogenic heart and Myogenic heart

Neurogenic heart	Myogenic heart
(1) The heart beat is initiated by a ganglion situated near the heart.	(1) The heart beat is initiated by a patch of modified heart muscle.
(2) The impulse of contraction originates from nervous system.	(2) 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.	(3) 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.	(4) Examples : Hearts of molluscs and vertebrates.

(b) **Origin and conduction of heart beat :** Initiation of heart beat is under special bundles of cardiac muscles called nodal tissue. The cardiac muscles have less actin and myosin. So, structurally they become more a nerve than muscle and functionally they are similar to neurons.

(1) **Morphology of nodal tissue :** The nodal tissue consists of the following –

(i) **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 autrohythmicity (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.

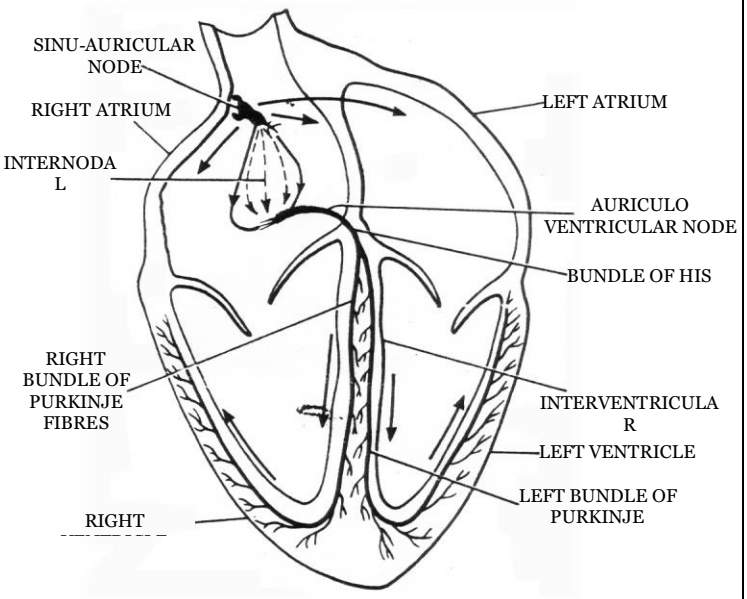


Fig. – Conducting system of rabbit's heart (ventral view)

(ii) **Atrio-ventricular node or A.V. node :** Also called reserve pacemaker, node of Twara 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.

(iii) **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.

(iv) **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.

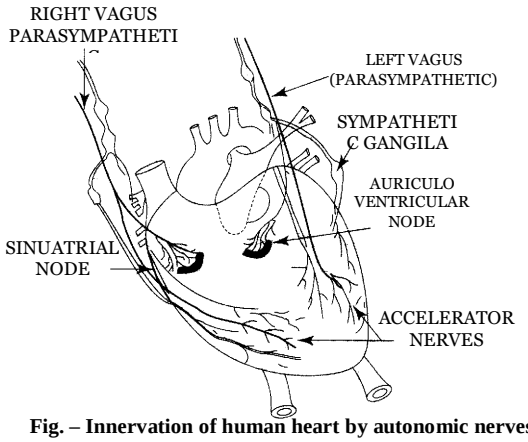


Fig. – Innervation of human heart by autonomic nerves

(2) **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 1*m*/*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 (arrhythmia). 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.

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 rate : Heart beat/minute or number of cardiac cycles/minute. Example – frog-64/*min*., rabbit-200/*min*., human-70-80/*min*. 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

(c) **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 vegal.

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 MAD (Mono Amino Oxidase).

When there is increase in blood O_2, the parasympathetic or vagal (10^{th} 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.

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

Thyroxine hormone also increases the heart beat by increasing energy production.

(d) **Factors affecting heart rate**

- Heart rate increases with increase in basal metabolic rate (BMR).
- Heart increases as the size of the animals body decreases.
- Decrease in *pH* also increases heart rate.
- Heart rate increases with increase in temperature.
- Increase in Na^+ ions in blood or in cardiac muscles, increase heart rate.

- Increase in Ca^{2+} ions in blood increase heart beat but if they are injected in cardiac muscles, heart stops in contracted phase which is called Systolic Arrest.
- Injection of K^{+} ions in heart muscles stop impulse generation. So, heart stops in diastolic or Relax phase.
- H^{+} ions reduce force of contraction of heart.
- Increased inspiration, muscular exercise, low oxygen tension, injection of adrenaline, thyroxine, sympathin – all increase heart rate.
- Increased expiration, during sleep, injection of acetylcholine decrease heart rate.
- Stenosis – Narrowing of valve is called stenosis.

5.5 Cradiac cycle

A regular sequence of three events :

(i) Auricular systole (0.1 sec)

(ii) Ventricular systole (0.3 sec)

(iii) Joint Diastole or complete cardiac diastole (0.4 sec)

During the completion of one heart beat is called as cardiac cycle. These events are repeated in a cyclic manner during each heart beat.

(i) **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.

(ii) **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.)

(iii) **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.

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 × Rate of heart beat

$$= 70\ ml \times 75\ times/minute = 5040\ ml/minute \simeq 5\ litres/minute$$

Total amount of blood in human body is about 6.8 *litres* (7% of body weight). During mild exercise, the cardiac output rises to about 11 *litres*. Cardiac output is directly proportional to the size of the organism, metabolic rate etc. but is inversely proportional to age.

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

- Cardiac fraction – 200 *ml*/*min.*
- Hepatic fraction – 1500 *ml*/*min.* (28% of blood as liver is the busiest organ of body and has maximum power of regeneration).
- Renal fraction – 1300 *ml*/*min* (25% of blood)
- Myofraction – 600-900 *ml*/*min*.
- Cephalic organs – 700-800 *ml*/*min.*
- Remaining organs – Remaining blood.

(ii) **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*.

(iii) **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.

(iv) **End diastolic volume :** 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.*

(v) **End systolic volume :** 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*.

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

(vii) **Venous return :** Amount of impure blood returning to righ atrium per minute is called venous return and is equal to 5.25 *litres*. The venous return is due to many factors –

(a) Little blood pressure in the veins.

(b) **Skeletal muscle pump :** Veins usually pass through skeletal muscles which, on contraction, exert milking action on veins. So, there is upward movement of blood.

(c) **Respiratory pump :** Due to the movement of diaphragm during breathing, blood moves upward in the veins.

(d) Pressure difference in venae cavae and right atrium. The negative pressure created in right atrium due to the atrial diastole results in sucking up of blood from venae cavae into the atrium.

5.6 Heart sounds

In normal heart, four sounds are heard. First and second sounds have audible frequencies, so, they can be heard very easily. 3rd and 4th sounds are having very less frequency (less than 20 Hertz). So, they can't be heard easily. Third heart sound is running water sound. Fourth heart sound is also called Atrial sound as it appears when blood flows from atria into ventricles due to atrial contraction.

Differences between first and seconds heart sounds

First heart sound (Lubb)	Second heart sound (Dup)
(1) It is produced by closure of bicuspid and tricuspid valves at the start of ventricular systole.	(1) It is produced by closure of semilunar valves at the start of ventricular diastole.
(2) It is low pitched, less loud and of long duration.	(2) It is higher pitched, louder, sharper and of short duration.
(3) It lasts for 0.15 seconds.	(3) It lasts for 0.1 second.
(4) Its principal frequencies are 25 to 45 cycles per second.	(4) Its principal frequency is 50 cycles per second.

Heart sounds can be heard by an instrument called stethoscope by placing its receiver on left side of the chest at the fourth intercostal space. Hearing of sound with the help of stethoscope is called Auscultation. The quality of heart sounds indicates the state of the heart valves. Defective or damaged heart valves lead to the backflow of blood either from ventricles to auricles or from aortae to ventricles. Such defects are detectable as abnormal hissing sound called "Murmur".. Defective valves may be replaced or repaired surgically. Syphilis and Rheumatic fever cause Murmur. The instrument used to magnify and record the heart sound is called Phonocardiogram.

5.7 Electrocardiogram (ECG)

A graphic record of electrical events occuring during a cardiac cycle is called Electrocardiogram. The instrument used for rcording 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 :

(i) **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.

(ii) **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 port of the base line between any 2 deflections is called Interval.

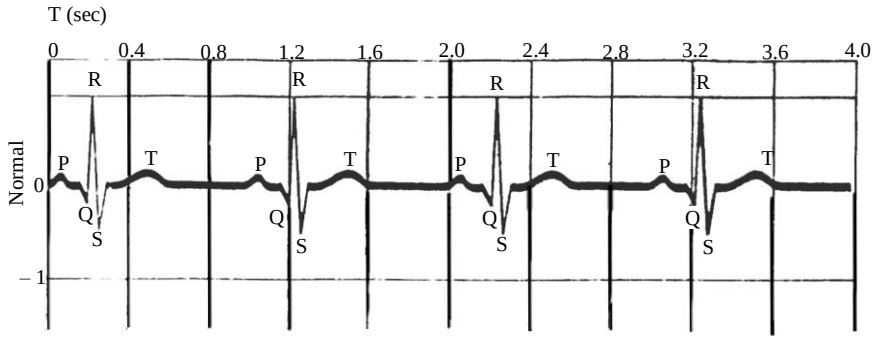


Fig. – Normal

***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 pukinje 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.

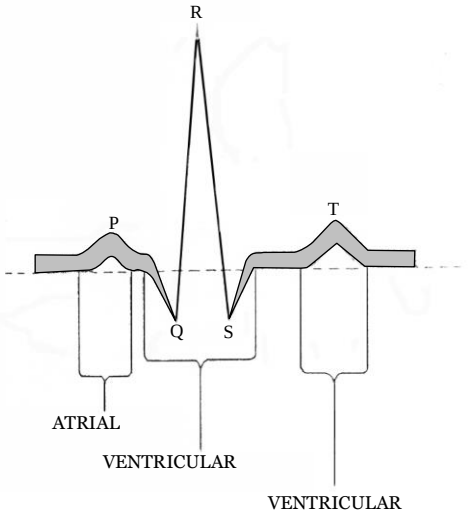


Fig. – Normal ECG deflections, Depolarisation and repolarisation

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.

If S.A. node is degenerated, the *P* wave disappears. This condition is called Heart fail. Atrial repolarisation wave is not seen in normal ECG because at this time, the depolarisation wave of ventricles is being recorded. When there is degeneration of bundle of His, the *P* to *R* interval increases. This is called Wenckebach phenomenon.

If bundle of His is completely cut, the *P*-*R* interval becomes infinite as the bundle of His is to transmit the cardiac impulses. It is called total heart fail or total heart block. In arborisation heart block, the defect lies in purkinje fibres. In heart attack, *T* waves become negative. When there is decrease in blood

supply to a part of heart, there occurs death of myocardium. This condition is called Myocardial infarction (MI). It is acute heart attack. The ST part of ECG is depressed when heart muscles receive insufficient oxygen and is elevated in acute MI. When there is degeneration of myocardium and deposition of fibres, the condition is called fibrillation during which, ECG obtained is bizzare or non-decipherable.

Vector cardiogram : Represents the direction of transmission of impulse.

History of ECG : The ECG was first recorded by Waller in frog. First human ECG was prepared by Einthoven who also discovered the electrocardiograph and discussed the principles of ECG. Hence, he is commonly called "Father of Electrocardiography".

5.8 Blood vessels

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

(i) Arteries (ii) Capillaries (iii) Veins

Vasa vasorum : Supply blood to the wall of large blood vessels.

(i) **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 μm. the arterioles further divide into smaller vessels called meta-arterioles (70 μm) 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.

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

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

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

Muscular arteries show vasoconstriction and vasodilation and provide blood to the organs.

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.

End arteries : In organs like heart, branches of different arteries do not unite rather they terminate due to which the alternate pathways are not available. In such cases, blocking of any artery leads to necrosis of related part of organ. To develop alternate pathway in such conditions is called as By pass surgery.

(ii) **Capillaries :** Smallest blood vessels, discovered by Marcello Malpighl (also layered nucleated squamous epithelial cells called 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 :

(a) **Arteriolar capillary :** Which supplies nutrition, respiratory gases etc. to the body cells.

(b) **Veinular capillaries :** Which collect the metabolic wastes from the body cells.

Capillaries possess abour 5% 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.

(iii) **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 is stout, blood filled painful veins specially of the limbs due to defective watch pocket valves.

(a) **Histology of arteries and veins :**

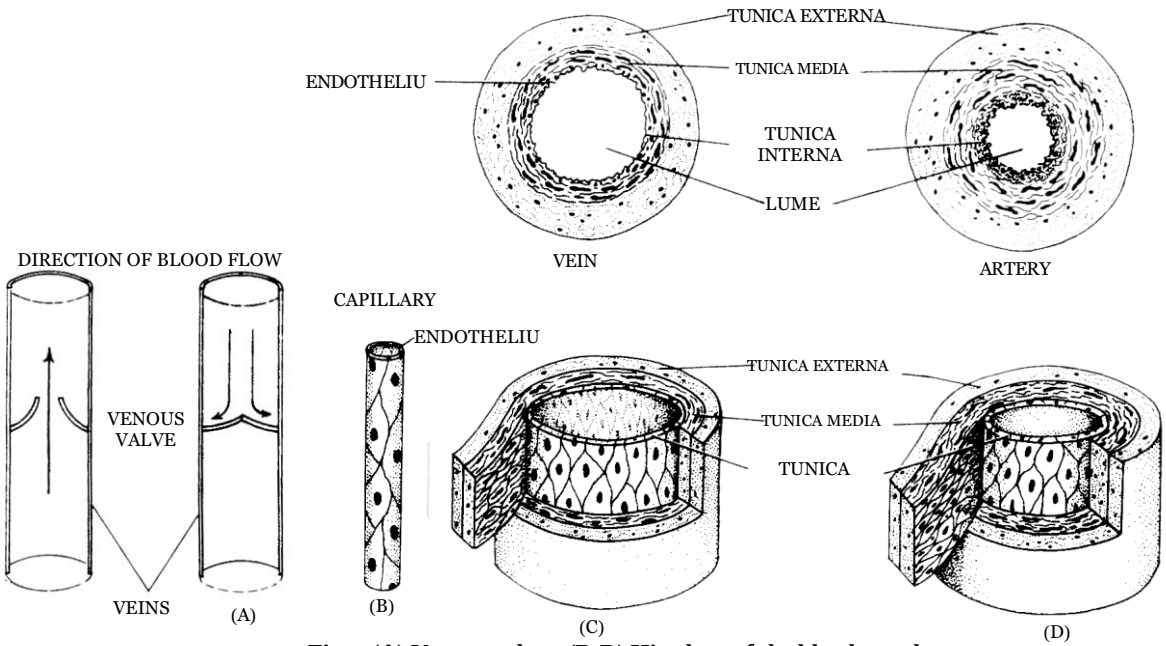


Fig. – (A) Venous valves, (B-D) Histology of the blood vessels

(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.

Differences between arteries and veins

S.No.	Characters	Arteries	Veins
(1)	Wall	Thick, more elastic, non collapsible.	Thin, less ealstic, 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)	Disintensibility	Less	More

(b) **Blood pressure :** The pressure exerted by the 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). 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 *mm Hg* = 40 *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 perssure wave of contraction travels down to the wall to 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 bind 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.

Important Tips

- There is an inverse relationship between heart rate and blood pressure. The process is called Marey's law of heart.
- During measurement of blood pressure, a sound is heard in the cubital artery with the help of stethoscope. This sound is called Karot Koff sound.
- Blood pressure means arterial blood pressure.

(c) **Factors affecting blood pressure :**

(1) **Age :** With the advancing age, BP increases after the age of 60 years, it is calculated as 100 + 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 dilation 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.

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.

A blood pressure of 220/120 *mm Hg* may cause internal haemorrhage due to rupturing of some blood vessels. Cerebral haemorrhage due to rupturing of some blood vessels cerebral haemorrhage or complete cessation or great decrease in blood supply to some part of brain causes stroke or CVA (Cerebrovascular accident). Hypertension is commonly called as silent killer.

High density lipoproteins (HDL) are responsible for excretion of cholesterol and thus, reduce the risk of coronary heart diseases. Low density lipoproteins (LDL) and very low density lipoproteins (VLDL) cause deposition of cholesterol in the wall of the arteries and thus, increase the risk of coronary heart diseases. The blood pressure was first measured by Stephen Halls in horse. Highest blood pressure is recorded in giraffe.

5.9 Types of 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 –

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

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.

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.

(ii) **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.

(iii) **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 sytemic circulation involves two circuits –

(a) Arterial circulation or Arterial system

(b) Venous circulation or Venous system

Time taken by blood to circulate in the body from heart to heart is called circulation time. The amount of blood flowing per minute in pulmonary and systemic circulation is same.

(a) **Arterial system :** It involves aorta, arteries, arterioles and meta-arterioles. It supplies oxygenated blood to all parts of the body except lungs.

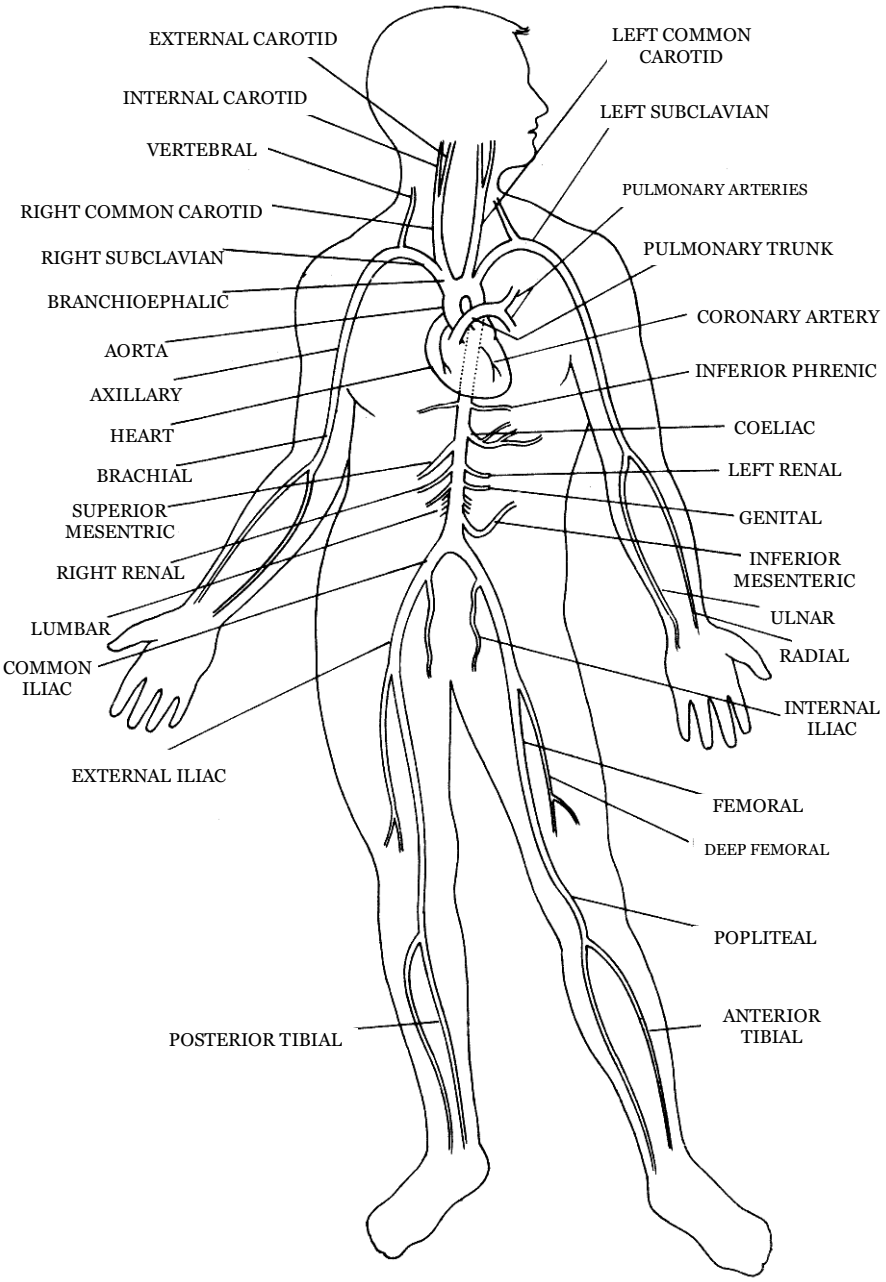


Fig. – Arterial system in human body

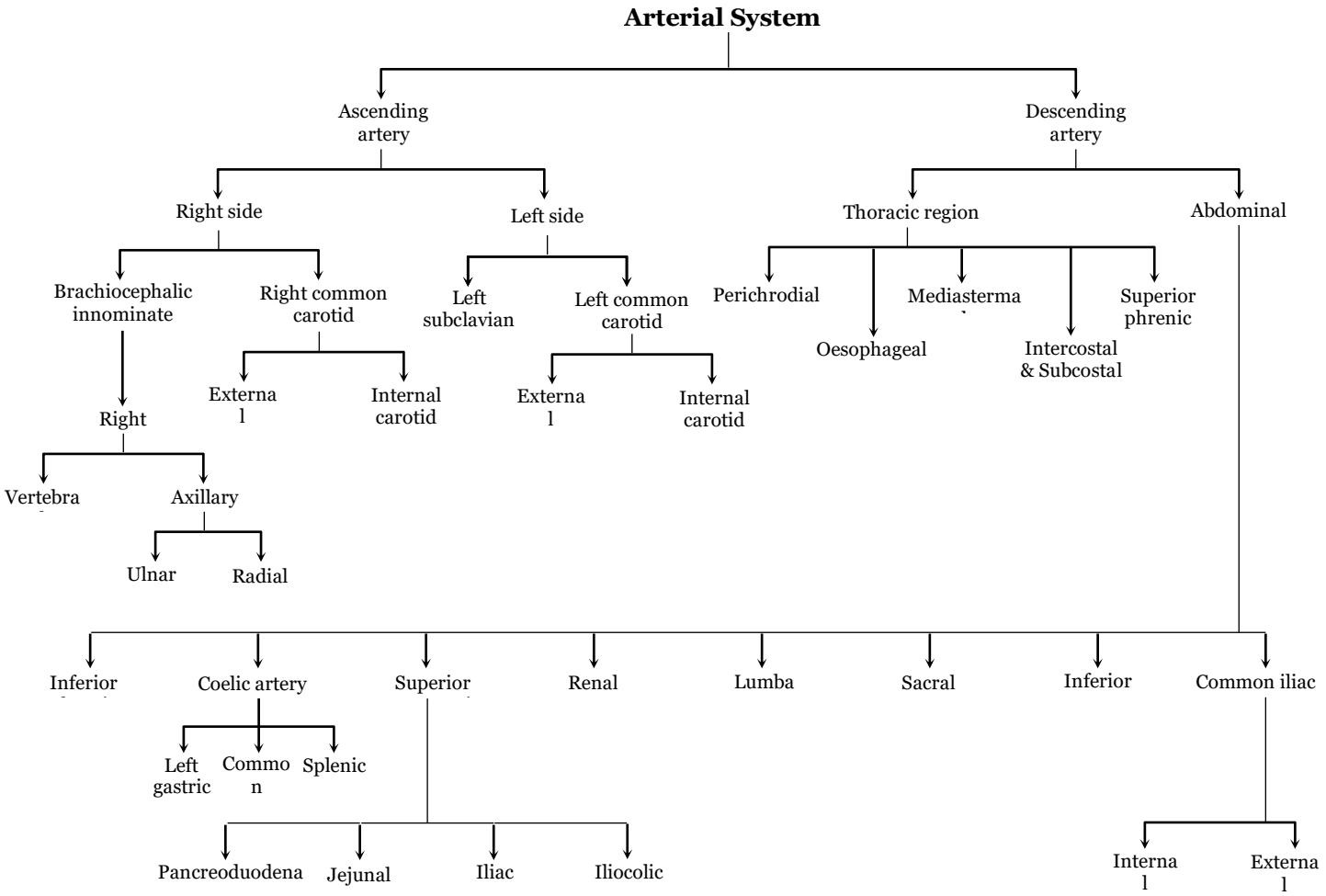
The left ventricle of the heart pumps the oxygenated blood into a single, question marked shaped, long vessel called left carotid-systemic aorta. It is the largest blood vessel of the body. The initial part of systemic aorta is dilated and is called aortic sinus. It possess some baroreceptors and some CO_2 sensitive cells. Barroreceptors are supplied with 9^{th} cranial nerve (glossopharyngeal).

After ascending from the heart, the systemic aotra 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 sytemic aorta has following parts –

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

Arch of aorta : It gives – Innominate or Brachiocephalic artery left common carotid artery left subclavian artery.

(2) **Descending aorta :** The aorta turns towards the back of heart and finally converts into dorsal aorta. While dorsal aorta is in thorax, it is called thoracic aorta; when it goes down into diaphragm, it is called abdominal aorta. Mammals have left systemic arch while birds have right systemic arch.



(1) **Ascending aorta**

(i) **From convexity of the arch of aorta**

(a) **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 tributaries.

(b) **Left common carotid :** Unpaired artery, enters into head and divides into left external and internal carotids which supply the left parts of the head by their tributaries.

(1) The external carotids of both sides provide blood to thyroid gland, tongue, throat, face, ear, scalp.

(2) 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.

(ii) **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.

(2) **Descending aorta :** The descending dorsal aorta divided into thoracic and abdominal aorta.

(i) **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).

(ii) **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

(a) **Inferior phrenic artery :** Right and left to supply the lower surface of the diaphragm.

(b) **Coeliac artery :** Unpaired, divides into three branches

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

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

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

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

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

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

(3) **Ilial artery :** To ileum and jejunum.

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

(d) **Supra renal artery :** Supplies the adrenal glands.

(e) **Renal arteries :** One pair, supply to kidney.

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

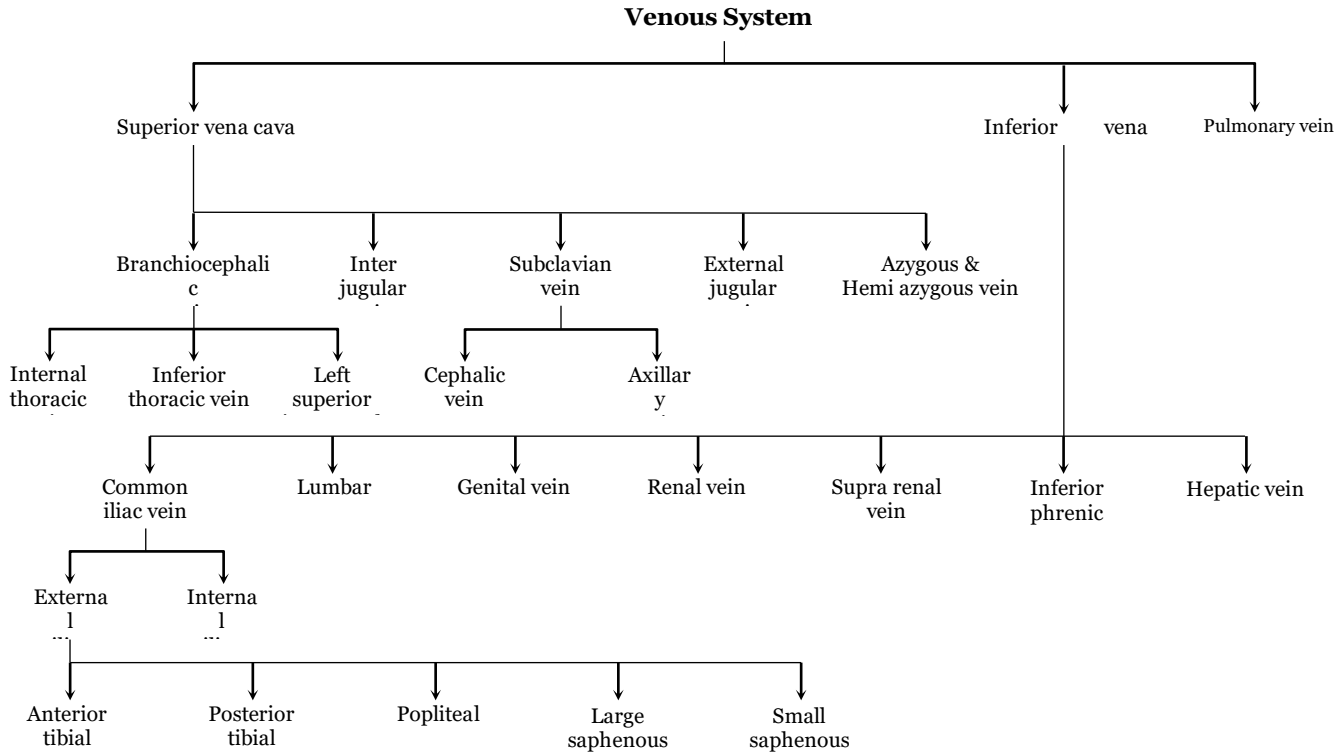
(g) **Sacral artery :** Supplies the tissues of sacral region.

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

(i) **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 lies 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.

Inguinal canal : Connects abdominal cavity with the cavity of scrotum. So, through this canal, spermatic artery (testicular artery), subclavian vein and sperm duct pass.

(b) **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 –

(i) **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.

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

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

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

(ii) **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.

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

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

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

(iv) **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.

(v) **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 :** 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 –

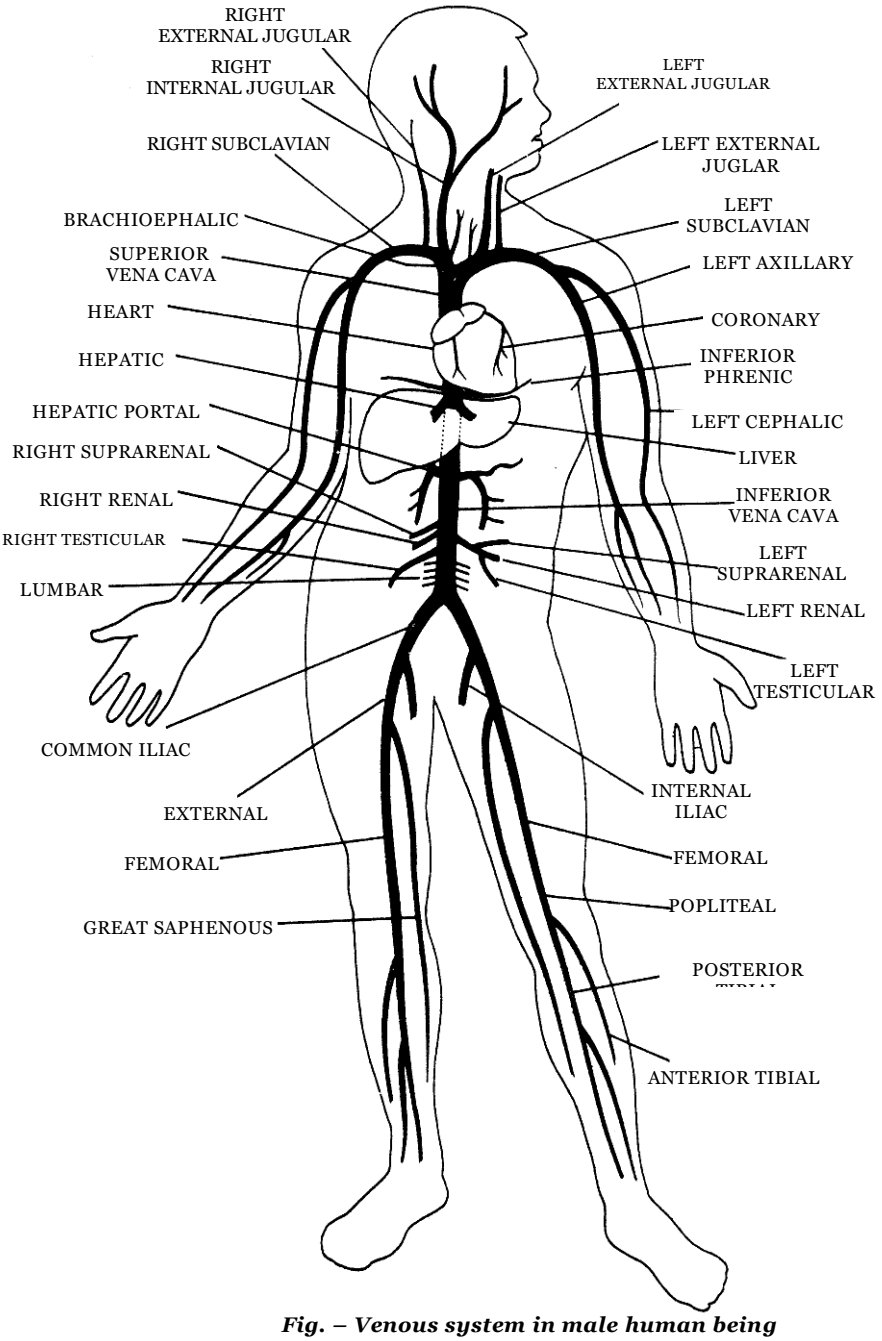


Fig. – Venous system in male human being

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

(ii) **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. Last saphenous vein is the longest vein of the body.

(iii) **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).

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

(v) **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.

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

(vii) **Suprarenal vein :** Two, right and left, collects blood from adrenal glands. Right one opens into inferior vena cava whereas left one opens into left renal vein.

(viii) **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.

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

5.10 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 :

(i) Hypothalamo-hypophysial portal system

(ii) Hepatic portal system

(iii) Renal portal system

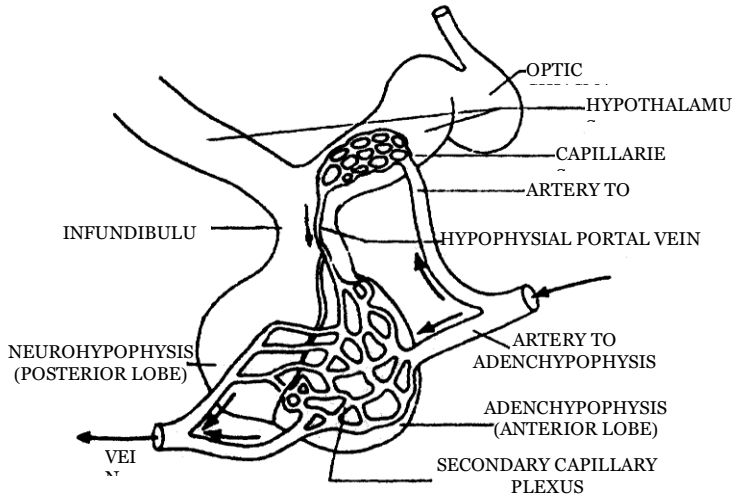


Fig. – Human hypophysial portal system

(i) **Hypothalamo-hypophysial portal system :** Present in higher vertebrates (amphibia, reptiles, birds and mammals). Blood from hypothalamus is collected by hypophysial portal vein which ends in

anterior lobe of pituitary gland. The superior hypophysial 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-hypophysial portal vein.

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

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

(a) **Posterior 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.

(b) **Anterior 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.

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

(d) **Right gastric vein :** Receives blood from stomach and duodenum.

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

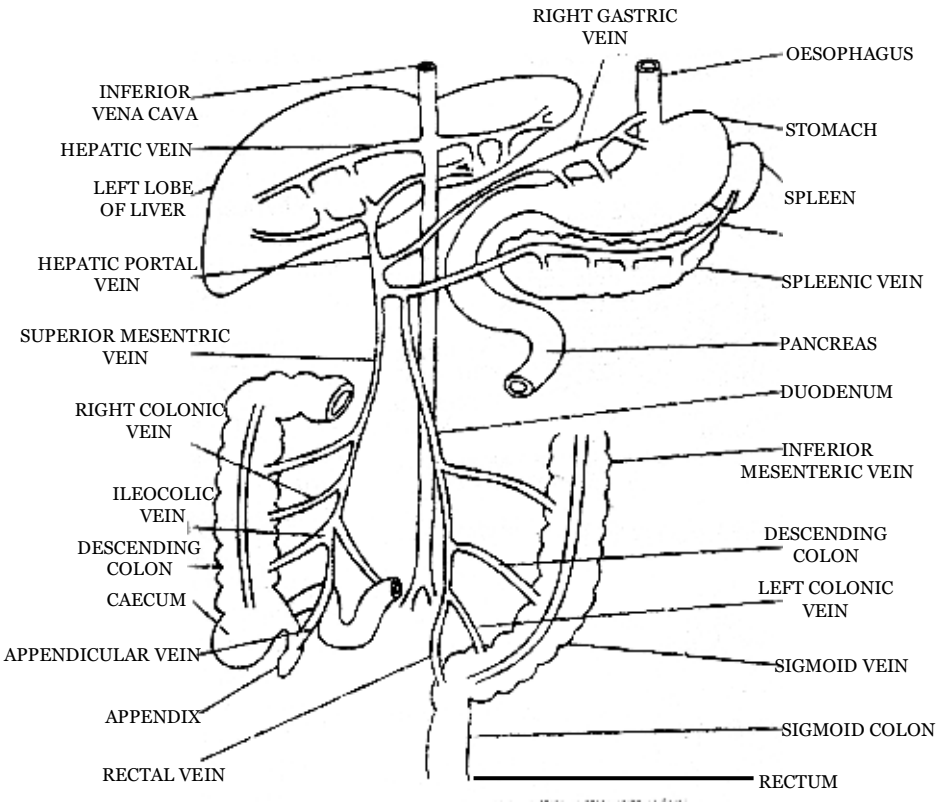


Fig. – Human hepatic portal

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.

(iii) **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, thence 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 due to the following facts :

(a) It is an *Evolutionary trend* that fishes and amphibians have well developed renal portal system, while in reptiles and birds this system gets reduced. Finally in mammals it ultimately disappears.

(b) The heart of mammals is four chambered.

(c) Due to the four chambered heart in mammals there is total separation of oxygenated and deoxygenated blood.

(d) Posterior portion of body gets oxygenated blood from the heart and after oxidation process, etc. the blood does not get so much impurities that it should go to the kidneys first for filtration as happens in fishes and amphibians.

Renal portal system in frog consists of one pair of renal portal vein, each one formed by the union of formal 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.

5.11 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 :

(i) Lymph (ii) Lymphatic system in frog

(iii) Lymphatic system in human (iv) Lymphatic organ

(i) **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*). Most of the compounds come out by filtration and few such as glucose come out by diffusion.

These compounds get collected in the intercellular space as Tissue fluid or Interstitial fluid which is, infact, a part of blood. So, it must return to blood otherwise blood volume will decrease. For this, the outflux of plasma fluid into capillaries is prevented by colloid osmotic pressure in plasma (28 *mm Hg*) which counteracts the above two forces. When the blood flows from arteriolar to venous part of the capillaries, the capillary pressure falls to 10-15 *mm Hg* due to which the blood capillaries absorb waste material and CO_2 from filtered blood. Thus, at the side of veinlets, net diffusion pressure = 28 – 15 = 13 *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.

Differences between lymph and blood

S.No.	Characters	Blood	Lymph
(1)	RBC	Present	Absent
(2)	Blood platelets	Present	Absent
(3)	WBC	Persent, generally 7000/*cu mm*	Persent, 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 :

Lymph = Blood – [RBC + platelets + plasma proteins of high molecular weight]

Composition of lymph : Microscopic examination of lymph depicts that is 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 :

(1) Water 94% (2) 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 is collected, *i.e.* in liver 6%, in limb 2% of intestinal part 4%. The varieties of proteins are found – albumin, globulin and fibrinogen. In addition to this, traces of prothrombin, fibrinogen.

(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 *mgm* per 100 *ml*.

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

- Normally the rate of lymph formation is equal to the rate of its return to the blood stream.

(ii) **Lymphatic system in frog :** In frog, all lymph capillaries empty into large, irregular lymph spaces called lymph sinuses. The latter are lined by a membranous squamous epithelium and occur in all parts of body. The major lymph sinuses are :

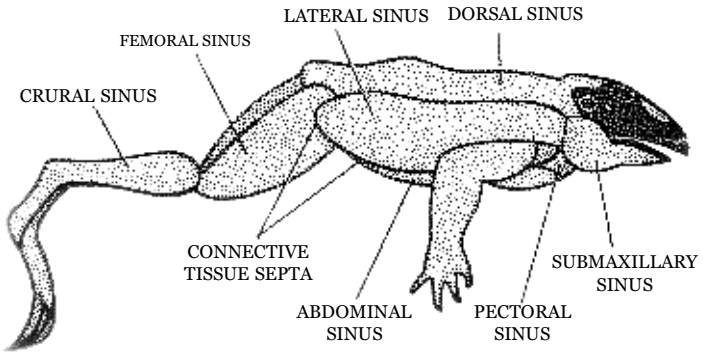


Fig. – The subcutaneous lymph sinuses

(a) **Subcutaneous lymph sinuses :** These are several sinuses located beneath skin and separated from each other by thin septa of connective tissue (figure). Major subcutaneous sinuses are brachial lymph sinuses in forelimbs, dorsal and lateral trunk sinuses and pelvic lymph sinuses in posterior part of trunk, and crural or femoral lymph sinuses in hindlimbs.

(b) **Subvertebral lymph sinus (= cisterna magna) :** This is a single large lymph sinus located beneath vertebral column throughout the length of the trunk. Kidneys are lodged in this sinus.

A number of lymph capillaries empty into the body cavity or coelem also. This proves that the coelomic fluid is also lymph, and the coelom is a large lymph sinus.

Lymph hearts : Two pairs of small, sac-like structures, one pair located behind the transverse processes of third vertebra, and the other in the region of urostyle, are closely connected with lymph sinuses in frog (figure). These have thin, but muscular walls. by contraction of their walls, these regularly pulsate and pump the lymph of sinuses into veins. Obviously, these are "lymph heart". The anterior lymph heatrs pump the lymph into subscapular veins and the posterior ones into femoral veins.

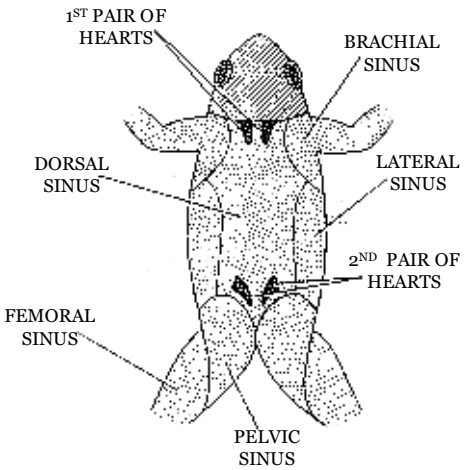


Fig. – Lymph hearts of frog

(iii) **Lymphatic system in human**

(a) **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.

(c) **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 muscles of body wall and internal organs, (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 lymphata gogue. Blocking of lymph flow causes oedema.

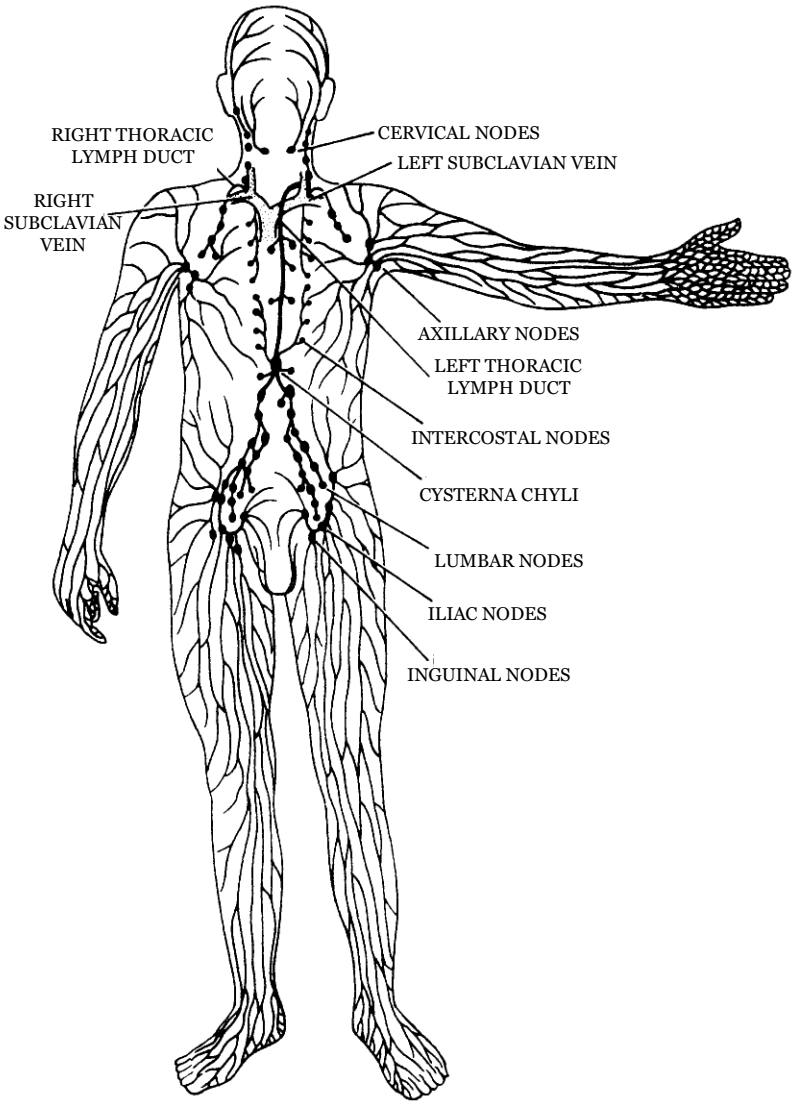


Fig. – Lymphatic system of mammals shown in man (ventral view)

(d) **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.

(3) **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.

(4) **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.

Lymph nodes are covered by capsule of white collagen tissue. Outer region of lymph node is called cortex and inner region is called medulla. In medulla, there are medullary cords, (cord like arrangement of lymphocytes). Cortex possess follicles (clusters of lymphocytes), outer part of which possess T-cells and macrophages while the inner part possess B-cells.

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.

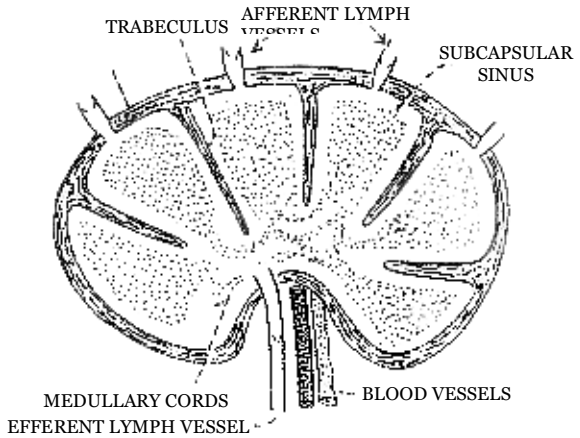


Fig. – Scheme to show some features of the structure of a lymph node

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 payer'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 Tonsilitis.

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. In these nodes some of the so-called lymphatic channels contain blood, while the rest of the nodes possesses the same structure as the typical lymph node. 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.

(iv) **Lymphatic organs :** The lymphatic organs present in our body are chiefly spleen (haemolymphatic organ) and thymus (endolymphatic organ).

(a) **Spleen :** In frog, a small and spherical, dark red organ, called spleen, is found attached, by means of a fold of peritoneum, to the anterior part of large intestine in rabbit, the spleen is some what flattened and elongated, and attached to the hind border of stomach.

Structure of spleen : Spleen is madosermal in origin. Spleen is the largest solid mass of reticulo-endothelial tissue in the body. Histologically it is formed by following structure –

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

(2) **Trabeculae :** Narrow fold like septa or trabeculae extend inwards from the capsule, dividing the spleen tissue into several incomplete lobules. These are better developed in rabbit and other mammals than in frog.

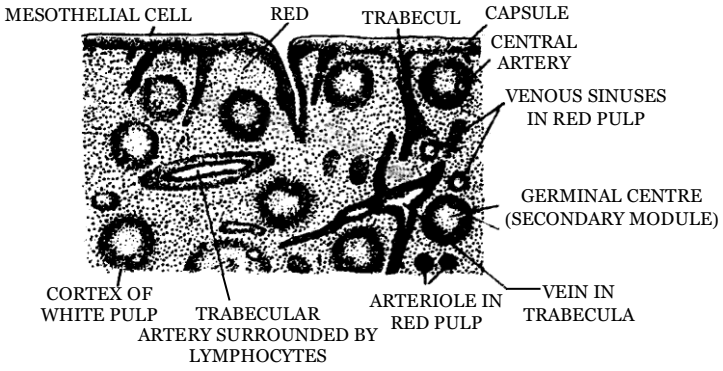


Fig. – Histological structure of spleen (Diagrammatic)

(3) **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

(i) **White pulp :** The white pulp is the accumulation of lymphatic tissue surrounding a major arterial vessels of the spleen. This lymphatic tissue is comprised of lymphocytes, plasma cells, macrophages or other free cell lying in the meshwork of reticular fibres at various points along the course of the vessels where the infiltration of lymphocytes is greater, it forms spherical or ovoid nodules which are called as splenic nodules of white pulp. The splenic nodules may have typical germinal centres.

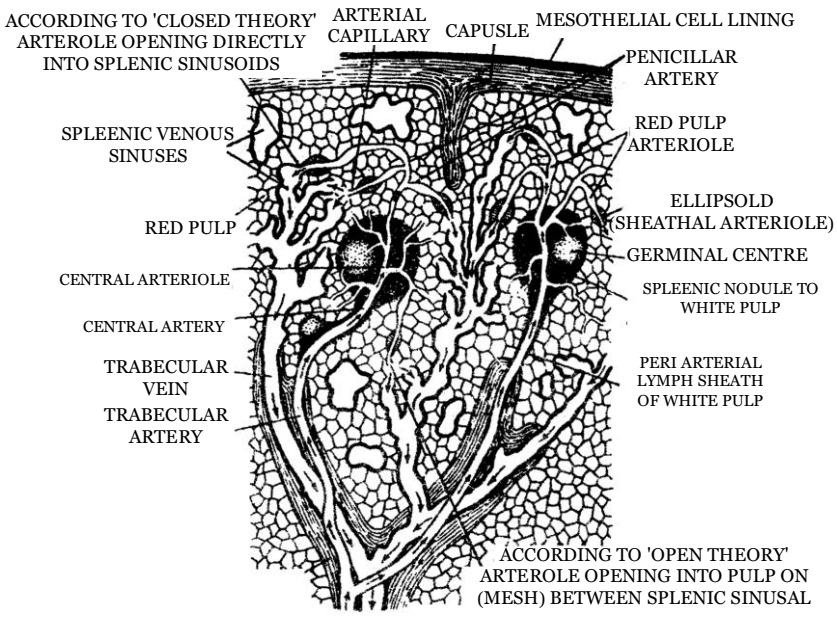


Fig. – Anatomy of circulation in a splenic lobule showing both closed circulation and open circulation (Diagrammatic)

(ii) **Red pulp :** It is a modified lymphatic tissue and is mostly infiltrated with cells of the circulating blood. It consists of two components –

(a) Splenic sinuses or sinusoids.

(b) Splenic cords or Billroth cords [big blood sinuses]. It is raddish due to excessive number of RBCs. Red pulp of spleen contains reticular fibres, erythrocytes, lymphocytes, macrophages, monocytes etc.

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.

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 wornout blood corpuscles, dead and live pathogens, cell debris, pigment granules and other useless particulate materials, thus regularly cleaning the blood of its impurities.

(b) It is active haemopoietic organ. In foetal life, the red pulp possess myeloblast, erythroblast and megakaryocytes. Hence, in foetus, it produces blood. In adults, the red pulp possess 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". When required, their blood is squeezed into general circulation. Similarly, RBCs stored in spleen are also released into general circulation when required.

(d) Many lymphocytes of spleen produce antibodies.

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

(f) Haemolysin is formed in spleen.

(g) Haemoglobin is broken down into haem and globin by spleen. The haem is further split into iron and pigment haematoidin, which becomes bilirubin of plasma. Iron first stored is splenic pulp then transferred into liver and bone marrow. After splenectomy this storage function suffers and more iron is lost.

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

(b) **Thymus :** It is a bilobed mass of lymphiod tissue which is situated in the upper chest near front side of heart. It is prominent in children but begins to degenerate in the adults. It stimulates the development and differentiation of T-lymphocytes, which produce antibodies, thus, increasing the resistance to infection.

Important Tips

- 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.
- Lymph serves to return the interstitial fluid to the blood.
- Oedema (Edema) or Dropsy – A local swelling due to the accumulation of tissue fluid in tissues caused by the defective circulation of blood or lymph.
- Lymph nodes are secondary lymphatic organs because they harbour lymphocytes. Primary lymphoid organs are bone marrow and thymus.
- Lymph nodes are maximum in armpits and groin.
- 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.
- Diseasess where there is more destruction of RBCs such as malaria, banti disease, there is enlargement of spleen called as splenomegaly.
- Thymus is concerned with the immunological reactions.
- In AIDS, there occurs generalised swelling of all lymph nodes.
- Spleen is absent in cyclostomes.
- Cardiology – Study of heart.
- Pericarditis – Inflammation of pericardium.
- Endocarditis – Inflammation of endocardium, generally caused due to the rheumatic fever.
- Frank-Starling law – Within certain physiological limits, the heart pumps all the blood that comes in it.
- Largest sized heart is found in Blue whale.
- Papillary muscles of ventricles are found only in the heart of mammals.
- Valves in heart were first reported by Fabricious.
- World's first heart transplant was performed by Dr. Christian Barnard on 55-year old Louis Wash kansky 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.
- Cardiomegaly – Enlargement of heart.
- 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.
- 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.
- Coronary angiography – X-ray of the arteries, supplying the heart, after injecting them with radio-opaque material.

ASSIGNMENT

TYPES OF CIRCULATION

Basic Level

1. Poikilothermic (cold blooded) or exothermic animals are those in which

(a) Body freezes (b)Body temperature remains constant

(c) Body temp. changes according to surroundings (d)None of the above

2. An open circulatory system occurs in

(a) Man (b) Reptiles (c) Animals (d) Insects

3. William Harvey is known for the discovery of

(a) Blood transfusion (b) Blood clotting (c) Blood circulation (d) Blood purification

4. The blood vascular system of mammals is known as double vascular system because

(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

5. Which one of the following does not have an open circulatory system

(a) Chelone (b) Cockroach (c) Frog's tadpole (d) (a) and (b) both

Advance Level

6. Mammals are said to have a "double circulatory system". This means

(a) That the blood vessels are paired

(b) That there are two types of blood vessels attached to every organ; an artery and a vein

(c) That there are two system; one from the heart to the lungs and back to the heart and other to and from rest of the body

(d) That the blood circulates twice as quickly

7. The heart of fish is different from the other group because

(a) It has lymph only (b) It pumps only arterial blood

(c) It pumps only venous blood (d) It pumps only lymph

CIRCULATORY SYSTEM

Basic Level

8. The heart of a crocodile consists of

(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

9. Open vascular system is found in

(a) Man (b) Fish (c) Prawn (d) Snake

10. In amphibia, the heart has

(a) Two auricles and two ventricle (b)Two auricles and one ventricle

(c) One auricle and two ventricles (d)One auricle and one ventricle

11. Which of the following is the correct statement about the circulatory system of cockroach

(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

12. In Pheretima lymph glands produces

(a) Phagocytic cells (b) Lymphocytic cells (c) Amoebocytic cells (d) Oxyntic cells

13. How many lateral hearts are in pheretima

(a) 4 (b) 8 (c) 16 (d) 12

14. Four pairs of pulsatile heart in pheretima are located in seg

(a) 7, 9, 12 and 13 (b) 11, 14, 17 and 18 (c) 10, 13, 16 and 17 (d) 4, 5, 10 and 13

15. Open circulatory system is observed in

(a) Cockroach (b) Frog (c) Fish (d) Reptiles

16. Single circuit circulatory system is characteristic of

(a) Fishes (b) Amphibians (c) Aves (d) Mammals

17. Double circuit circulation is seen in

(a) Humans and rabbit (b) Pigeon and rat (c) Lizard and crocodile (d) All of the above

Advance Level

18. Blood of periplaneta does not carry oxygen because

(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

19. In the evolution of animals a heart to pump the blood is found for the first time in

(a) Annelids (b) Roundworms (c) Arthropods (d) Flat worms

20. Regarding blood circulation, it may be said that in Pheretima the dorsal vessel is a

(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 & distributing vessel in intestinal region

(d) Distributing vessel in first thirteen segments & collecting vessel in intestinal region

21. Identify the animal which has neurogenic heart

(a) Rat (b) Rabbit (c) Hamster (d) Periplaneta

22. Which of the following has myogenic heart

(a) Frog (b) Humans (c) Rabbit (d) All of the above

23. Which of the following chordata does not have a heart

(a) Petromyzon (b) Lung fishes (c) Branchiostoma (d) Herdmania

PHYSIOLOGY OF HEART

Basic Level

24. Heart beat can be recorded and displayed as

(a) ECG (b) EEG (c) ERG (d) EMG

25. Innervation of heart in the intact animals is primarily meant for

(a) Initiation of heart beat (b) Regulation of heart beat

(c) Release of acetylcholine only (d) Release of adrenalin only

26. Purkinje's fibres are special types of

(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

27. Identify the cardiac inhibitor

(a) *Y*-aminobutyric acid (b)5' Hydroxytryptamine (c)Adrenaline (d) Acetylcholine

28. Identify the wrong statement

(a) The arterial and venous pressure of blood constitutes the blood pressure

(b) Defective heart valve are the cause of heart murmur

(c) When the semilunar valves close the DUP sound is produced

(d) Contraction of right ventricle pumps blood into pulmonary vein

29. Identify the correct statement

(a) The lubb-dup sound of heart beat is due to closure of mitral-tricuspsid valve followed by semilunar valve

(b) The passage of blood from post caval to diastolic right auricle is due to gravity

(c) One heart beat in man lasts for 0.2 sec.

(d) Pulmonary artery originates from left ventricle

30. Regulation of heart beat in mammals is due to

(a) The volume of blood in the circulatory system (b) The presence of excess of oxygen in blood

(c) The presence of thyroxine in blood (d) The presence of pacemaker in the heart

31. Purkinje's fibres of the vertebrate heart are modified

(a) Parasympathetic nerves (b)Sympathetic nerves (c)Motor nerves (d) Muscle cells

32. The nerve like modified muscle in the right auricle is known as

(a) Lymph node (b) Atrio-ventricular node (c) Pacemaker (d) Bulbus arteriosus

33. Pace maker of the heart is

(a) S.A. node (b) A.V. node (c) A.V. septum (d) I.A. septum

34. The first heart sound is

(a) 'Lubb' sound at the end of systole (b) 'Dub' sound at the end of systole

(c) 'Lubb' sound at the beginning of systole (d) 'Dub' sound at the beginning of systole

35. How many times does the heart of humans beat per minute

(a) 80 (b) 120 (c) 72 (d) 60

36. The heart of a healthy man beats normally per minute

(a) 60–70 times (b) 70–80 times (c) 80–90 times (d) 85–95 times

37. Heart beat can be initiated by

(a) Sinu-auricular node (b) Sinu-ventricular node (c) Sodium ion (d) Purkinje's fibres

38. Which one is the correct route through which pulse making impulse travels in the heart

(a) SA node $\rightarrow$ Purkinje fibres $\rightarrow$ Bundle of His $\rightarrow$ AV node $\rightarrow$ Heart muscles

(b) AV node $\rightarrow$ SA node $\rightarrow$ Purkinje fibres $\rightarrow$ Bundle of His $\rightarrow$ Heart muscles

(c) AV node $\rightarrow$ Bundle of His $\rightarrow$ SA node $\rightarrow$ Purkinje fibres $\rightarrow$ Heart muscles

(d) SA node $\rightarrow$ AV node $\rightarrow$ Bundle of His $\rightarrow$ Purkinje fibres $\rightarrow$ Heart muscles

39. The rate of heart beat per minute is highest in case of

(a) Elephant (b) Whale (c) Man (d) Mouse

40. The viscosity of blood is important in maintaining

(a) Acid-base balance (b) Diastolic blood pressure

(c)Systolic blood pressure (d) Osmotic pressure

41. Regulation of heart beat in mammals is due to

(a) Presence of excess of oxygen in blood (b) The presence of pacemaker in the heart

(c) The presence of thyroxin in blood (d) The volume of blood in the circulatory system

42. Pace maker of the heart is situated

(a) In wall of right atrium close to eustachian valve (b)On intra-auricular septum

(c) On inter-venticular septum

(d)In wall of left atrium close to the opening of pulmonary veins

43. Stimulation of the vagus nerve will make the heart beat

(a) Faster (b) 70 times / minute (c) Slower (d) Normal

44. During systole

(a) Auricles and ventricles contract simultaneously

(b)Auricles and ventricles contract separately

(c) Only auricles contract (d)Only ventricles contract

45. What is the maximum efficiency of heart

(a) 10 – 15 % (b) 20 – 25 % (c) 40 – 60% (d) 100%

46. Blood leaving and moving to heart has higher concentration of

(a) Glucose (b) Urea (c) Bile (d) Erythrocytes

47. If the vagus branch of frog is stimulated, the heart will show

(a) Stoppage of heart beat (b)Decreased heart beat

(c) Increased heart beat (d)No change

48. Artificial pace maker is transplanted in

(a) Inter ventricular septum (b)Below the collar bone

(c) Inter auricular septum (d) Right auricle

49. The rate of heart beat is controlled by

(a) CNS (b) SN

(c) CN (d) Autonomic nervous system

50. **Assertion (A)** : Smaller the organism, higher is the rate of metabolism per gm weight.

Reason (R) : Heart rate of six month old baby is much higher than an old person

(a) Both (A) and (R) are true and (R) is the correct explanation of (A)

(b) Both (A) and (R) are true but (R) is not the correct explanation of (A)

(c) (A) is true but (R) is wrong

(d) (A) and (R) both are wrong

51. Bundle of HIS is found in

(a) Muscles (b) Brain (c) Heart (d) Liver

52. In rabbit oxygenated blood flows from

(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

53. Systole refers to the contraction of

(a) SA node (b) AV node (c) Major arteries (d) Atria and ventricles

54. Heart beat is initiated by

(a) AV node (b) SA node (c) Purkinje fibres (d) Papillary muscles

55. Impulse originating from sinu-atrial node are transmitted to the

(a) Atrio-ventricular node (b)Bundle of His (c) Pacemaker (d) Purkinje system

56. Heart beats are controlled by a nodal tissue which is composed of

(a) Purkinje fibres (b) Myonemes (c) Collagen fibres (d) Telodendrites

57. During diastole

(a) Blood enters lungs (b) Blood leaves the ventricle

(c) Blood leaves the heart (d) Blood enters the heart

58. During systole of ventricle

(a) Blood enters the heart (b)Blood leaves the heart

(c) Blood leaves the ventricle (d) Blood enters lungs

Advance Level

59. Acetylcholine is secreted by

(a) Adrenal cortex (b) Adrenal medulla

(c) Parasympathetic neuron (d) Sympathetic neuron

60. Heart beat originates from

(a) Pacemaker (b) Cardiac muscles (c) Left atrium (d) Right ventricle

61. Heart beat of humans is controlled by

(a) Sympathetic and parasympathetic nervous system (b)Medullary hormones

(c) Hypothalamus (d) (a) and (b)

62. Which one of the following is a matching pair

(a) Lubb – sharp closure of AV valves at the beginning of ventricular systole

(b) Dupp – 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 hear beat Purkinje fibres

63. First heart sound occurs at

(a) Opening of semilunar valve (b) Closing of semilunar valve

(c) Onset of auricular systole (d) Sudden closure of A.V. valves

64. The pace-setter in the heart is called

(a) Purkinje fibres (b) Sino-aterial node (SAN)

(c) Papillary muscle (d) Atrio-ventricular node (AVN)

65. Apex beat of heart is synchronous with

(a) First sound (b) Second sound (c) Third sound (d) Fourth sound

66. The typical Lubb-Dup sounds heard in the heart beat of a healthy person are due to

(a) Closing of the tricuspid and bicuspid value (b) Blood flow through the aorta

(c) Closing of the tricuspid and semilunar valves (d) Closing of the semilunar valves

67. If heart of a mammal was injected with 2% $CaCl_2$ solution, then

(a) Heart beat will increase (b)Heart beat will decrease

(c) Heart beat will stop (d) No effect

68. The auriculo-ventricular node in human heart was discovered by
(a) Hiss (b) Loewis (c) Ringer (d) William Harvey

69. The murmuring sound in heart takes place due to
(a) The defective and leaking valve (b) The thrombosis in coronary artery
(c) Defect in SA node (d) The arterial pulse

70. The beating of heart of man is heared on the left side because
(a) The left ventricle is towards the left side (b) Both the ventricles are towards the left side
(c) Entire heart is on the left side (d) The aorta is on the left side

71. The cardiac output of human heart per min is
(a) 4320 ml (b) 5000 ml (c) 1500 ml (d) 2000 ml

72. What is the volume of blood drained by heart in one ventricular stroke
(a) 1 *l* (b) 800 ml (c) 500 ml (d) 80 ml

73. In terms of heart function, epinephrine is antagonistic to
(a) Norepinephrine (b) Acetylcholine (c) Dopamine (d) Prostaglandin

74. The heartbeat is regulated by
(a) Pacemaker (b) Vagus nerve (c) Sympathetic nerve (d) All the above

HEART

Basic Level

75. Which of the animal has only deoxygenated blood in its heart
(a) Scoliodon (b) Rabbit (c) Pigeon (d) Snake

76. Blood returns from lungs to heart through
(a) Right auricle (b) Right ventricle (c) Left ventricle (d) Left auricle

77. In the heart of mammal the bicuspid valve is situated between
(a) Left auricle and left ventricle (b) Post caval and right caval
(c) Right auricle and left auricle (d) Right ventricle and pulmonary aorta

78. Nature of valves in the heart is
(a) Membranous (b) Muscular (c) Tendinous (d) Ligamentous

79. Chordae tendinae are found in
(a) Ventricle of heart (b) Atria of heart (c) Joints (d) Ventricle of brain

80. Covering of heart is called
(a) Pericardium (b) Peritoneum (c) Perineurium (d) Periostium

81. The middle layer of heart is known as
(a) Endocardium (b) Pericardium (c) Epicardium (d) Myocardium

82. Post caval in right auricle is guarded by

(a) Eustachian Valve (b) Bicuspid valve (c) Tricuspid valve (d) Atrio-ventricular valve

83. Tricuspid valve are present between

(a) Right auricle and right ventricle (b) Sinous venosus and right auricle

(c) Left auricle and left ventricle (d) Superior and inferior vena cava

84. Auricles of human heart contains

(a) Columnae carnae (b) Chordae tendenae (c) Papillary muscles (d) Purkinje's fibres

85. Right auricle of mammalian heart receives blood from

(a) Sinus vinosus (b) Pulmonary veins (c) Precavals (d) Pre and postcavals

86. During ventricular diastole

(a) The auricles relax (b) The heart contracts

(c) The heart pumps blood (d) The ventricles relax

87. In rabbit, the four chambered heart promotes

(a) Double circulation (b) Single circulation

(c) Systematic circulation (d) Venous circulation

88. Trilobed valve present between right atrium and ventricle in mammalian heart is

(a) Triac (b) Triad (c) Tricuspid or besian (d) Trigeminal

89. For reaching left side of heart, blood must pass through

(a) Liver (b) Kidneys (c) Lungs (d) Brain

90. 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

91. Mixing up of arterial and venous blood does not take place in a heart having

(a) Two chambers (b) Four chambers (c) Three chambers (d) None of the above

92. Tricuspid valve is present in

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

93. Mitral valve in mammals guards the opening between

(a) Stomach and intestine (b) Pulmonary vein and left auricle

(c) Right auricle and right ventricle (d) Left auricle and left ventricle

94. Tunica media of an elastic artery is made up of mainly

(a) Smooth muscle fibre (b)Loose alveolar tissue

(c) Elastic fibres (d)Collagen fibres

95. Which of the following statements is false

(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

96. Histology of heart superficially shows the following structure except

(a) Endocardium (b) Cardiac muscle (c) Fibrous pericardium (d) Tunica intima

97. Cardiac muscle is composed of

(a) Striated, branched and voluntary muscle fibres

(b) Unstriated (smooth), spindle shaped and voluntary muscle fibres

(c) Unstriated (smooth), spindle shaped and involuntary muscle fibres

(d) Striated, branched and involuntary muscle fibres

98. How much of the total blood volume is present in heart

(a) 2.5% (b) 17% (c) 9% (d) 15%

99. Bicuspid valve is also called as

(a) Mitral valve (b) Eustachean valve (c) Pulmonary valve (d) Ventricular valve

100. Largest heart is found in

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

101. Which of the following has the thickest wall

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

102. The blood returning to the heart from lungs via pulmonary vein has more

(a) RBC per ml of blood (b)Haemoglobin per ml of blood

(c) Oxygen per ml of blood (d) Nutrient per ml of blood

103. Which of the following structure is absent in rabbit's heart

(a) Left auricle (b) Left ventricle (c) Sinus venosus (d) Pace maker

104. Heart of elephant is

(a) Neurogenic (b) Myogenic (c) Both (a) and (b) (d) None of these

105. What is correct about sinus venosus

(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

106. The wall of heart is made up of

(a) Epicardium (b) Myocardium (c) Endocardium (d) All of the above

107. Pylangium is part of

(a) Truncus arteriosus (b) Left atrium (c) Right atrium (d) Ventricles

108. The contraction of the heart of frog commences from

(a) Sinus venosus (b) Right auricle

(c) Left auricle (d) Interauricular septum

109. Heart is simple tubular and ventral in

(a) Urochordata (b) Cyclostomata (c) Cephalochordata (d) Vertebrate

110. Valve of Thebesius occurs in the heart of

(a) Fish (b) Frog (c) Rabbit (d) Chameleon

111. Heart of prawn carries

(a) Oxygenated blood (b) Deoxygenated blood (c) Mixed blood (d) No blood

112. In frog's heart, there are muscular ridges which consist of fibres called

(a) Myonemes (b) Purkinjee fibres (c) Telodendria (d) Columneae carnae

113. Even the ventricles of reptiles are partitioned but there is mixing of blood

(a) Due to common ejection and entrance of blood in lungs

(b) Auricles are non-separated

(c) Heart is partially four-chambered (d) None of these

114. In the mammalian heart, ventricular filling of blood takes place due to

(a) Relaxation of right ventricle (b) A higher blood pressure in right auricle

(c) Adequate blood in the right auricle (d) All the above actions

115. The thick muscular projections on the walls of the ventricle are called

(a) Chordae tendinae (b) Columnae carnae (c) Conus arteriosus (d) Truncus arteriosus

Advance Level

116. Atherosclerosis refers to the ailment of

(a) Lungs (b) Heart (c) Kidney (d) Liver

117. Inter-auricular septum in the embryonic stages has a/an

(a) Fossa ovalis (b) Fenestra ovalis

(c) Fenestra rotunda (d) Inter-auricular aperture

118. The sinu-auricular valve occurs

(a) In the sinus venosus (b) In the edges of sinu-auricular aperture

(c) In the truncus arteriosus (d) At the auriculo-ventricular aperture

119. The coronary sinus in the heart is situated along its

(a) Left margin (b) Right margin

(c) Diaphragmatic surface (d)Lower boarder of the heart

120. Purkinje fibre is found in

(a) Conduction system of heart (b) Brain

(c) Nephrons of kidneys (d) Sensation of skin

121. Neurogenic heart is characteristic of

(a) Lower vertebrates (b) Humans (c) Rat (d) Rabbit

122. Eustachian valve which is of no significance in the adult mammal, is a vestigial organ, a vestige of

(a) Spiral valve (b) Sinus venosus (c) Sino-auricular valve (d) Semilunar valve

123. Which is not true for cardiac muscles

(a) Presence of intercalated disc (b) Striated nature

(c) Involuntary (d) Voluntary

124. The pericardium and the pericardial fluid help in

(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

125. The atrio-ventricular valves of the heart is prevented from turning inside out by tough strands of connective tissue is called as

(a) Tendinous cords (b) Tricuspid (c) Pocket valve (d) Mitral valve

126. Wenckebach phenomenon is seen in

(a) Complete heart block (b)Partial heart block

(c) Ventricular fibrillation (d)Myocardial infarction

127. Since it is the sinu-auricular node which initiates the impulses the heart of mammal is called

(a) Cholinergic (b) Adrenergic (c) Neurogenic (d) Myogenic

128. Which one of the following doctors performed the first heart transplant

(a) Hargovind Khorana (b) Christian Bernard (c) Watson (d) William Harvey

129. The tricuspid valve is present at the origin of

(a) Carotid arch (b) Pulmonary arch (c) Truncus arteriosus (d) Systemic arch

130. Bicuspid and tricuspid valve are supported by

(a) Columnae carnae (b) Endocardium (c) Chordae tendinae (d) Epicardium

131. What happens if the sympathetic nervous system is stimulated

(a) Heartbeat increases (b) Cardiac output decreases

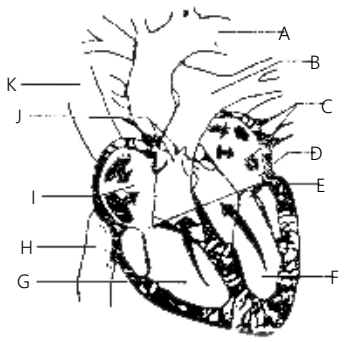
(c) Blood pressure is lowered (d) Pulse becomes erratic and falls steadily

132. Sinus venosus is spread over

(a) Dorsal surface of the heart of frog (b) Dorsal surface of the heart of rabbit

(c) Ventral surface of the heart of frog (d) Ventral surface of the heart of rabbit

133. In the diagram of the vertical section of human heart given below certain parts have been indicated by alphabets; choose the answer in which these alphabets have been correctly matched with the parts they indicate



(a) 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.

(b) A = Aorta, B = Pulmonary artery, C = Pulmonary veins, 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.

(c) A = Aorta, B = Superior vena cava, C = Inferior vena cava, D = Right ventricle, E = Tricuspid and Mitral valves, F = Left auricle, G = Left auricle, H = Pulmonary veins, I = Left ventricle, J = Semilunar valves, K = Pulmonary artery.

(d) 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.

134. Largest heart occurs in

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

135. In India first successful heart transplant was performed at

(a) Escorts Hospital, New Delhi (b) Apollo Hospital, Madras

(c) AIIMS, New Delhi (d) Batra Hospital, New Delhi

136. First successful heart transplant was conducted by

(a) Dr. N. Trihan (b) Dr. Venugopal (c) Dr. M.S. Mani (d) Dr. Gambhir

137. Foramen of panizzae is found in the heart of

(a) Frog (b) Pigeon (c) Crocodile (d) Rabbit

CARDIAC CYCLE

Basic Level

138. What is not true about the pace maker

(a) It initiates and maintains heart beat at the rate of 72/min.

(b) It is present in the right auricle

(c) Its activity is modulated by various chemicals

(d) It is not a characteristic of myogenic heart

139. What is true about the pace maker present in human heart

(a) Initiates and regulates heart beat (b)Increases cardiac output

(c) Is not affected by acetylcholine (d)Does not respond to epinephrine

140. What is not true about human heart

(a) Myogenic (b) Rhythmicity

(c) Heart beat initiated and controlled by SA node

(d) AV node modulate and dominate the activities of pace maker

141. AV node was discovered by

(a) Loewis (b) His (c) Ringer (d) Harvey

142. Bundle of His is a network of

(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

143. If the pace maker is absent

(a) Only auricles will contract (b) Only ventricles will contract

(c) Cardiac muscles will contract in a coordinated manner

(d) Cardiac muscles will not contract in a coordinated manner

144. A pace maker is meant for

(a) Transplanting liver (b) Transplanting heart

(c) Initiation of heart beats (d) Regulation of blood flow

145. Identify the incorrectly matched pair

(a) Diastole – Phase of contraction of cardiac muscle

(b)Systole – Dilation phase of cardiac muscle

(c) Duration of cardiac cycle in humans – 0.8 sec. (d) Haemoglobin – Respiratory pigment

146. QRST is related with

(a) Ventricular contraction or depolarization (b) Auricular contraction

(c) Auricular relaxation (d) Cardiac cycle

Advance Level

147. In an ECG, QRS wave represent

(a) Activity of pace setter (b)Auricular relaxation

(c) Ventricular contraction (d)Ventricular relaxation

148. In an old man's ECG, *T*-waves shall be

(a) Flat (b) Inverted (c) Very prominent (d) Same as in adults

149. Although much CO_2 is carried in the blood, yet blood does not becomes acidic.

This is because

(a) In CO_2 transport, blood buffers play an important role

(b) CO_2 combines with water to form H_2CO_3 which is neutralised by $NaCO_3$

(c) CO_2 is continuously diffused through the tissues and is not allowed to accumulate

(d) CO_2 is absorbed by leucocytes

150. What is the end diastolic volume of blood in a normal adult heart

(a) 50 *ml* (b) 70 *ml* (c) 90 *ml* (d) 110 *ml*

151. Which of the following cardiac effects can be observed if the potassium concentration is increased two to three times the normal value

(a) Weakness of heart (b) Abnormal rhythm (c) Death (d) All the above

152. In all the leads of ECG, all following are positive waves except

(a) *P* (b) *Q* (c) *R* (d) *T*

153. Which of the following is a repolarization wave

(a) *P* (b) *T* (c) *QRS* (d) None of these

154. ECG records

(a) Electric current of the body (b) Potential differences

(c) Pulse rate (d) Quantity of blood pumped per minute

155. Sinu-atrial node is innervated by branches of

(a) V cranial nerve (b) X cranial nerve

(c) IX cranial nerve (d) VI cranial nerve

BLOOD VESSEL AND PRESSURE

Basic Level

156. A man will be unconscious if the blood supply to the brain is stopped for more than

(a) 2 second (b) 5 second (c) 10 second (d) 30 second

157. The blood pressure is high in

(a) Arteries (b) Veins

(c) Capillaries (d) Veins of portal system

158. Fall in blood pressure due to loss of blood is soon restored because the

(a) Blood vessels dilate (b) Blood cells decrease in number

(c) Heart beat is increased (d) Heart beat is decreased

159. Serotonin in the blood

(a) Relaxes blood vessels (b)Prevents clotting of blood

(c) Helps in clotting of blood (d) Constricts blood vessels

160. Systolic pressure is higher than diastolic pressure because

(a) Arteries are contracting during systole

(b) Blood is pumped with a pressure in the arteries by the heart during systole but not during diastole.

(c) Arteries resist during systole only

(d) Volume of blood is higher in systole than that of diastole in the heart

161. In several vertebrates the rate of heart beat and increase in blood pressure is caused by a hormone

(a) Thyroxin (b) Secretin (c) Noradrenalin (d) Adrenalin

162. In man, blood passes from the post caval into the diastolic right atrium of the heart because of

(a) Pushing of venous valves (b) Suction pull

(c) Beating of S.A. node (d) Pressure between post caval and atrium

163. Sphygmomanometer measure

(a) Nerve conduction rate (b)Heart beat rate (c) Blood pressure (d) Pulse rate

164. Renin is released by the kidney when the arterial blood pressure

(a) Gets elevated (b) Becomes low (c) Remains constant (d) Becomes high

165. Cardiac output signifies

(a) The amount of blood entering the heart per unit time

(b) The amount of blood entering the lung per unit time

(c) The amount of blood leaving the heart per unit time

(d) The amount of blood leaving the lung per unit time

166. Normal diastolic pressure in young man is about

(a) 20 *mm Hg* (b) 80 *mm Hg* (c) 110 *mm Hg* (d) 130 *mm Hg*

167. How much arterial pressure rises during arterial contraction (*mm Hg*)

(a) 2 – 4 (b) 4 – 6 (c) 6 – 8 (d) Does not rise at all

168. If glucose is to be injected in human blood, the property to be matched with glucose is

(a) Density (b) Viscosity (c) Osmotic potential (d) Sugar group

169. For the diffusion to take place effectively in capillaries the blood stays there for how long

(a) 1 – 3 *second* (b) 5 – 9 *second* (c) 9 – 13 *second* (d) > 20 *second*

170. Heart rate is increased by all the following except

(a) Anoxia (b) Moderate CO_2 excess

(c) Elevated body temperature (d) Increased intracranial pressure

171. Ventricular contraction is preceded by atrial contraction by what duration

(a) 1 *second* (b) 1/2 *second* (c) 1/4 *second* (d) 1/6 *second*

172. Uremia disease is associated with

(a) High serum cholesterol (b)High blood glucose (c)High blood urea (d) *Rh* factor in blood

173. Heart beat and pulse rate is increased under conditions of

(a) Psychogenic stress (b) Fever (c) Muscular exercise (d) All of the above

174. The heart beat increases at the time of interview due to

(a) Corticotrophic hormone (b) Hyper secretion of renin

(c) Secretion of adrenaline (d) Antidiuretic hormone secretion

175. Pulse can easily be detected on superficial artery like that of

(a) Diaphragm (b) Thigh (c) Wrist (d) Humerus

176. An adult human with average health has systolic and diastolic pressure as

(a) 80 *mm Hg* and 88 *mm Hg* (b) 70 *mm Hg* and 120 *mm Hg*

(c) 120 *mm Hg* and 80 *mm Hg* (d) 50 *mm Hg* and 80 *mm Hg*

177. The thickening of walls of arteries are called

(a) Arthritis (b) Aneurysm (c) Arteriosclerosis (d) Both (a) and (b)

178. Putting adrenaline on the heat will cause the heart beat to

(a) Retard (b) Accelerate (c) Produce louder sound (d) Stop

179. Average cardiac output is

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

180. Heart beats are affected by

(a) Carbon dioxide (b) Oxygen (c) Vagus nerve (d) All the above

181. We feel sleepy just after taking meals because

(a) Blood pressure increases (b) Blood pressure decreases

(c) Body weight increases (d) We feel lithargic

182. The pulse beat is measured by the

(a) Artery (b) Capillary (c) Vein (d) None

183. Identify the correct statement

(a) When the ventricles contract, the pressure is highest

(b) Blood pressure in human varies with age

(c) Systolic pressure in human is 120 mm of *Hg* and diastolic is 80 *mm* of *Hg*

(d) All of the above

184. Blood clot inside a blood vessel is known as

(a) Thrombus (b) Fibrinolysis (c) Thrombosis (d) Clot

185. Heart beat are accelerated by

(a) Cranial nerves and acetylcholine (b) Sympathetic nerves and acetylcholine

(c) Cranial nerves and adrenaline (d) Sympathetic nerves and epinephrine

186. Blood capillaries are made of

(a) Endothelium and thin coat of connective tissue

(b) Endothelium and thin coat of muscle fibres

(c) Endothelium and thin coat of connective tissue and muscle fibres

(d) Only endothelium

187. Stethoscope was invented by

(a) Waksman (b) Koch (c) Laennec (d) Jenner

Advance Level

188. Below normal heart beat is called

(a) Bradycardia (b) Tachycardia (c) Hyperpiesis (d) All of these

189. Blood pressure increases and heart rate decreases in response to

(a) Exercise (b) Haemorrage

(c) Exposure to high altitude (d) Increased intracranial pressure

190. Deficiency of which of the following causes obesity, low plasma Na^+, high K^+ and increased blood pressure

(a) Growth hormone (b) Adrenaline (c) Cortisol (d) Thyroxine

191. Starling's law is related to

(a) Venous return to heart (b)Force of heart beat

(c) Frequency of heart beat (d)Peripheral resistance

192. Oxygen-fick method is used to measure

(a) Blood pressure (b) Cardiac reserve

(c) Cardiac output (d) Capillary blood flow

193. Plethysomograph is used to measure

(a) Velocity of blood (b) Mean volume flow

(c) Excitability of heart (d) Conducting of stimuli in heart

194. Lymph flows in the lymph vessels due to

(a) Presence of valves in their walls (b) Gravity

(c) Contraction and dilation of heart

(d) Pressure exerted by the contraction of surrounding body tissue

195. In allergy and urticaria the local arterioles dilate due to increased substance from mast cells, called

(a) Adrenaline (b) Antitoxin (c) Epinephrine (d) Histamine

196. In man, the normal blood pressure is maintained by the blood protein called

(a) Haemoglobin (b) Albumin (c) Fibrinogen (d) Heparin

197. Stimulating of sympathetic nerves of the heart accelerates it through

(a) Release of acetylcholine (b) Inhibition of adrenalin

(c) Release of adrenalin (d) Inhibition of renin

198. *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

ARTERY AND VEINS

Basic Level

199. Identify the main systemic artery which originates from the left ventricle

(a) Carotid (b) Pulmonary (c) Jugular (d) Aorta

200. The artery which supplies blood to the diaphgram is known as

or

The diaphragm is supplied with blood by

(a) Cardiac artery (b) Phrenic artery (c) Lingual artery (d) Lumber artery

201. Diameter of capillaries for RBC to pass should be

(a) 4μ (b) Less than 5μ (c) More than 5μ (d) More than 10μ

202. Femoral artery supplies blood to

(a) Hind limb (b) Rectum

(c) Dorsal region of thigh (d) Ventral region thigh

203. Iliac artery carries blood to the

(a) Lungs (b) Ileum (c) Hind limbs (d) Brain

204. The wall of blood capillaries is made up of

(a) Mesenchymal cells (b) Connective tissues (c) Endothelial cells (d) Fibrocytes

205. Which of the following has no muscular wall

(a) Artery (b) Vein (c) Arteriol (d) Capillary

206. Select the correctly matched pair

(a) Papillary muscles – Blinking of eye lids (b) Carotid artery – Oxygenated blood to heart

(c) Blood vessels of diaphragm – Phrenic vessels (d) Systole – Causes entry of blood in heart

207. Smallest lumen blood vessel in the body is

(a) Capillary (b) Artery (c) Vein (d) Venacava

208. In which region the lymphatic system and blood circulatory system meet

(a) Liver (b) Precaval (c) Pulmonary artery (d) Systematic arch

209. The process of blood clot formation within the circulatory system is

(a) Thrombosis (b) Thrombocytes (c) Thrombin (d) Thrombocytopenia

210. Blood vessels that contain valves are called

(a) Arteries (b) Veins (c) Capillaries (d) All the above

211. Thrombin occurs in the vertebrates in

(a) The liver and is important for bile secretion (b) The stomach and digests proteins

(c) The blood and is important for clotting (d) The blood and gives it red colour

212. Blood leaving lungs is rich in

(a) Oxygen (b) Haemoglobin

(c) Carbon dioxide (d) More number of RBC

213. Juxta glomerular cells are present in

(a) Afferent arteriole (b) Efferent arteriole (c) Between (a) & (b) (d) All the above

214. The artery can be distinguished from the vein in having

(a) Thicker walls (b) More blood cells (c) More plasma (d) Larger cavity

215. A vein differs from the artery in having

(a) Narrow lumen (b) Strong cuticular and muscular wall

(c) Valves to control direction of flow (d) Dark pigmented wall

216. Oxygenated blood is carried by

(a) Pulmonary vein (b) Pulmonary artery (c) Renal vein (d) Hepatic portal vein

217. Blood to the heart is brought by the venous system by

(a) Innominate and anterior abdominal (b) Subclavian alone

(c) Vena cavae (d) Anterior abdominal alone

218. What is blood pressure

(a) The pressure of blood on the heart muscle

(b) The pressure of blood exerted on the walls of arteries and veins

(c) The pressure of blood on the walls of veins only

(d) The pressure of blood on the walls of arteries only

219. The velocity of blood flow is minimum in

(a) Capillaries (b) Arterioles (c) Small arteries (d) Aorta

220. Valves are necessary in veins but not in arteries because

(a) Blood flows with greater force in veins (b) Blood in veins flows without jerk

(c) Blood from heart may not be pushed back into veins

(d) Pressure in veins is low, which can flow the blood

221. The blood coming out of lungs is richer than that entering into lungs in

(a) Oxygen (b) Carbon dioxide (c) (a) and (b) both (d) None of these

222. The veins

(a) Have thick elastic walls (b) Contain valves

(c) Are called resistance vessels (d) Store less blood than arteries

223. Which part of the circulatory system serves to supply blood to the heart

(a) Coronary (b) Portal (c) Pulmonary (d) Systemic

224. Pulmonary veins

(a) Carry pure blood from heart to lungs (b) Carry impure blood from lungs to heart

(c) Carry pure blood from lungs to heart (d) Carry impure blood to lungs

225. The posterior venacava

(a) Divides into the hepatic portal veins (b) Opens into the left auricle

(c) Commences at the kidney (d) Begins at the hind end of abdomen

226. Oxygenated blood is found in

(a) Pulmonary veins (b) Pulmonary arteries (c) Right atrium (d) Right ventricle

227. Which is correct about veins

(a) Valves are absent (b) Carry blood towards heart

(c) Always carry oxygenated blood (d) Always carry deoxygenated blood

228. The blood vessel which brings oxygenated blood from lungs towards the heart of frog is

(a) Pre caval (b) Post caval (c) Pulmonary vein (d) Pulmonary artery

229. When the right ventricle contracts the blood goes into

(a) Aorta (b) Brain (c) Pulmonary artery (d) None

230. Arteries are

(a) Thin-walled and blood flows under diminished pressure

(b) Thick-walled and blood flows under high pressure

(c) Thin-walled and blood flows under high pressure

(d)Thick-walled and blood flows under diminished pressure

231. All arteries carry oxygenated blood except

(a) Systemic (b) Hepatic (c) Pulmonary (d) Cardiac

232. The pre-caval veins collect blood from

(a) Trunk and hind limbs (b)Fore limbs and hind limbs

(c) Head and fore limbs (d)Head and hind limbs

233. The post-caval vein collects blood from

(a) Hind limbs (b) Hind limbs and organs of the body cavity

(c) Body cavity organs (d) Renal organs

234. Which of the following is different from others in absence of muscular coat

(a) Veins (b) Arteries (c) Capillaries (d) Arterioles

235. Right systemic arch is absent in

(a) Reptiles (b) Birds (c) Mammals (d) None of the above

236. Iliac artery carries blood to

(a) Hind limb (b) Fore limb (c) Lung (d) Brain

237. The blood vessel of frog which opens in its right ventricles bringing oxygenated blood is

(a) Pulmocutaneum artery (b)Inferior vena cava

(c) Pulmocutaneum vein (d)Superior vena cava

238. Splenic artery arises from

(a) Anterior mesenteric artery (b) Coeliac artery

(c) Posterior mesenteric artery (d) Intestinal artery

239. Thoracic duct is associated with

(a) Purkinje fibres (b) Hepatic duct (c) Innominate vein (d) Aorta

240. The carotid labyrinth of frog is concerned with the control of

(a) Number of RBCs (b) Number of WBCs (c) Blood pressure (d) Blood glucose level

241. Common thrombosis leading to myocardial infarction is of

(a) Right circumflex coronary artery (b) Left circumflex coronary artery

(c) Left anterior descending artery (d) Right coronary artery

242. Pulmonary aorta in mammalian embryo communicates with carotico – systemic aorta by a thin vessel called ductus arteriosus which later closes and remains in adult as

(a) Fossa ovalis (b) Ligamentum arteriosus

(c) Carotico-pulmonary aperture (d) None of these

243. The internal carotid artery

(a) Supplies impure blood to kidney (b) Supplies oxygenated blood to brain

(c) Brings impure blood from the brain (d) Supplies oxygenated blood to heart

Advance Level

244. The two branches of the iliac artery are

(a) Femoral and renal (b) Femoral and sciatic

(c) Vesiculo – epigastric and femoral (d) Renal and sciatic

245. The pre-caval vein is formed of

(a) External jugular and innominate (b) Innominate and subclavian

(c) External jugular, innominate and subclavian (d) External jugular and subclavian

246. The post-caval is constituted by

(a) Renal, gonadial and hepatic (b) Renal and gonadial

(c) Gonadial and hepatic (d) Hepatic and renal

247. The unpaired systemic branch is

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

248. The shoulder and fore limb are connected to the heart by

(a) Dorsal aorta (b) Subclavian artery (c) Oesophageal (d) Occipito-vertebral

249. Which of the following carries glucose from digestive tract to liver

(a) Hepatic artery (b) Hepatic portal vein (c) Pulmonary vein (d) None of these

250. Which of the following blood vessels in mammals normally carry largest amount of urea

(a) Hepatic portal vein (b) Hepatic vein (c) Renal artery (d) Hepatic artery

251. What percent of total blood coming out of heart, goes to kidney

(a) 25% (b) 50% (c) 75% (d) 40%

252. What is the approximate number of capillaries in human body

(a) 10 thousand (b) 10 million (c) 10 billion (d) 10 trillion

253. All followings are vasoconstrictor agents except

(a) Norepinephrine (b) Angiotensin (c) Vasopressin (d) Prostaglandins

254. Vasa vasorum supplies blood to

(a) Pericardium (b) Blood vessels

(c) Tunica adventitia and external part of tunica media (d) Vas deferens

255. Rouget cells surround the walls of

(a) Arteries (b) Veins (c) Arterioles (d) Capillaries

256. Which one of the following has elastic wall

(a) Arteriole (b) Dorsal aorta (c) Precaval (d) Post caval

257. In the inguinal canal lies

(a) Posterior mesentric artery (b) Spermatic artery

(c) Internal carotid artery (d) Dorsal aorta

258. Which one of the following is found both in frog and in rabbit

(a) Spinal accessory nerve (b)Diaphragm

(c) Hepatic portal system (d)Eustachian tube

259. Largest blood vessel in body is

(a) Carotid artery (b) Dorsal aorta (c) Phrenic artery (d) Coronary artery

260. Thrombosis in which coronary artery is met most frequency in MI

(a) Right coronary artery (b) Left anterior descending artery

(c) Left circumflex coronary artery (d) Right circumflex coronary artery

261. Systemic heart refers to

(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

262. The lymphatic fluid opens into the blood circulation via a duct into the

(a) Artery supplying the spleen (b) Vein coming from liver

(c) Jugular vein (d) Venacava near the heart

263. Which substance is more in blood flowing through hepatic vein than blood flowing through portal vein

(a) Water (b) Urea

(c) Fatty acid (d) Amino acid + oxygen

264. Carotid artery carries

(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

265. Innominate is

(a) A nerve and artery (b) A muscle and artery

(c) Skeleton part and artery (d) A nerve and vein

266. Valves are found in veins to check the backflow of blood flowing under

(a) Low pressure (b) High pressure (c) No pressure (d) Very high pressure

267. 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

(a) A =*t*, B = *p*, C= *r*, D = *q* (b) A =*t*, B = *r*, C= *p*, D = *s*

(c) A =*s*, B = *t*, C= *r*, D = *p*(d) A =*t*, B = *p*, C= *q*, D = *r*

PORTAL SYSTEM

Basic Level

268. Hepatic portal system starts from

(a) Digestive system to liver (b) Kidney to liver

(c) Liver to heart (d) Liver to kidney

269. Digested food materials entering the blood reach the heart by

(a) Hepatic portal vein, hepatic vein and post caval (b)Hepatic vein and post caval

(c) Hepatic portal vein and post caval (d)Hepatic portal vein and hepatic vein

270. Blood circulation that starts in capillaries and ends in capillaries is called

(a) Portal circulation (b) Hepatic circulation (c) Cardiac circulation (d) None

271. Renal portal system is absent in

(a) Rabbit (b) Frog (c) Toad (d) Salamander

272. A portal system is present in

(a) Liver (b) Hypothalamus (c) Pituitary (d) All of the above

273. When a vein instead of carrying the blood directly into the heart, first carries it to some intermediate organ like liver, is known as

(a) Portal vein (b) Renal portal vein (c) Hepatic portal vein (d) Pulmonary vein

Advance Level

274. Which one of the following vein breaks up into capillaries

(a) Renal vein (b) Hepatic portal vein (c) Pelvic vein (d) Pulmonary vein

275. The renal portal system is made of

(a) Femoral, renal portal veins (b) Sciatic, renal portal veins

(c) Renal portal veins (d) Femoral, sciatic, renal portal veins

276. 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

277. The hepatic portal vein before reaching the liver, joins the

(a) Dorso-lumbar (b) Gonadial veins

(c) Anterior abdominal vein (d) Femoro-renal

278. Venous system of frog differs from that of rabbit in presence of

(a) Hepatic portal system (b)Renal portal system

(c) 3 vena cavae (d)Hepatic vein

279. Which of the following organs has portal circulation

(a) Hypothalamus (b) Hypophysis (c) Kidney and liver (d) All of the above

280. Hypophysial portal system is found in

(a) Kidney (b) Liver (c) Brain (d) Heart

LYMPHATIC SYSTEM

Basic Level

281. Antibodies of the plasma are partly manufactured by

(a) Monocytes (b) Lymphocytes (c) Eosinophils (d) Neutrophils

282. Lymph (nodes) glands form

(a) Hormones (b) Lymphs (c) Antigens (d) Antibodies

283. 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 blood (d) Production of WBC

284. What will happen to an adult human being if spleen is removed

(a) RBC production will be lowered (b) Antibody production will be lowered

(c) Filteration of dead RBC will not be there (d) WBC production will be lowered

285. Identify the organ which serves as storage depot for RBC

(a) Spleen (b) Bone marrow (c) Liver (d) Gall bladder

286. Identify the correct statement

(a) Interstitial fluid is returned to blood by lymph

(b) Kidney produces a hormone erythropoietin which stimulates RBC formation

(c) Spleen controls blood volume in blood vessels

(d) All of the above

287. Which of the following body fluid is colourless

(a) Plasma (b) Lymph (c) Cerebrospinal fluid (d) All of the above

288. Lymph is colourless because

(a) WBC are absent (b) WBC are present

(c) Heamoglobin is absent (d) RBC are absent

289. Spleen is

(a) Haemopoeitic (b) Lymphoid (c) Reproductive (d) Celluloid

290. Lymphoid tissue is found in

(a) Thymus (b) Tonsils (c) Lymph nodes (d) All of these

291. The lymphocytes provide the principal defence mechanism by producing

(a) Antigens (b) Haemoglobin (c) Immunoglobins (d) Myoglobins

292. In our body, the blood bank is

(a) Red bone marrow (b) Spleen (c) Liver (d) Heart

293. The lymphocytes protect from

(a) Pathogens (b) Lymph (c) Leucocytes (d) Toxins

294. The lymph differs from the blood in having

(a) Blood with more RBC and less WBC (b) Blood without plasma

(c) Plasma without proteins (d) No RBC but more WBC

295. Lymph is blood minus

(a) Blood corpuscles (b) Blood plasma (c) RBC (d) WBC

296. The old worn out RBCs are filtered out by

(a) Kidney (b) Liver (c) Spleen (d) Heart

297. Lymph glands and nodes help to

(a) Excrete the urea (b) Eliminate the ammonia

(c) Prepare blood (d) Destroy the bacteria

Advance Level

298. In connection with circulatory system, valves are present

(a) Not only in heart and blood vessels or 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

299. Humoral antibodies are produced by

(a) β – cells (b) T – cells (c) Globulins (d) Plasma cells

300. After vaccination, the body build up

(a) Toxins (b) Antibodies (c) Lymph (d) Plasma

301. Cords of billroth are blood spaces which at found in which of the followings

(a) Liver (b) Kidneys (c) Spleen (d) Tonsils

302. A yellow substance oozing out from wound has

(a) Lymph+RBC+WBC (b) Lymph+RBC+dead bacteria

(c) Lymph+WBC+dead bacteria (d) Lymph+dead leucocytes

303. Function of human spleen is to

(a) Control the pulse rate (b)Secrete hormone

(c) Stimulate heart (d)Control blood volume

304. Which organ is considered as "Graveyard of RBC" where most of them are destroyed by macrophages

(a) Red bone marrow (b) Spleen (c) Kidney (d) Intestine

305. Lymph vessels are united to form

(a) Lymph heart (b) Cisterna chyle (c) Thoracic duct (d) Jugular vein

306. The lymph serves to

(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

307. In rabbit, function of spleen is

(a) Blood purification (b) Respiration (c) Excretion (d) None of the above

308. Which vertebrate organ receives only oxygenated blood

(a) Gill (b) Lung (c) Spleen (d) Liver

309. Squeezing of leucocytes out from the endothelium of capillaries to fight foreign agents is known as

(a) Haemolysis (b) Diapaedesis (c) phagocytosis (d) Rouleaux

310. Antibodies defend the body from the invading antigen by

(a) Combining with it to abolish its free mobility and thus preventing it from acting in a damaging manner

(b) Eliminating the toxins released by it

(c) Phagocytosis

(d) Transporting it to the liver where it is destroyed

BLOOD

Basic Level

311. The life span of neutrophils is

(a) 120 days (b) 118 days (c) 10-12 hours (d) 24-72 hours

312. Basophil cells are the storage and release site for

(a) Prothrombin (b) Vitamin K (c) Histamine (d) Epinephrine

313. Identify the motile, phagocytic corpuscle of mammalian blood

(a) Thrombocytes (b) Monocytes (c) Neutrophils (d) Basophils

314. Blood coagulation is assisted by

(a) Phagocytes (b) Thrombocytes (c) Erythrocytes (d) Leucocytes

315. Where the granulocytes are formed

(a) In kidney (b) In liver (c) In red bone marrow (d) In small intestine

316. In which one of the following white ghost are found

(a) Thrombocytes (b) Lymphocytes (c) Choanocytes (d) Erythrocytes

317. If the number of leucocytes is increased beyond normal limits in the blood it shows that

(a) The person is becoming stronger by acquiring more WBCs

(b) It is a normal process

(c) There is some infection in the body (d) He is anaemic

318. Neutrophils serve as

(a) Mopping up (b) Histiocytes (c) Macrophages (d) Shock troops

319. Heamoglobin is a type of

(a) Vitamin (b) Skin pigment (c) Carbohydrate (d) Respiratory pigment

320. Which one of the following is the percentage of inorganic salt in the protoplasm

(a) 5 – 7 percent (b) 50 – 60 percent (c) 0.1 – 2.5 percent (d) 2 – 3 percent

321. Which element is responsible for the low haemoglobin content in the blood

(a) Sulphur (b) Iron (c) Iodine (d) Aluminium

322. The break down product of haemoglobin is

(a) Iron (b) Bilirubin (c) Biliverdin (d) All the above

323. If a child's blood does not clot, he is prescribed by the doctor

(a) Heparin (b) Vitamin *C* (c) Vitamin *D* (d) Vitamin *K*

324. Normal haemoglobin contents of a healthy man per 100 *ml* of blood is about

(a) 11.5 to 12.5 *gms* (b) 12.0 to 14.0 *gms* (c) 12.5 to 14.5 *gms* (d) 14.0 to 16.0 *gms*

325. The chief difference between the erythrocytes (RBC) of man and frog is

(a) Human erythrocytes have more haemoglobin (b) Human erythrocytes have more nuclei

(c) Human erythrocytes have two nuclei (d) Human erythrocytes have no nuclei

326. The cation (mineral) necessary for coagulation of blood is

(a) *Na* (b) *Ca* (c) *K* (d) *Cl*

327. Significant role of clotting of blood is played by

(a) Neutrophils (b) Thrombocytes (c) Erythrocytes (d) Leucocytes

328. Bicarbonate ions can be generated in

(a) Lymphocyte (b) Neutrophil (c) Basophil (d) RBC

329. Urea is transported by

(a) WBC (b) Haemoglobin (c) RBC (d) Blood and plasma

330. Conversion of fibrinogen to fibrin is catalysed by

(a) Thrombin (b) Prothrombin (c) Thromboplastin (d) Thrombokinase

331. A chemical that prevents blood clotting is most useful in the treatment of

(a) Leukemia (b) Anaemia

(c) Coronary thrombosis (d) Haemophilia

332. The nucleus in WBC is

(a) Round (b) Oval (c) Spindle shaped (d) Irregular

333. Accumulation of tissue fluid may be due to

(a) Diapedesis (b) Rouleux (c) Rupture of RBC (d) Phagocytosis

334. T-Lymphocytes originate from

(a) Thymus (b) Bone marrow (c) Liver (d) None of these

335. The condition in which the body's internal environment remains relatively constant within its limits is

(a) Autotrophy (b) Haemolysis (c) Homeostasis (d) Apoptosis

336. Blood platelets are concerned with

(a) Transport of CO_2 (b) Release of antitoxins

(c) Production of antibodies (d) Release of thromboplastin

337. The normal level of Haemoglobin per 100 *ml* of blood in women is

(a) 14 *gms* (b) 18 *gms* (c) 12 *gms* (d) 20 *gms*

338. Hematology is the study of

(a) Bone (b) Blood (c) Cartilage (d) Nerve

339. Which of the following is capable of carrying oxygen

(a) Lymph (b) Serum (c) Blood (d) Plasma

340. Number of RBC in man increases if he lives at higher altitude because

(a) There is more oxygen (b)There is less oxygen

(c) There are no germs in air (d) More heat is needed to warm the body

341. Non-nucleated cell is

(a) Erythrocyte (b) Leucocyte (c) Muscle cell (d) Bone cell

342. Platelet plug is associated with

(a) Hemostasis (b) Clot retraction (c) Fibrin formation (d) Homeostasis

343. In which of the following ER is absent

(a) Human monocyte (b) WBC (c) Embryo cell (d) Mammalian RBC

344. Haemoglobin contains

(a) 70% globin+30% haematin (b) 80% globin+20% haematin

(c) 95% globin+05% haematin (d) 90% globin+10% haematin

345. In some human beings clotting of blood takes long time due to the defect in

(a) RBCs (b) WBCs (c) Blood platelets (d) Blood plasma

346. RBC of which are nucleated

(a) Rabbit (b) Camel & Ilama (c) Embryo of man (d) Both (a) and (c)

347. If haemoglobin is replaced by haemocyanin, the blood will carry

(a) Less oxygen (b) More oxygen

(c) No oxygen (d) Same amount of oxygen

348. The volume of RBC will increase in

(a) Isotonic solution (b) Hypotonic solution (c) Hypertonic solution (d) None of these

349. What remains after the removal of fibrinogen from plasma

(a) Clot (b) Haemolymph (c) Lymph (d) Serum

350. The blood protein involved in blood coagulation is

(a) Thrombin (b) Fibrinogen (c) Prothrombin (d) Fibrinoprotein

351. Glomerular filtrate is almost similar to blood plasma except

(a) RBC (b) WBC (c) Protein (d) All the above

352. The white pus of an infected part in the body is composed of

(a) Dead leucocytes+blood serum (b) Living erythrocytes+serum

(c) Dead erythrocytes+plasma (d) Living leucocytes+serum

353. Carbonic anhydrase is present in high concentrations in

(a) Plasma (b) Erythrocytes (c) Leucocytes (d) Nephrons

354. The disease as a result of prolonged clotting time is due to the lack of plasma thromboplastin component necessary for the formation of thromboplastin, is

(a) Christmas disease (b) Heamophilia

(c) Hypoprothrombinaemia (d) Hartnup disease

355. The blood groups in man were discovered by

(a) Mendel (b) Francis Nelton (c) S. Miller (d) Landstiener

356. In a haemophilic person tooth extraction may result in death by excessive bleeding due to

(a) Absence of a certain plasma protein necessary to change protein into thrombin

(b) Presence of a certain plasma protein necessary to prevent blood clotting

(c) Absence of a certain plasma protein necessary for haemorrhage

(d) Presence of a certain plasma protein necessary for a haemorrhage

357. Coagulation will be retarded by

(a) Lowering of RBC count (b) Increasing temperature

(c) Removing heparin (d) Lowering thrombocyte count

358. Which change is importance in blood coagulation

(a) Trapping of blood cells (b) Formation of insoluble fibres

(c) Shrinkage and hardening of clot (d) Interweaving of fibres

359. For clotting of blood which of the following is necessary

(a) *Ca* and thromboplastin (b)*Na* and thromboplastin

(c) *Na* and *K* ions (d)*Na* and prothrombin

360. Which of the following helps in blood coagulation

(a) K^+ (b) Na^+ (c) Mg (d) Ca^{++}

361. In numerical system for international nomenclature of blood coagulation features, clotting factor-VIII is

(a) Antihaemophilic factor (b)Antihaemophilic globulin

(c) Platelet cofactor-I (d)All the above

362. Prothrombin time is longer in deficiency of all the following factors except

(a) Factor-V (b) Factor-VII (c) Factor-X (d) Factor-XIII

363. The number of leucocytes ranges from (per cc)

(a) 4,000 to 13,000 (b) 1 million to 1.5 million (c)2,000 to 3,000 (d) 5,000 to 6,000

364. Which of the following statements is false

(a) Red blood corpuscles are also called leucocytes

(b) White blood cells from a part of the body's defence mechanism against infection

(c) Platelets are also called thrombocytes

(d) In the blood, oxygen is mainly carried in chemical combination with haemoglobin

365. Number of *RBCs* in blood is

(a) 54 lakh / cubic mm (b) 50 lakh / cubic mm (c) 60 lakh / cubic mm (d) 30 lakh / cubic mm

366. Polycythemia is

(a) Increased RBCs count (b)Increased WBCs count

(c) Decreased WBCs count (d)Decreased platelets count

367. If *pH* of blood is artificially changed to 8, what is most likely to happen

(a) The tissues will not get oxygen as oxyhaemoglobin will not dissociate into oxygen and haemoglobin

(b) The carbon dioxide will not be released from carbonic acid and carbonates

(c) The carbonic anhydrase will be completely inhibited

(d) It will generate carbon monoxide and the animal will die of carbon monoxide poisoning

368. Which of the following statement is correct about blood

(a) Transport of O_2 by RBC and CO_2 by blood plasma

(b) Transport of O_2 and CO_2 both is carried by RBC and WBC

(c) Transport of O_2 by RBC and CO_2 by WBC

(d) Transport of O_2 and CO_2 by RBC and blood plasma both

369. The main constituent of plasma proteins is

(a) Heparin (b) Fibrinogen (c) Globulin (d) Albumin

370. The number of RBCs per mm^3 of blood is ….. millions

(a) 5.5 (b) 7.0 (c) 8.0 (d) 3.0

371. What will be the volume of blood in a healthy adult male weighing 75 kg

(a) 6.0 litre (b) 5.6 litre (c) 7.5 litre (d) 4 litre

372. Blood can be stored by addition of

(a) Histamine (b) Epinephrine (c) Citrate and oxalate salts (d)Prothrombin

373. If blood cells are eliminated from the blood, the liquid left is

(a) Serum (b) Plasma (c) Lymph (d) Synovial fluid

374. The process of formation of the various types of blood cells is known as

(a) Haemagglutination (b) Haemolysis (c) Haemophilia (d) Haemopoiesis

375. Haemoglobin is a

(a) Copper containing pigment (b) Iron containing pigment

(c) Magnesium containing pigment (d) Calcium containing pigment

376. The RBCs of mammals are

(a) Circular biconcave (b) Oval biconcave (c) Circular biconvex (d) Oval biconvex

377. Haemopoesis takes place in the bone marrow of

(a) Femur (b) Radius (c) Vertebrae (d) None of the above

378. The RBC would burst or a cell swells or bursts if immersed in a solution. The solution is

(a) Saturated (b) Hypotonic (c) Hypertonic (d) Isotonic

379. The buffer salts present in the blood are

(a) Potassium (b) Sodium (c) Sodium and potassium (d)Cobalt

380. Regeneration can occur throughout the human life in

(a) Blood cells (b) Retina (c) Skin (d) Hair

381. In mammalian RBC, the percentage of haemoglobin is

(a) 40% of biomass (b) 34% of biomass (c) 90% of biomass (d) 50% of biomass

382. Haemoglobin – *S* is present in

(a) Megaloblastic anaemia (b)Hereditary spherocytosis

(c) Sickel cell anaemia (d) Erythroblastosis foetalis

383. The rise of blood sugar above the normal level is known as

(a) Glucosuria (b) Glycolysis (c) Hyperglycemia (d) Hypoglycemia

384. The normal percentage of glucose in the blood of man is 0.1%. It is found in

(a) Plasma (b) RBC (c) WBC (d) Serum

385. The sample of a healthy human blood is

(a) Alkaline (b) Acidic (c) Neutral (d) None of these

386. Erythropoesis may be stimulated by the deficiency of

(a) Iron (b) Oxygen (c) Protein (d) None of these

387. In which form the CO_2 is carried in the blood

(a) Sodium carbonate (b) Sodium bicarbonate

(c) Potassium carbonate (d) Magnesium bicarbonate

388. An antibody is a

(a) Molecule that specifically inactivates an antigen (b)WBC which invades bacteria

(c) Secretion of mammalian RBC (d)Component of blood

389. If RBC are placed in hypertonic solution, they

(a) Burst (b) Shrink (c) Die (d) Retain the size

390. Formation of red blood cells in a normal human adult occurs in

(a) Kidneys (b) Spleen (c) Bone marrow (d) Lymph nodes

391. Mammals have biconcave RBC. The physiological use for it is

(a) To decrease the surface area (b) To increase the surface area

(c) To be packed like coins (d) None of the above

392. Persons living in mountains (high altitudes) have rosy cheeks because

(a) They are adapted to that environment

(b) They take apple daily

(c) Their RBC concentration becomes high due to low oxygen pressure

(d) All the above

393. Persons living at high altitude will have

(a) Increased alveolar capacity (b) Increased number of erythrocytes

(c) Haemoglobin curve shifts towards right (d) All of the above

394. Anaemia is due to deficiency of

(a) *Ca* (b) *P* (c) *Fe* (d) *Mg*

395. At high altitude the RBC in the human blood will

(a) Increase in size (b) Decrease in size (c) Increase in number (d) Decrease in number

396. Rabbit's RBC is

(a) Spherical (b) Biconcave (c) Enucleate (d) All the above

397. A mature human erythrocyte has the typical characteristics of

(a) A eukaryote cell (b) A prokaryote cell

(c) Both eukaryote cell and prokaryote cell (d) Neither eukaryote nor prokaryote cell

398. Blood is

(a) Endodermal in origin (b)Exodermal in origin

(c) Mesodermal in origin (d)Ectodermal in origin

399. Which one of the following belongs to different group

(a) Erythrocyte (b) Lymphocyte (c) Monocyte (d) Neutrophil

400. The *pH* of the blood is maintained balancing the ratio of

(a) Lactic acid and pyruvic acid (b) $NaHCO_3$ and H_2CO_3

(c) CO_2 and H_2O (d) Pyruvic acid and H_2CO_3

401. The internal device to maintain body temperature constant is

(a) Increasing and decreasing amount of urine (b) Variable blood circulation

(c) Variable rate of blood digestion (d) None of the above

402. The medium of plasma is

(a) Acidic (b) Basic (c) Neutral (d) None of these

403. Clot of blood contains

(a) Prothrombin (b) Thrombin (c) Fibrinogen (d) Fibrin

404. Which one of the following in blood absorbs oxygen

(a) WBCs (b) Plasma (c) RBCs (d) Platelets

405. The protein which prevents coagulation of blood in the blood vessel is

(a) Platelets (b) Globular protein (c) Albumin (d) Heparin

406. Oxygen is transported by

(a) Blood plasma (b) RBCs (c) Leucocytes (d) Thrombocytes

407. White and red blood cells are formed in

(a) Liver (b) Heart (c) Bone marrow (d) Spleen

408. Which of the following is the smallest blood particle

(a) Leucocytes (b) Thrombocytes (c) Phagocytes (d) Erythrocytes

409. The fluid of the blood from which all blood corpuscles are removed is known as

(a) Plasma (b) Vaccine (c) Haem (d) Serum

410. If an experiment, animal is made anaemic, production of which hormone will be stepped up

(a) Erythrocytin (b) Erythroblastin (c) Erythropoietin (d) Enkephalin

411. Which one of the following substances in the blood in man imparts the oxygen carrying capacity to it

(a) Haemocyanin (b) Haemoglobin

(c) Haemerythrin or haemoerythrin (d) Sodium ions

412. The organs yolk sac, kidney, spleen, liver and bone marrow are

(a) Erythropoietic (b) Red organs (c) Diapedic (d) (a) and (b)

413. de Castello and Sturli discovered

(a) A blood group (b) B blood group (c) AB blood group (d) Rh blood group

414. Factors present on surface of RBC related to heredity are

(a) Blood groups (b) Antigens (c) Antibodies (d) Haemoglobin

415. Blood dust present in the blood plasma is known as

(a) Blood platelets (b) Chylomicrons (c) Haemoconia (d) Chyluria

416. One of the following cells can't respire

(a) Epidermal (b) Intestinal (c) Erythrocytes (d) Leucocytes

417. *Rh* factor is named after

(a) Monkey (b) Drosphlla (c) Rat (d) Man

418. Blood sample of a healthy human being is

(a) Acidic (b) Neutral (c) Alkaline (d) Variable

419. For safe blood transfusion

(a) Donor's RBC should not contain antibodies against recepient serum

(b) Recepient serum should not contain antigens against donor's antibodies

(c) Recepient's serum should not contain antibodies against RBC of donors

(d) Receipient's RBC should not contain antibodies against donor's antigens

420. In purpura of purple blue there is thrombocytopenic

(a) Change of haemoglobin into blue (b) Change of haemoglobin into red black

(c) Change of haemoglobin into yellow (d) Change of haemoglobin into white

421. Thrombocytopenic purpura is a haemorrhagic disorders. This is because of

(a) Very high platelet count (b) Very low platelet count

(c) Low concentration of fibrinogen (d) Absence of vitamin *K*.

Advance Level

422. Thrombocytopenia is a condition

(a) With decreased number of platelets in blood (b) With decreased number of RBCs in blood

(c) With increased number of platelets in blood (d) With increased number of WBCs in blood

423. Blood cells that contain heparin and histamine is

(a) RBC (b) Thrombocytes (c) Lymphocytes (d) Basophil

424. Identify the incorrectly matched pair

(a) Thromboplastin – Platelet secretion (b) Thrombin – Blood clotting

(c) Lymphocytes – Immunocompetent cells

(d) Macrophage – Blood cells that transport antibodies

425. Megakaryocytes

(a) Are carriers of oxygen (b)Produce leucocytes

(c) Produce blood platelets (d)Are called bone cells

426. The life span of WBC in man is about

(a) 160 – 180 days (b) 80 – 90 days (c) 20 – 25 days (d) 1 – 15 days

427. "Diapedesis" means

(a) High mortality rate of WBCs

(b)Squeezing out WBCs of the walls of capillaries

(c) Squeezing out RBCs of the walls of capillaries

(d)Squeezing out blood platelets of the walls of capillaries

428. "Leucopenia" is

(a) Decrease in the total number of WBCs below 4,000/ mm^3

(b) The destruction of bone marrow by pathogens

(c) Decrease in the total number of lymphocytes by 2-5%

(d) Increase in the total number of WBCs above 6,000/ mm^3

429. What is not true about mammalian blood cells

(a) Human WBC live for 12-13 days

(b) RBC : WBC ratio is 600 : 1

(c) Abnormal increase in RBC is called Leucopenia

(d) Erypthropoietin stimulates RBC production if a person goes and lives at high altitude

430. Mitochondria are not found in

(a) Eucaryotic cells (b) Leucocytes (c) Erythrocytes (d) Neurons

431. All of the following are correct except

(a) Monocyte produces fibrinogen

(b) Megakaryocytes give rise to platelets

(c) Leukocytes function in immunological and inflammatory condition

(d) Monocytes, granulocytes, some lymphocytes and RBCs are produced in the bone marrow

432. Intravascular clotting of blood is prevented by

(a) Histamine (b) Histamine and serotonin

(c)Hirudin (d) Heparin secreted by liver

433. Albumin, fibrinogen, prothrombin are manufactured in

(a) Liver (b) Bone marrow (c) Spleen (d) Pancreas

434. The swelling in any part of our body, caused by infiltration of serum into subcutaneous cellular tissue, is called

(a) Abscess (b) Oedema (c) Dropsy (d) Thrombus

435. Which proteolytic enzyme induces lysis of fibrin during fibrinolysis

(a) Fibrin (b) Plasmin (c) Thrombin (d) Platelet factor VIII

436. Which is used as anticoagulant in blood cells counting

(a) CH_3COOH (b) $H.CHO$ (c) EDTA (d) C_6H_6

437. Fibrin is produced by

(a) Proteolysis (b) Thrombokinase (c) Liver (d) Prothrombin

438. When a decrease in both number and size of RBC occurs, the cells may show a multiplicity of distortion in shape. This will result in anaemic condition known as

(a) Haemolytic anaemia (b) Chlorotic anaemia (c) Microcytic anaemia (d) Macrocytic anaemia

439. In blood CO_2 is mainly transported through

(a) Haemoglobin (b) Lymph (c) RBC (d) Plasma

440. *pH* of human blood varies between

(a) 6.0 to 7.0 (b) 7.0 to 8.0 (c) 7.3 to 7.45 (d) 7.5 to 8.0

441. Identify the incorrectly matched pair

(a) Percentage of RBC in blood – Haematocrit value

(b) Coronary ischemia – Inadequate blood flow to heart

(c) β – lymphocytes – involved with tissue rejection

(d) Leucocyte with lobed nucleus and granular cytoplasm – Neutrophil

442. Blood groups in man were discovered by

(a) Landsteiner (b) Eccles (c) Linus Pauling (d) Waddington

443. Which of the following is absent in blood serum

(a) Fibrinogen (b) Clotting factors (c) Blood cells (d) All of the above

444. The erythrocytes of mammals are non-nucleated except in

(a) Rabbit (b) Monkey (c) Camel (d) Man

445. What is true about RBC of humans

(a) It contains myoglobin

(b) Fragile, abnormal RBC are phagocytosed in spleen, kidney and bone marrow

(c) Serum is blood minus blood cells

(d) Cu^{+2} is necessary for erythropoiesis in bone marrow

446. The amount of blood supplied to brain per minute is

(a) 450 *ml* (b) 550 *ml* (c) 750 *ml* (d) 1.000 *ml*

447. Metals required for synthesis of haemoglobin are following except

(a) Iron (b) Copper (c) Mercury (d) Cobalt

448. Haemotocrit is related with

(a) Amount of *Hb*/100 *ml* of blood (b) Counting number of RBC

(c) Cell volume when packed together (d) Oxygen carrying capacity of haemoglobin

449. In haemoglobin iron is attached with globin protein by

(a) Hydrogen bond (b) Ionic bond (c) Covalent bond (d) Coordinate bond

450. Which one of the following anticoagulant is added in blood during storage

(a) Sodium carbonate (b) Sodium oxalate (c) Sodium chloride (d) Sodium hydroxide

451. The matured erythrocyte in a mammal does not have

(a) RNA (b) DNA (c) Proteins (d) Haemoglobin

452. Heparin

(a) Converts prothrombin to thrombin (b) Converts fibrinogen to fibrin

(c) Converts fibrin threads to a clot and release serum

(d) Prevents coagulation of blood

453. RBC are nucleated in

(a) Man (b) Rat (c) Frog (d) Rabbit

454. What does the human RBCs lack

(a) Haemoglobin (b) Cytoplasm (c) Nucleus (d) Cell membrane

455. Breakdown of *Hb* forms

(a) Bile pigments (b) Glubulin (c) *Hb*-protein (d) Urea

456. The lion that always keeps the cardiac muscle unit in contracting state is

(a) Sodium (b) Potassium (c) Calcium (d) Magnesium

457. Antibodies fight against

(a) Infection (b) Thirst (c) Starvation (d) Heart failure

458. The clinging of RBCs together in the blood and forming a pile of coin like structure is known as

(a) Coagulation (b) Islets (c) Lacuna (d) Rouleau

459. The normal blood sugar level in a man is

(a) 80-100 mg / 100 ml (b) 80-120 mg / 100 ml (c) 80-160 mg / 100 ml (d) 80-140 mg / 100 ml

460. Reticulocytes are

(a) Immature RBC (b) WBC (c) Blood platelets (d) Lymphocytes

461. In haemoglobin iron is present in

(a) Ferrous form (b) Ferric form (c) Metallic form (d) Any form

462. Cells containing heparin and serotonin are

(a) Lymphoid cells (b) Mast cells (c) Fibroblasts (d) Macrophages

463. Which one of the following is not related to the clotting of blood

(a) Fibrin (b) Fibrinogen (c) Ca^{++} (d) Na^{+} of the plasma

464. The life span of thrombocytes in blood of mammal is

(a) 1 – 10 days (b) 1 – 5 days (c) 3 – 5 days (d) 10 – 12 days

465. Sickle cell anaemia is very common in South Africa due to

(a) More pupulation of tse-tse files (b) Change in the γ – chain in the haemoglobin

(c) Change in the α – chain in the haemoglobin (d) Change in the β – chain in the haemoglobin

466. RBC in mammals have no nucleus because

(a) It has degenerated during development (b) They do not have nucleus since early

(c) Nucleus is harmful for RBC (d) Nucleus decreases surface area

467. One haemoglobin carry how many molecule of O_2

(a) 4 (b) 2 (c) 6 (d) 8

468. Which one of the following prevents coagulation

(a) Heparin (b) Histamin (c) Thyroxin (d) All

469. When RBCs are immersed in hypotonic solution, one of the following occurs

(a) Crenation (b) Haemolysis (c) Enucleation (d) None

470. The ratio of RBC to WBC in man is

(a) 6 : 1 (b) 60 : 1 (c) 600 : 1 (d) 6000 : 1

471. The RBC in the body die after about

(a) 120 days (b) 150 days (c) 157 days (d) 70 days

472. Cells which help in stopping the flow of blood are

(a) WBC (b) Leucocytes (c) RBC (d) Thrombocytes

473. Blood platelets are the source of

(a) Fibrinogen (b) Ca^{++} (c) Thromboplastin (d) Haemoglobin

474. "Haemolytic jaundice" is caused due to

(a) High mortality rate of RBCs (b) High mortality rate of WBCs

(c) High birth rate of RBCs (d) High birth rate of WBCs

475. "Obstructive jaundice" is

(a) Obstruction due to the gall bladder stone (b) Obstruction due to the kidney stone

(c) Obstruction due to heart failure (d) Obstruction in spleen

476. In the 8^{th} month of human embryo the haemopoesis takes place in

(a) Liver (b) Bone marrow

(c) Spleen (d) Endothelium of blood vessels

477. Blood clotting can be prevented by the use of potassium oxalate. It is due to

(a) Checking of conversion of fibrinogen into fibrin

(b)Inactivation of all factors for blood coagulation

(c) Neutralization of acidic medium (d)Removal of free Ca^{++} ions

478. In mammals the urea is transported by

(a) Blood plasma (b) Erythrocytes (c) Haemoglobin (d) Leucocytes

479. Thrombin occurs in vertebrates in

(a) Blood and imparts red colour (b) Blood and important for clotting

(c) Liver and initiates secretion (d) Stomach and digests proteins

480. The iron free compound of haemoglobin is

(a) Globin (b) Haematin (c) Bilirubin (d) Haemotoxin

481. The coagulation of blood occurs due to

(a) Formation of serum (b)Change of fibrinogen in the network of fibrin

(c) Destruction of erythrocytes (d) Destruction of leucocytes

482. Blood coagulation in not interfered by

(a) Low Ca^{++} (b) Less number of blood platelets

(c) Low fibrinogen (d) Low WBC concentration

483. One of the diagnostic feature of blood cancer is

(a) Increased number of β – lymphocytes (b) Decrease in number of T – helper cells

(c) Excessive increase of WBC (d) Absence of platelets

484. Blood cancer is also called

(a) Haemolytic anaemia (b) Leukemia (c) Anaemia (d) Pernicious anaemia

485. Sickle cell anaemia is most common in

(a) India (b) Africa (c) Mexico (d) Europe

486. Chronic haemolytic anaemia is characteristic of person afflicted with

(a) Pernicious anaemia (b) Leukemia (c) Polycythemia (d) Sickle cell anaemia

487. Identify the correctly matched pair

(a) Serum – plasma anticoagulant factor (b) Plasma – Blood and blood cells

(c) Phagocytic cells – Absent in lymph nodes (d) Lymphoid organ – Adam's apple

488. The normal range of urea in the blood of humans is

(a) 2*mg* – 5*mg* / 100 *ml* of blood (b)5*mg* – 10*mg* / 100 *ml* of blood

(c) 17*mg* – 30*mg* / 100 *ml* of blood (d)0.1*mg* – 0.5*mg* / 100 *ml* of blood

489. Identify the incorrectly matched pair

(a) Uremia – excessive amount of urea in blood (b) Hyperglycemia – excess glucose in blood

(c) Absence of factor VIII – Haemophilia (d) X-linked disorder – Glycosuria

BLOOD GROUP GENETICS

Basic Level

490. A person with blood group *O* receives blood transfusion from person with the blood group

(a) *O* only (b) *O* and *AB* (c) *O*, *A* and *B* (d) *AB* only

491. When blood of one person is mixed with the serum of an other person then in certain cases, clumping of RBCs takes place. the clumping is due to

(a) Antitoxin – antibody reaction (b) Antigen – antibody reaction

(c) Haemolysis (d) Blood coagulation

492. Which one of the following has the least constancy in shape

(a) Muscle fibres (b) Neurons (c) RBC (d) WBC

493. *Rh* factor is a protein present

(a) On RBC (b) In plasma (c) On WBC (d) In serum

494. If mother has blood group B, father has A group, the offspring will be of

(a) A group (b) O group (c) Any of the group (d) AB group

495. The royal bleeder disease or haemophilia is an example of

(a) Sex – linked inheritance(b)X – linked character

(c) Cris – cross inheritance (d)All of these

496. Incompatibility of *Rh* group between husband or wife will result in the birth of a baby with a disorder called

(a) Anaemia (b) Haemophilia

(c) Pernicious anaemia (d) Erythroblastosis fetalis

497. Rh-factor was discovered by

(a) Land steiner and Weiner (b) Strasburger

(c) Wheeler (d) Hornberg

498. Persons with *O* blood group can take blood from

(a) A (b) B (c) O (d) AB

499. The blood group with antibody – *a* and antibody – *b* is

(a) *A* (b) *B* (c) *O* (d) *AB*

500. A cell with a kidney – shaped nucleus is

(a) Eosinophil (b) Lymphocyte (c) Monocyte (d) Neutrophil

501. The possible blood groups of the offsprings of the parents with blood group *O* and *AB* will be

(a) A and B (b) O and AB (c) A, B and AB (d) O, A, B and AB

502. What is the function of white blood cells

(a) Clotting (b) Respiration

(c) Eating harmful organisms (d) None of these

503. An 'antigen' is

(a) that which acts with plasma (b) That which opposes the action of antibody

(c) The stimulus for antibody production (d) The antibody only

504. Universal donar has blood group

(a) *AB* (b) O^- (c) O^+ (d) O^- or O^+

505. Between which two blood groups, the blood transfusion is possible

(a) A and O (A = Donor) (b)B and A (B = Donor)

(c) AB and AB (AB = Donor) (d) AB and O (AB = Donor)

506. Besides blood transfusion study of blood groups is also helpful in

(a) Personally estimation (b)Settling paternity disputes

(c) Health status (d)None of the above

507. Haemophilia is

(a) A type of mosquito lacking a haemocoel (b) The royal disease

(c) Faulty blood clotting (d) (b) and (c) both

508. When both parents are of blood type AB, they can have children with

(a) A, B, AB and O blood types (b) A, B and AB blood types

(c) A and B blood types (d) A, B and O blood types

509. Antigen-A and antibody-b are present in which blood group

(a) *B* (b) *A* (c) *AB* (d) *O*

510. Antibody is to

(a) To induce the formation of antigen (b) To help in production of WBC

(c) Formed by WBC (d) None of the above

511. Chemical nature of antibody is

(a) Protein (b) Lipid (c) Lipoprotein (d) Nucleoprotein

512. A cubic millimeter of blood contains about

(a) 50,000 white blood corpuscles (b) 7, 000 white blood corpuscles

(c) 1,000 white blood corpuscles (d) 20,000 white blood corpuscles

513. Blood of which blood group can be given to a person with AB blood group

(a) AB only (b) O only (c) A or B (d) All the above

514. The possible blood group of children born to parents having A and AB groups are

(a) O, A (b) A, B, AB (c) O, A, B (d) O, A, B, AB

515. Which of the following diseases is related to abnormality in clotting of blood

(a) Polycythemia (b) Microcytic anaemia (c) Haemophilia (d) Sickle cell anaemia

516. If thymus gland of an infant is removed which of the following will not form

(a) *T* – lymphocytes (b) β – lymphocytes (c) Erthryocytes (d) Granulocytes

517. If a person is injured, he should be given blood. Which of the following blood group should be given without checking the patient's own blood group

(a) A (b) B (c) AB (d) O

518. Cells in blood that destroy invading disease producing bacteria

(a) Platelets (b) RBC (c) Skin cells (d) WBC

519. Which of the following statements is correct for blood group *O*

(a) *A* and *B* antigen present (b)*A* antigen and *b* antibodies present

(c) Antigen and antibodies both absent (d)No antigen but both *a* and *b* antibodies are present

520. The child of a couple has a blood group B. His mother's blood group was AB. What will be blood group of father

(a) A (b) B (c) AB (d) O

521. What is the meaning of blood group 'B'

(a) The person can form antibody for 'B' (b) The person cannot form antibody for 'B'

(c) The person cannot give blood to 'O' group (d) The person can receive blood of group 'AB'

522. In sickle cell anaemia RBC becomes

(a) Sickle shaped (b) More flexible and strong

(c) Is genetically inherited (d) Shape and size do not change

523. Which blood group accepts blood of groups *A* and *B*

(a) *AB* (b) *A* (c) *B* (d) None of these

Advance Level

524. Identify the correct statement

(a) Clumping of blood of one person with the other is an example of blood coagulation

(b) If the RBC contain both antigen A and B then the serum will be devoid of antibody *a* and *b*

(c) Antigen A reacts with antibody B

(d) All antigens are glycoprotein

525. No antigens occur in the RBC of a person with the blood group

(a) A (b) AB (c) O (d) B

526. The antigen present on the RBC of a person with blood group A, B and AB are chemically

(a) Sterols (b) Glycolysides (c) Glycoprotein (d) Protein

527. What will be the likely blood group of children born out of the marriage between father with blood group O and mother with AB.

(a) A and B (b) AB (c) O (d) B and O

528. A person is detected to have antigen A in his RBC, his blood group would be

(a) O (b) A (c) A or O (d) B

529. Person with this blood group can receive blood only from a person with the same blood group

(a) O (b) B (c) AB (d) A

530. Blood transfusion from a donor of *AB* group given to a patient of *B* group is not successful because

(a) Patient lacks antibody - *a* (b) Patient lacks antibody - *b*

(c) Patient has antibody - *a* (d) Patient has antibody - *b*

531. Antigens are present

(a) Inside nucleus (b) On cell surface

(c) Inside cytoplasm (d) On nuclear membrane

532. Which of the following blood groups is a universal recipient in blood transfusion

(a) A (b) B (c) AB (d) O

533. In a patient with blood group *AB*, the agglutinins present in serum are

(a) Antigen *A* and *B* (b) Antigen *A*

(c) Antigen *B* (d) Neither antigen *A* nor antigen *B*

534. *M* and *N* blood groups are of importance in

(a) Blood transfusion (b) Medicolegal tests (c) (a) and (b) both (d) None of these

535. What is not true about *Rh* factor

(a) 95% of human population is *Rh*– and 5% *Rh*+ (b) *Rh* factor was discovered by Landsteiner

(c) *Rh* factor is named after Rhesus monkey (d) Rh+ man can marry Rh+ women

536. If the foetus is Rh^+ and mother is Rh^- then

(a) Foetus will transmit antigen to mother blood

(b) Foetus will transmit antibody to mother blood

(c) Foetus is attacked by antibodies of mother blood

(d)Foetus is attacked by antigen of mother blood

537. Blood groups is due to

(a) Specific antigen on the surface of WBC (b) Specific antibodies on the surface of RBC

(c) Specific antigen on the surface of RBC (d) Type of haemoglobin present in blood

538. Erythroblastosis foetails occurs

(a) When the mother is *Rh* positive and child is *Rh* negative

(b) When the father and child are both *Rh* negative but the mother is *Rh* positive

(c) When the mother and child are both *Rh* positive but the father is *Rh* negative

(d) When the mother is *Rh* negative and child is *Rh* positive

539. Erythroblastosis is caused due to

(a) Blood coagulation

(b) Mixing of 'A' and 'B' blood groups

(c) Condition in the foetus brought about by the *Rh* incompatibility (d) Haemophilia

540. Erythroblastosis foetails occurs when

(a) Husband is Rh^- and wife Rh^- (b)Wife is Rh^+ and husband Rh^-

(c) Wife is Rh^+ and husband Rh^+ (d)Wife is Rh^- and husband Rh^+

541. The genotype I^BI^B and I^BI^O produces the blood group type

(a) *A* (b) *B* (c) *AB* (d) *O*

542. The problem, due to Rh^- factor arises when the blood of two $(Rh^+ and\ Rh^-)$ mixup

(a) In a test tube (b) Through transfusion (c) During pregnancy (d) In the laboratory

543. Antiserum contains

(a) Antigens (b) Leucocytes (c) Antibodies (d) None of these

544. The two children of a couple have the blood group *A* and *B*. Their mother's blood group is *O*. What is the blood group of their father

(a) *A* (b) *B* (c) *O* (d) *AB*

545. A women with the blood group A^+ married a man with the B^+ blood group. Their children would have the blood group

(a) *A* and *B* (b) *A* and *AB* (c) *B* and *AB* (d) *A*, *B*, *AB* and *O*

546. The genotype of the husband was I^0I^O and that of the wife I^AI^B. Their children will have the blood group

(a) A and B (b) AB (c) A, AB (d) A, AB, B + O

547. If the father has the blood group *A* and the child *O* his genotype will be

(a) I^AI^O (b) I^OI^O (c) I^AI^A (d) None of these

548. A hematologist wanted to prepare a table showing blood group donor and recipient. Which of the following is correct in this regard

(a) *AB* donor and *O* recipient (b) AB donor and AB recipient

(c) B donor and A recipient (d) A donor and O recipient

549. From the following, find the one where blood transfusion would be fatal

(a) AB donor and O recipient (b) O donor and B recipient

(c) O donor and O recipient (d) O donor and AB recipient

550. If both antibodies *a* and *b* are present in the plasma but there is no antigen in RBC, the blood group of the person shall be

(a) *A* (b) B (c) AB (d) O

551. A person with blood group A can donate blood to person with blood group

(a) A (b) A and AB (c) AB and O (d) B and O

ANSWER

CIRCULATORY SYSTEM

BASIC AND ADVANCE LEVEL

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
c	d	c	d	d	c	c	c	c	b	d	a	a	a	a	a	d	a	a	d
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
d	d	c	a	b	a	d	d	a	d	d	c	a	c	c	b	a	d	d	b
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
b	a	c	b	b	b	b	b	d	b	c	a	d	b	a	a	d	c	c	a
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
d	a	d	d	a	c	c	b	a	a	a	d	b	d	a	d	a	a	a	a
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
d	a	a	d	d	d	a	c	c	a	b	a	d	a	b	d	d	c	a	a
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
b	c	c	b	d	d	a	a	a	c	a	d	c	d	b	b	a	b	b	a
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
a	c	d	a	a	b	d	b	b	c	a	a	b	d	c	b	c	d	a	d
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
d	c	d	c	a	a	c	a	a	d	d	b	b	b	b	b	a	c	d	b
161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
d	d	c	b	c	b	c	c	a	d	c	c	d	c	c	c	c	b	c	d
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200
b	a	d	a	d	d	c	a	d	c	b	c	b	d	d	b	c	c	d	b
201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220
a	a	c	c	d	c	a	b	a	b	c	a	d	a	c	a	c	b	a	c
221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
a	b	a	c	d	a	b	c	c	b	c	c	b	c	b	a	a	b	c	c
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
d	b	b	c	c	a	a	b	b	b	a	c	d	c	d	b	b	c	b	a
261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280
c	c	b	b	c	a	b	a	a	a	a	d	c	b	d	d	c	b	d	c
281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
b	d	c	c	a	d	d	d	b	d	c	c	a	d	c	c	d	a	a	b
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320
c	c	d	b	c	c	a	c	b	a	c	c	b	b	c	b	c	c	d	d
321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340

b	d	d	d	d	b	b	d	d	a	c	d	a	b	c	d	a	b	c	b
341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360
a	b	d	c	d	b	a	b	d	b	c	a	b	a	d	a	d	b	a	d
361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380
d	d	a	a	a	a	c	a	d	a	a	c	b	d	b	a	a	b	c	a
381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400
b	c	c	a	a	b	b	a	b	c	b	c	d	c	c	d	b	c	a	b
401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420
d	b	d	c	d	b	c	b	a	c	b	a	c	b	c	c	a	c	c	a
421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440
b	a	d	d	c	d	b	a	c	c	a	d	a	b	b	c	d	c	d	c
441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460
c	a	d	c	b	c	c	c	d	b	b	d	c	c	a	c	a	d	b	a
461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480
a	b	d	d	d	a	a	a	b	c	a	d	c	a	a	b	d	a	b	a
481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500
b	d	c	b	b	d	a	c	d	a	b	d	a	c	d	d	a	c	c	c
501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520
a	c	c	d	c	b	d	b	b	c	a	b	d	b	c	a	d	d	d	a
521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540
b	a	a	b	c	d	a	b	a	c	b	c	d	b	a	c	c	d	c	d
541	542	543	544	545	546	547	548	549	550	551									
b	b	c	d	d	a	a	b	a	d	b									

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