Chapter 2

Systemic Anatomy and Physiology

THE CIRCULATORY SYSTEM

THE BLOOD

Blood is the transport medium of the body. The circulating blood carries oxygen from the lungs, food from the digestive tract, waste products from the tissues, i.e. carbon dioxide from the tissues, hormones from the endocrine glands and heat from the site of production to the cooler parts of the body. The color of the blood varies with its oxygen contents, thus in arteries it is bright scarlet and in veins it is dark red or purple. Blood consists of a fluid called plasma, in which are suspended a large number of cells, red cells (erythrocytes or red corpuscles), white cells (leucocytes or white corpuscles) and platelets (thrombocytes). Plasma accounts for 55% of the blood volume and the suspended cells for 45% (packed cell volume). The total blood volume of an average adult is about 5 L.

The distribution of water in the body constitutes about 60% of total body weight in men and 50% in women. This difference is due to body mass which is the total weight of fat free tissue, and this is greater in man than in women. The total body water is divided between two main compartments:

1. **Intracellular fluid:** The fluid within the cells, this constitutes 70% of the total body water.
2. **Extracellular fluid:** It is about 30% of the total body water and is present within.
   a. The interstitial fluid is the fluid surrounding the cells (20% of total body water)
   b. The plasma which is about 10% of the total body water and transcellular fluid includes synovial fluid, urine, the digestive juices in the alimentary canal and the cerebral spinal fluid (about 150 ml). The water balance of the body is maintained by the rate of water excretion by the kidneys. This rate of excretion is controlled by antidiuretic hormone secreted from the posterior pituitary gland.

THE PLASMA

Plasma is a slightly alkaline yellowish fluid which consists of the following:

Water	90%
Proteins	Albumin and globulin
Inorganic salts	Sodium chloride, sodium bicarbonate and smaller amounts of potassium, calcium, magnesium,

	phosphorus (as inorganic phosphate), sulfate and iron. These are referred as plasma electrolytes.
Foodstuffs (nutrients)	Glucose, amino acids, fats and vitamins
Waste products	Urea, uric acid and creatinine
Fibrinogen, prothrombin hormones, enzymes	Necessary for the clotting of blood

The plasma proteins are generally too large a molecule to leave the blood vessels. They are thus important for maintaining the osmotic pressure of blood and preventing loss of fluid from the circulation. At the arterial end of the capillary, the hydrostatic force within the vascular compartment is sufficient to cause fluid to pass into the interstitial space. However, at the venous end of the capillary, the osmostic pressure of the plasma proteins exceeds the hydrostatic pressure and most of the fluid is returned to vascular compartment. The residual fluid is usually drained away by the lymphatic system. In some disorders of kidney, protein is lost in the urine in large amounts, osmotic pressure of blood falls and fluid gathers in the intercellular tissue spaces causing swelling, known as edema. Plasma proteins have some buffering capacity and this way they help to maintain a constant blood pH .

The globulin fraction of the plasma proteins contains the antibodies which are important in the body's defence against infection.

THE BLOOD CELLS

There are three type of blood cells:

1. Red cells (erythrocytes),
2. White cells (leucocytes) and
3. Platelets (thrombocytes).

The erythrocytes are most numerous of the blood cells, biconcave (this shape provides larger surface area for oxygen and carbon dioxide exchange than a spherical one), non-nucleated discs about 7.2 cm in diameter. The cell membrane is elastic and deformable allowing the red cell to be distorted to pass through narrow capillaries. Their normal count in an adult male is 5×10^{12}/L of blood.

The erythrocyte contain a special colored protein called hemoglobin in combination of haem (ferrous-iron-containing pigment) and globin. A normal person has about 14.5 gm hemoglobin/100 ml of blood. Hemoglobin has a marked affinity for oxygen with which it combines reversibly in the lungs where oxygen tension is high. In tissue where cell metabolism produces carbon dioxide, hemoglobin delivers its oxygen. Increasing of hemoglobin within the cells, prevents its loss in urine and destruction by macrophages.

The formation of erythrocytes (erythropoesis) take place in the red bone marrow from large nucleated cells. These cells divide to form progressively smaller cells and as the erythrocytes mature they loose their nucleus. In the absence of sufficient iron and vitamin B_{12}, folic acid, the cells produced are microcytic and macrocytic respectively.

A normal red cells has life span of 120 days in the circulation. Afterwards the cell is destroyed in the macrophage system. The hemoglobin is released, iron and globin are separated out. Thus bile pigment (bilirubin) is formed in the liver, excreted in bile, whereas iron is stored as ferritin until needed for new hemoglobin formation.

If anticoagulated blood is allowed to stand in a narrow vertical tube (western green/ wintrobe), the erythrocytes will settle (ESR) at a particular rate. This rate is increased in various diseases.

Anemia is the condition in which the hemoglobin concentration is below normal. There may be following causes:

1. Blood loss—either acute or chronic
2. **Inadaquate red cell production:** This may occur due to the lack of essential factors (iron, vitamin B_{12} or folate) and may be caused by destruction of the bone marrow by certain chemicals, X-rays, drugs, secondary carcinoma invasion or leukemia.
3. Increased red cell destruction, known as hemolysis. Hemolytic anemias may be due to abnormalities of the red cells, which are, therefore, destroyed more quickly than normal red cells or due to the factors (malaria, drugs or antibodies) which lead to premature destruction of normal red cells.

The leucocytes or white blood cells are fewer in number than the red cells. The normal count ranges from 4 to 11×10^9/I and also there are variations from hour to hour in a healthy individuals. The white cells can be classified—granulocytes and agranulocytes. Granulocytes are of three type:

1. Neutrophils
2. Eosinophils
3. Basophils

These are 10 to 14 µm in diameter, the neutrophil plays a significant role in body's defence mechanism against infection (bacterial) by reaching at the site of infection as they are highly motile cells. Eosinophil which are phagocytic but less motile respondants to allergic conditions. Basophil are the least numerous of the granulocyte series. They are similar to tissue mast cells and are important in certain hypersensitivity reactions.

Lymphocytes are formed in the bone marrow, from there they migrate to thymus (to become ' T ' lymphocytes or killer cells), and lymphatic tissue of GI tract (to become 'B' lymphocyte having capability to produce antibodies.

Monocytes are the largest cells amongst white blood cells (14–18 µm). They are phagocytic. Some circulate in the blood stream while others leave to join the macrophage system. The proportions of all the white cells in healthy are as follows:

Granulocytes 70% (neutrophil 40–75%).

Eosinophil 16% and basophil 0–1%, lymphocytes 20–45% and monocytes 2 to 10%.

Platelets (thrombocytes) are colorless cells, vary in shape, small (2–4 µm), non-nucleated and are $150–400 \times 10^9$ L in number. They are formed in bone marrow from magakaryocytes. Platelets play a very significant role in blood clotting.

Bone marrow: Bone marrow is found in the center of all bones and is of two types, red marrow and yellow marrow. Red marrow is usually present throughout the skeleton at birth but after the age of five years it is gradually replaced in the long bones by yellow marrow. By the age of 20–25 years, the red marrow is present only in the ribs, the sternum, the vertebrae, the skull, the pelvis and upper ends of the femora and humeri.

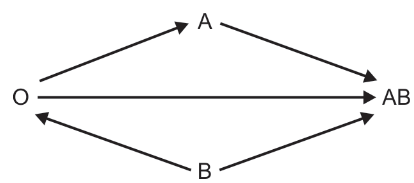
Blood Groups

The moderate to severe blood loss is often treated by transfusion and if blood of an incompatible group is transfused the cells of the given blood agglutinate (clumping or sticking of cells). This phenomenon gave the origin to blood group. There are four main blood groups—A, B, AB and O. The process of agglutination is caused by a substance, called an agglutinogen, which is present on the red cells, of one group react with a substance called an agglutinin which is present in the plasma of another group. The distribution of agglutinogens and agglutinins in people with different ABO blood group shown in Table 2.1.

Table 2.1: The distribution of agglutinogens and agglutinins in people with different ABO blood group

Blood group	O	A	B	AB
% age of population	46%	42%	9%	3%
Cells	—	Agglutinogen	Agglutinogen	A and B agglutinogen
Plasma	Anti-A and Anti-B agglutinins	Anti-B agglutinin	Anti-A agglutinin	–

Since blood group AB has no agglutinins in the plasma, persons of this blood group can often be transfused with blood of the other groups (universal receipient) whereas blood group O has no agglutinogen (universal donor) can donate blood to others without much complications. Thus blood transfusion may be given along with the lines indicated by the arrows.



In 1940 another important blood group was discovered and has been named Rhesus factor or Rh system. Unlike ABO system, no preformed Rhesus agglutinin (Anti-D) is found. However, a Rhesus negative (Rh-ve) person, can make Anti-D following sensitization with Rhesus positive blood. The ABO and Rhesus blood group systems are the main groups but there are others such as the M, N, Kell, Luther and Duffy which may be occasional causes of blood transfusion reactions.

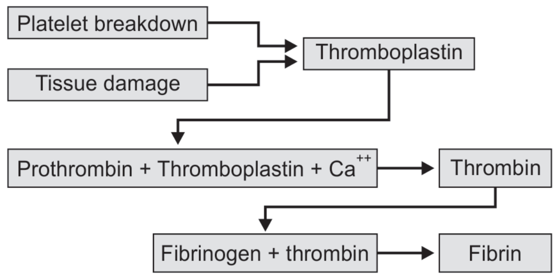
The Clotting of Blood

Whenever blood oozes from an injured blood vessel, it tends to clot, in an attempt to prevent further blood loss. The mechanism involved in blood clotting are complex. The process involves a number of steps in a so-called cascade system. The clotting cascad is a chain reaction initiated either by contact of platelets with damaged vascular endothelium or by contact with tissue fluid when the vessel wall is breached. In brief, it is a three stage process.

Stage I: The formation of thromboplastin (thrombokinase)

Stage II: Conversion of prothrombin to thrombin by the thromboplastin in the presence of Ca^{++}.

Stage III: Conversion of fibrinogen by the thrombin to fibrin.



There are thirteen clotting factors in all, which are required for the clotting mechanism to complete. Out of these in the absence of factor VIII, anti-hemophilic globulin (AHg), a condition known as hemophilia does occur. It is a sex linked disease in which males are the sufferer and females are the transmitters.

THROMBOSIS AND FIBRINOLYSIS

Normally blood does not clot within blood vessels but occasionally sometime this happen and is called thrombosis. There is also a natural system exists in blood vessels which opposes the clotting of blood. Plasminogen is converted to the active plasmin, which digests the insoluble fibrin. In healthy individuals the activities of the coagulation and fibrinolytic systems are balanced.

Bone marrow transplantation: Bone marrow transplantation is now being used to replace diseased marrow with healthy bone marrow cells obtained from suitably matched donor.

THE BLOOD VESSELS

The blood is pumped by the heart through a closed system of vessels. These vessels are of three types: arteries, capillaries and veins.

Arteries

The arteries carry the blood away from the heart to the tissues. They all consists of three coats: (i) Tunica adventitia (outer coat) is composed of fibrous tissue containing a few elastic fibers. (ii) Tunica media (middle coat) consists of smooth muscle fiber which run in circular direction. (iii) Tunica intima (inner coat) is composed of a single layer of endothelial cells with underlying elastic tissue (Fig. 2.1). In large arteries, there is more elastic tissues in tunica media than in small arteries. The very small arteries are called arterioles.

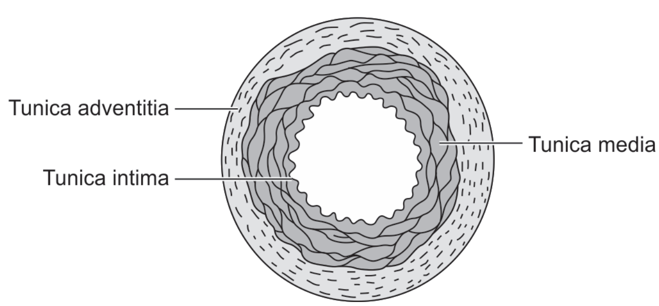


Fig. 2.1: Cross-section of an artery

Capillaries

The arterioles divide into very small vessels called capillaries. The wall of the capillary is composed of a single layer of endothelial cells which is continuous with the endothelial lining of the arterioles. It is through the wall of the capillaries that the exchanges between plasma and interstitial fluid take place. The diameter of a capillary is about the same as that of a red blood cell.

Veins

Veins, like arteries have three coat wall with some differences like the thickness of middle coat is much thinner and the lumen is larger as compared with arteries (Fig. 2.2a and b). Most of the large veins have on their inner surface, valves which serve to prevent back flow of blood. These are folds of tunica intima strengthened by connective tissue and elastic fibers. They are of particular importance in the lower part of the body when the blood is returning towards the heart against gravity.

The Heart and Circulation

The heart is a muscular pump, consisting of four chambers, two right and two left with normally no direct communication between two sides (Fig. 2.3). Blood is returned to the heart from the body through the superior and inferior venae cavae open into a thin walled chamber called the right atrium. The right atrium pumps the blood through a valve called the tricuspid valve into a chamber called right ventricle, the right ventricle in its turn pumps the blood through the pulmonary artery into the lungs. In the capillaries of the lungs, the blood takes up oxygen and releases carbon dioxide. The oxygenated blood passes through the pulmonary veins into a thin walled chamber called the left atrium. The left atrium pumps the blood through a valve, called the mitral valve, into the thickest walled chamber of the heart, the left ventricle. The left ventricle in turn pumps the blood into the aorta from where it is distributed to the body. These series of events occur in parallel so that left and right ventricles contract together. The general circulation of the body is known as the systemic circulation and the circulation of the lungs is called the pulmonary circulation. Greater pressure is required to pump the blood through systemic circulation as compared with pulmonary circulation. Thus the thickness of left atrium and left ventricle are self-explantory.

The Nerve Supply to the Heart

The heart is supplied by branches of the vagus and sympathetic nervous system.

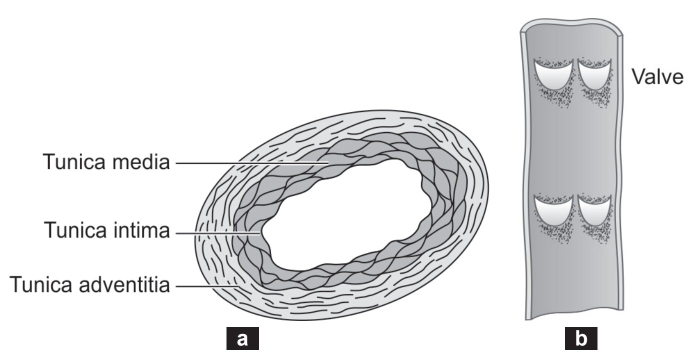


Fig. 2.2: Structure of a vein: (a) transverse section, and (b) longitudinal

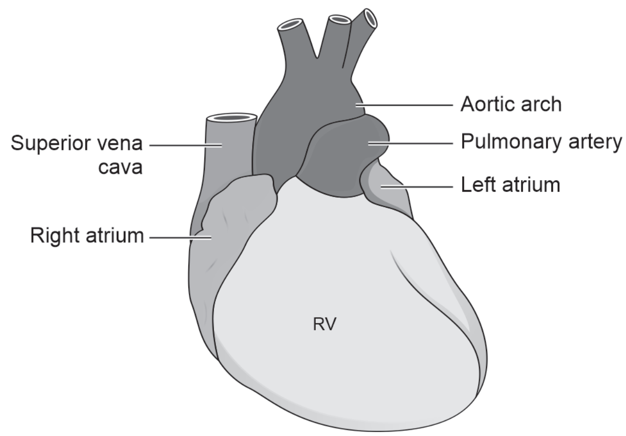


Fig. 2.3: The heart, anterior view

The Functions of the Heart

The functions of the cardiovascular system is to maintain an adequate supply of blood to all the body tissues according to their metabolic needs. Arterial blood carries oxygen, glucose and other nutrients to organs and tissues. Venous blood transport the 'waste' products of tissue metabolism such as carbon dioxide and lactic acid away from these tissues.

The blood supply to the vital systems, such as the brain and kidneys are always looked after by special features such as high atmospheric pressure in the arteries of these even after blood loss.

The flow of blood to exercising muscle is increased and this is important so that adequate supply of nutrients and simultaneouly removal of products of metabolism are maintained.

Cardiac Cycle

The heart muscle contracts rhythmically at the rate of 72 beats/min (in the resting state). Each contraction is in a cyclic manner. The origin of the impulse is at sinoatrial node (SA node) (Fig. 2.4) which is a group of specialized cells situated in the wall of the right atrium near the enterance of the superior vena cava. The SA node originates each heartbeat, therefore it is also known as pacemaker. The cardiac muscles are striated like skeletal muscle but they have syncytical like arrangement (having inter calated discs of low resistance area) enables a contraction wave to spread rapidly from cell to cell until the whole muscle mass is in a state of contraction. No nerves are involved in the spread of the contraction waves through cardiac muscle. Therefore, from SA node, the impulse spreads to AV (atrioventricular) node situated in the interatrial septum near the mouth of the coronary sinus. These two nodes (SA and AV) are supplied by fibers from sympathetic and vagal fibers of parasympathetic systems. From AV node, the contraction wave spreads to atrioventricular bundle (bundle of His). This bundle runs into the ventricles in the septum between the right and left ventricle. The sequence of events of heart contraction and relaxation, are known as cardiac cycle, which are as follows (Fig. 2.5). With the onset of ventricular systole, the pressure in the ventricle starts to rise.

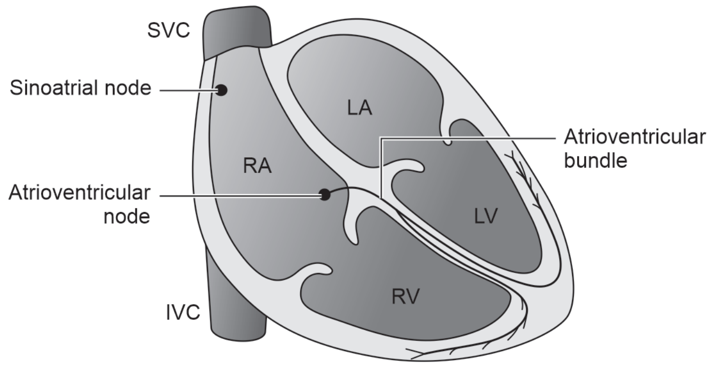


Fig. 2.4: Diagrammatic representation of the conducting system of the heart

As soon as it exceeds that in the corresponding atrium, the atrioventricular valves will shut. This simultaneous closure of the mitral valve (between left atrium and left ventricle) and tricuspid (between right atrium and right ventricle) valves with the onset of systole produces the first heart sound. It can be heard by applying the ear to the chest wall of the subject. The sound heard may be likened to the word 'lub' spoken very softly. It lasts for 0.15 seconds and the principal frequency of the sound produced are in the range of 25–45 cycles per second. As soon as the ventricular pressure exceed those in the aorta and the pulmonary artery (120 mm Hg), the aortic and pulmonary valves will open (semilunar). The opening of the valves does not produce any detectable sound. During the short interval of the time between the closure of the mitral valve and tricuspid valve and the opening of the aortic valve and pulmonary valve the left and right ventricle are closed chamber. Since blood is incompressible and although the contraction of the ventricular muscle is increasing the pressure in the ventricles, though there is no actual change in the volume is known isometric contraction phase. Soon after this the aortic and pulmonary valves are opened, the ventricle ejects their blood first rapidly (rapid ejection phase) and then slowly into aorta and in pulmonary artery. At the end of ventricular systole, the pressure in the ventricle drops and the aortic and pulmonary valves are closed as the pressure in these vessels now exceeds that in the ventricles. There is a short 'isometric relaxation phase' during which time the ventricles once again are closed chambers but as soon as the ventricular pressure has fallen below to that in the atria, the mitral and tricuspid valves are open, causing filling of ventricles.

The closure of the aortic and pulmonary valves gives rise to the second heart sound. This is of short duration and high pitched heard as 'Dup'. It lasts for 0.1 seconds the principle frequency is around of 50 cycles/second. The pressure and volume changes in all the heart chambers during cardiac cycle along with the heart sounds and ECG are shown in Fig. 2.5.

Electrocardiography (ECG)

Each impulse generated by the SA node and passing through the conducting system of the heart causes a series of electrical changes in the heart muscle which preceed the associated mechanical events. These electrical changes can be recorded by placing the electrode on the surface of the body. There are two basic type of electrode (lead system)—

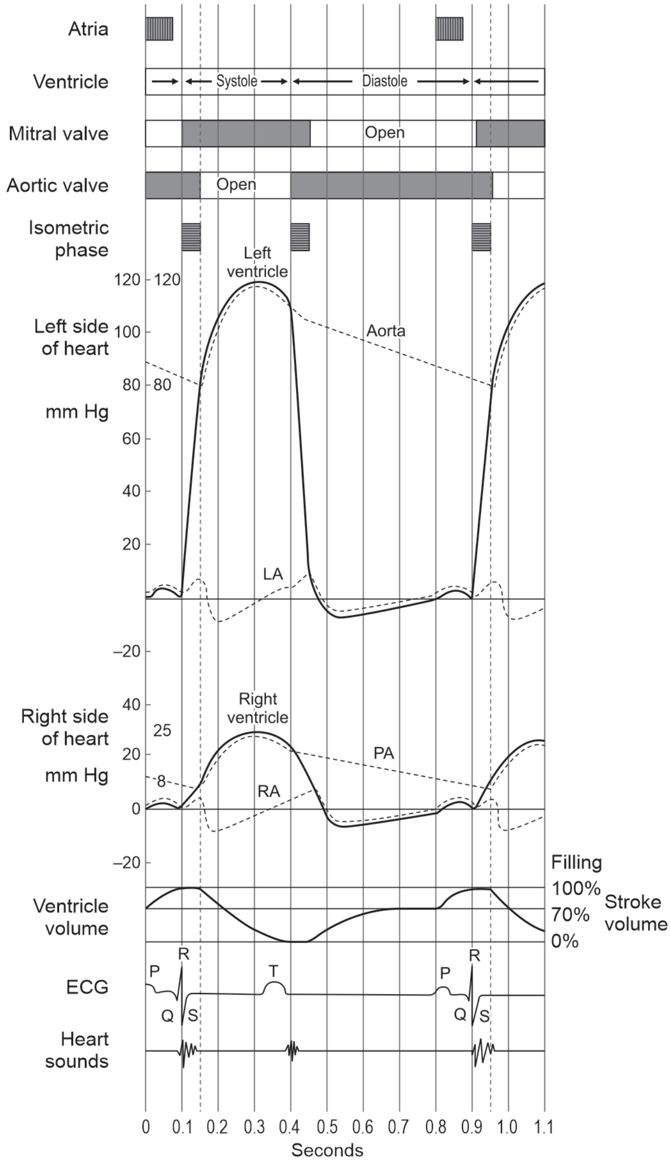


Fig. 2.5: The sequence of events in the cardiac cycle starting with the onset of atrial systole. Part of the subsequent cycle is shown. PA = Blood pressure in the pulmonary artery; RA = Right atrial pressure; LA = Left atrial pressure

bipolar and unipolar. By varying the position of the electrode, information about the passage of impulse through various parts of the heart can be obtained. The normal pattern of ECG is shown in Fig. 2.5 along with the cardiac cycle. The various peaks of ECG as 'P' wave it represents the passage of the impulse through the atria, the 'QRS' complex, the impulse passing through the ventricular recovery. Electrocardiography plays an important part in the investigation of the heart as a condition known as atrial fibrilation, the atria beats rapidly which are depicted in ECG pattern as large number of irregular, lower amplitude fibrilation.

Cardiac output: In each systole, the ventricle ejects 70 ml of blood into the aorta and this is known as stroke volume. At a normal resting heart rate 70/min, the heart pumps about 5 L of blood and this is known as cardiac output. Therefore cardiac output = stroke volume × heart rate.

Any factor affecting stroke volume and heart rate is going to affect CO (cardiac output). The stroke volume depends upon: (a) Volume of venous blood returning to the heart (venous return) and the venous return would depend upon peripheral resistance. (b) The strength of contraction, which does changes according to venous return. This relationship is known as 'Frank starling law'. Also whenever there is sympathetic stimulation the strength of contraction of heart muscle would increase at the cost of end systolic volume whereas the regulation of heart rate very much depends upon the activity of SA node, stimulation of vagal nerve would slow its (SA node) activity and impulsus from the sympathetic nervous system accelerate the heart rate as explained earlier. Thinking of exercise or actual doing the exercise would bring about the increase in heart rate as well as in strength of contraction.

Therefore, increase in cardiac output during exercise is justified as fulfilling the body demands for more oxygen. The cardiac output can be measured by dye dilution method.

THE BLOOD PRESSURE

The blood pressure is the pressure exerted by the blood on the lateral walls of the arterial vessels. The pressure is higher during left ventricular systole, around 120 mm Hg in healthy individuals. This is known as systolic blood pressure, when left ventricular systole is over, the aortic valve closes and the elastic arterial walls do recoil. Although the blood pressure falls, it does not reach zero because left ventricular systole occurs again. The lowest blood pressure is usually about 80 mm Hg and this is known as the diastolic blood pressure. The blood pressure is equal to cardiac output and peripheral resistance. The existance of normal blood pressure is quite essential as tissues of the body need an adequate blood flow and to provide this an adequate head of pressure must be available in the vessels supplying the tissues, particularly brain. The brain, in sitting or standing position, is situated at a higher level than the heart, and blood has to be pumped uphill from the heart to the brain. Unless an adequate blood pressure is maintained at the level of the heart, the cerebral blood flow will be insufficient to maintain consciousness. A person who faints due to a fall in blood pressure should be placed with his head at the same level as the heart, such as flat on the floor. The kidneys also need adequate blood pressure though for a different reason. There the pressure is needed for filtration (GTR) so that formation of urine remains to be continued.

We have studied earlier the factors affecting cardiac output. Now let us know various factors affecting peripheral resistance. The peripheral resistance depends mainly upon the smooth muscle of the arterioles and the pre-capillary sphincters, their smooth muscle is under the control of sympathetic nerve activity known as sympathetic tone or vasoconstrictor tone. The tone originates in the medulla in a collection of cells known as vasomotor center (VMC). As shown in Fig. 2.6 an increase in activity of VMC would decrease the diameter of the arterioles and would lead in the increase in peripheral resistance and arterial blood pressure. Conversely a decrease in VMC activity would cause fall in blood pressure.

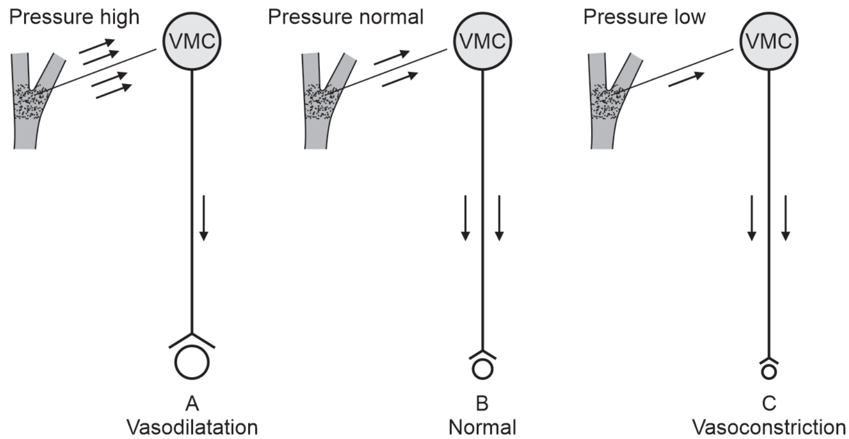


Fig. 2.6: Baroreceptor activity and arteriolar tone

A. High pressure in baroreceptor region gives increased baroreceptor activity, and a reduction in vasoconstrictor tone. This results in vasodilatation of the arterioles.
B. Normal, baroreceptor activity partially inhibits the vasomotor center (VMC) giving normal arteriolar tone.
C. A low pressure in the baroreceptor regions reduces baroreceptor inhibition of the VMC. The arteriolar tone increases giving vasoconstriction.

Baroreceptors are stretch receptors situated in aortic arch and carotid sinus, when stimulated (when blood pressure is increased) leads vasodilation via VMC as shown in Fig. 2.6 and during low blood pressure the reverse effect is observed. Baroreceptors along with other factors shown in Fig. 2.7 brings about changes in heart rate by acting on cardiac center.

The estimation of blood pressure (systolic and diastolic) in human beings can be carried out by using mercury sphygmomanometer.

BLOOD VOLUME

Blood volume which is about 75–80 ml/kg of body weight or 5L in an average adult is kept remarkably constant in health. Fluid is lost from the body in the urine, sweat, faeces and there is insensible loss through the lungs as water vapour and the skin. Fluid intake, which balances these losses is controlled by thirst. In addition, increased loss via one route is usually offset by decreased loss via another. For example, excessive sweating, caused by heat exposure is associated with a marked decrease in urine output.

Normally water deplition is prevented by the antidiuretic hormone as mentioned earlier. Conservation of sodium by the body is another important aspect to maintain the blood volumes. The mechanism by which it is maintained is known as renin-angiotensin-aldosterone system.

Therefore, blood flow through tissues and organs is dependent upon total blood volume, arterial blood pressure, the state of arterioles and blood viscosity.

THE PULMONARY CIRCULATION

The main pulmonary artery arises from the right ventricle through which venous blood is sent to lungs and from lungs arterialised blood returns to the heart via pulmonary

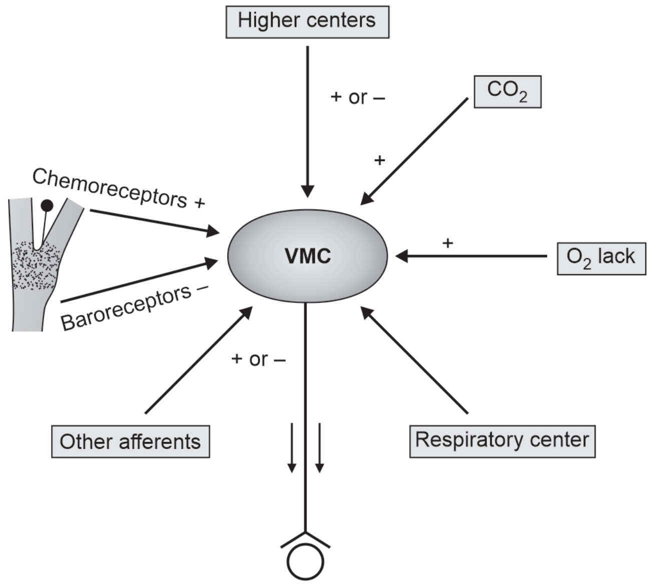


Fig. 2.7: Factors affecting the vasomotor center activity

veins to left atrium. This circulation in series with systemic circulation as shown in Fig. 2.8. It is low pressure system as there are no such resistance vessels as present in systemic circulation (the arterioles). Absence of arterioles make the blood flow through capillaries pulsatile. The blood flow in pulmonary circulation is high during systole as compared with diastole. The pressure in the pulmonary artery is only 25/5 mm Hg (systolic and diastolic respectively). Also pulmonary blood vessels are thin walled and distensible, having large capacity so that at one time it can contain one-fifth of the total blood (1 liter) volume.

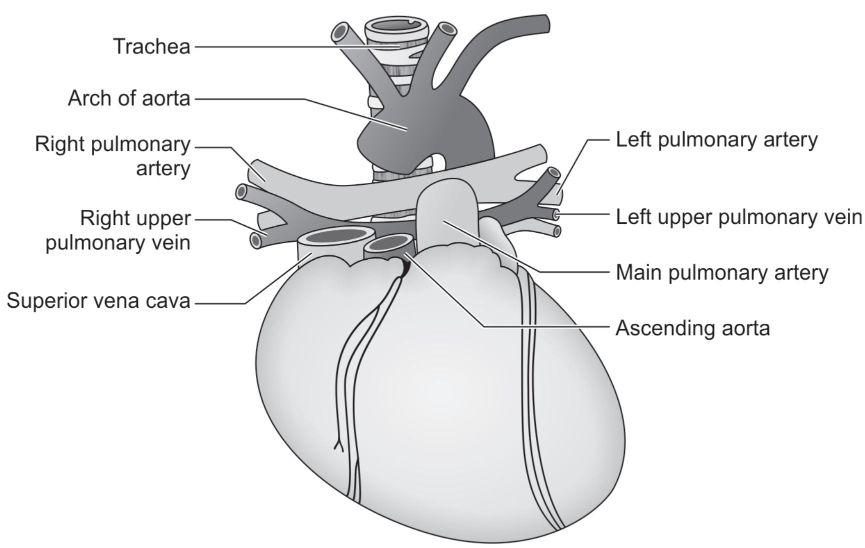


Fig. 2.8: View of the pulmonary arteries from the front. The ascending aorta and the superior vena cava have been removed

SYSTEMIC CIRCULATION

The Aorta

The aorta commences at the upper border of the left ventricle, it runs upwards and to the right for a short distance and then turns through 180° to run downwards close to the vertebral column to end at the level of the 4th lumbar vertebra by dividing into right and left common iliac arteries. Up to this point (thoracic aorta) the aorta is divided into the ascending aorta, arch of aorta, descending aorta and abdominal aorta. The ascending aorta is about 5 cm in length. It starts at the upper border of the left ventricle at the level of the lower border of the 3rd left costal cartilage behind the left half of the sternum. It runs upwards, forwards and to the right and ends at the level of the upper border of the 2nd right costal cartilage, where it is continuous with the arch of the aorta. It gives off two branches, the right and left coronary arteries. These arteries arise from the ascending aorta just above the aortic valve and supply the muscle of the heart.

The right coronary artery runs downwards in the groove between the right atrium and the right ventricle and then runs across the base of the heart to communicate with the left coronary artery (Fig. 2.9). The left coronary artery gives off a branch, called the intraventricular branch which runs in the groove between the two ventricles on the sternocostal surface of the heart, and then runs on to the posterior surface of the heart and communicates with the right artery.

The arch of the aorta connects the ascending and the descending thoracic aorta. It starts as a direct continuation of the ascending aorta and arches to the left and backward across the superior mediastinum, in front of the trachea and esophagus, to become continuous with the descending thoracic aorta on the left side of the lower border of the 4th thoracic vertebra. The lower surface of the arch (Fig. 2.10) of the aorta lies on the upper surface of the division of the main pulmonary artery into the right and left pulmonary arteries. Three branches arise from arch of the aorta—(a) the brachiocephalic artery, (b) the left common carotid artery and (c) the left subclavian artery.

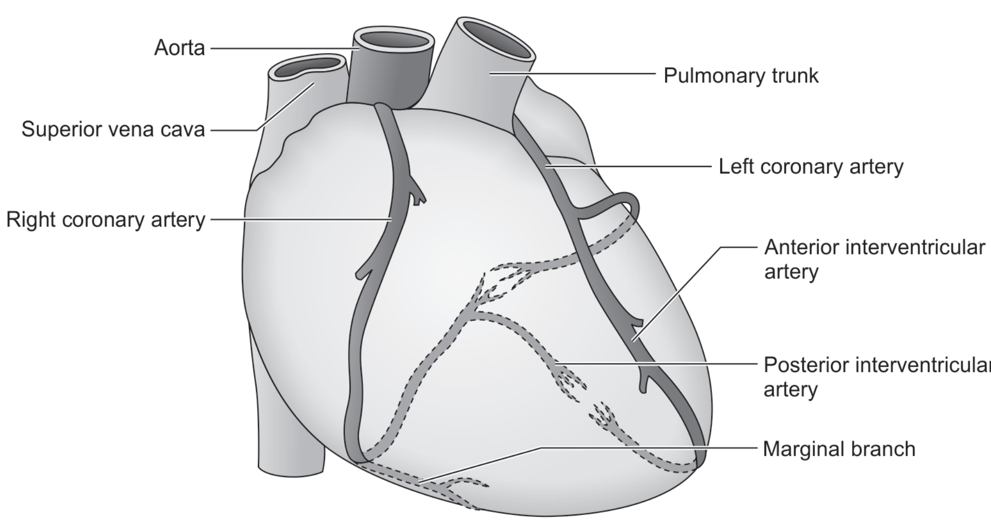


Fig. 2.9: Coronary arteries

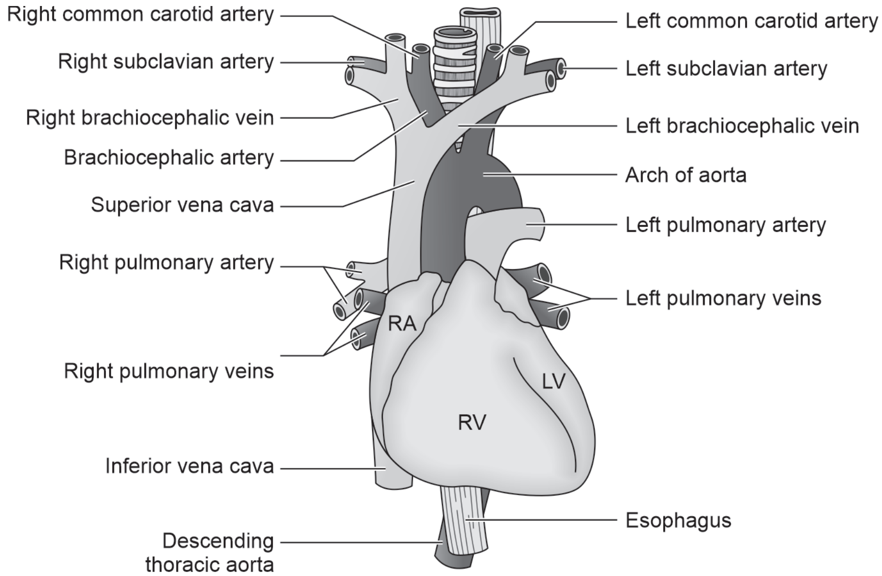


Fig. 2.10: The heart and the great vessels

The Arteries of the Head and Neck

The common carotid arteries are the main arteries of supply to the head and neck. The right common carotid artery arises from the brachiocephalic artery, whereas the left common carotid artery arises directly from the arch of the aorta. The other arteries of head, neck and brain are shown in Figs 2.11 and 2.12.

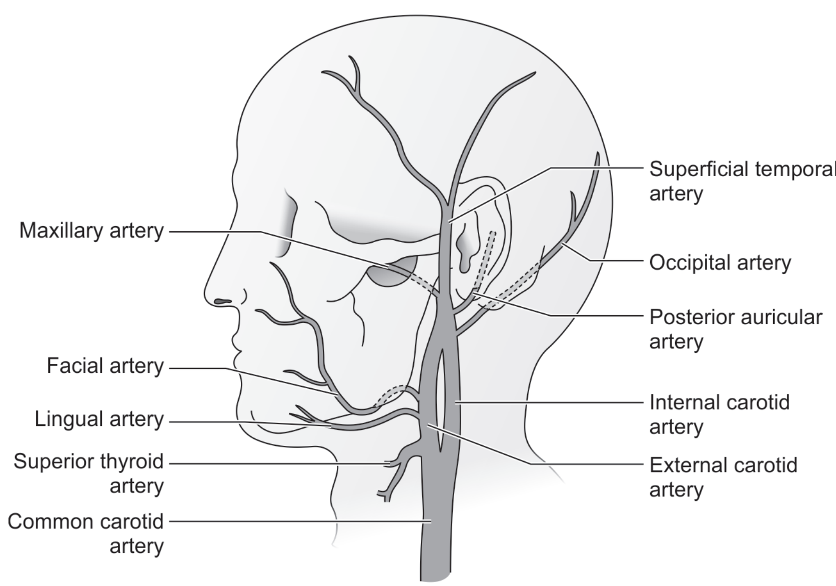


Fig. 2.11: Superficial arteries of the head

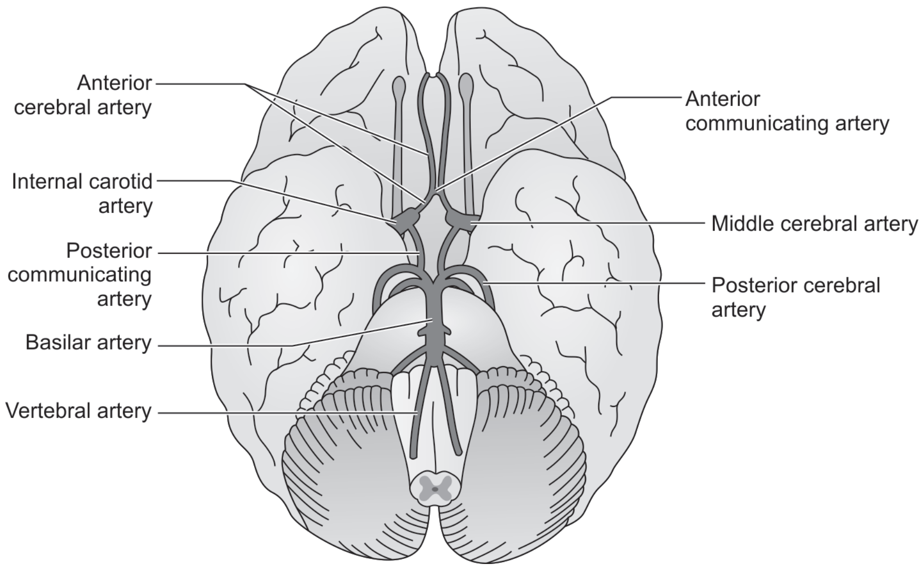


Fig. 2.12: The base of the brain, showing the Circle of Willis

The Arteries of the Upper Limb

The main arterial supply to the upper limb are the subclavian arteries and branches of brachiocephalic artery as shown in Fig. 2.13.

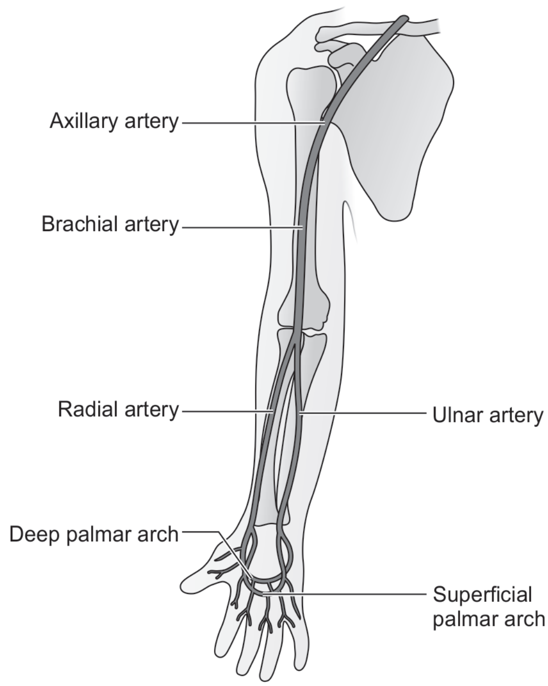


Fig. 2.13: Main arteries of the upper limb

The veins return the blood from the tissues to the heart. They start as small vessels or venules in the periphery and these gradually unite to form large trunks, until finally two main vessels called the superior and inferior venae cavae open into the right atrium of the heart. Veins are superficial and deepformer run close to the surface of the skin and are thus frequently visible. The deep veins many of which accompany the arteries and have the same name and route as the arteries. The descending thoracic aorta commences at the left side of the lower border of the 4th thoracic vertebra and runs downwards in the posterior mediastinum to enter the abdominal cavity through the aortic opening of the diaphragm at the level of the 12th thoracic vertebra. The abdominal aorta is the direct continuation of the descending thoracic aorta. It begins at the level of the lower border of the 12th thoracic vertebra and runs downwards on the left side of the anterior surface of the lumbar vertebra to end at the level of the 4th lumbar vertebra, where it divides into the left and right common iliac arteries. The inferior vena cava lies on the right side of the abdominal aorta, pancreas, duodenum and the peritoneum lie in front of it (Fig. 2.14). The arteries of the lower limb are the femoral artery, the popliteal artery, the anterior tibial artery, the posterior tibial artery and others as shown in Figs 2.15 and 2.16.

The veins return the blood from the tissues to the heart as mentioned earliar (Figs 2.17 to 2.20).

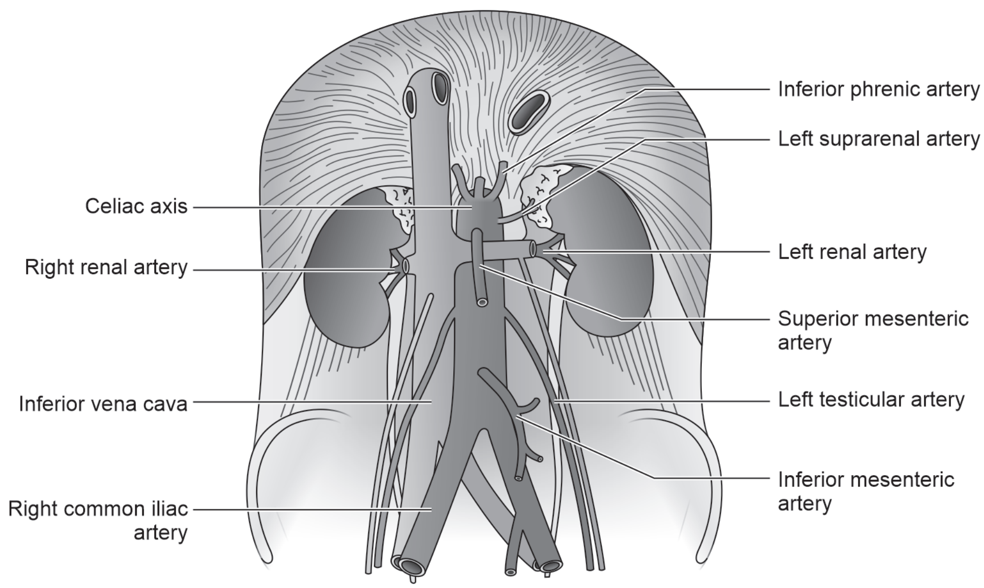


Fig. 2.14: The abdominal aorta and its main branches

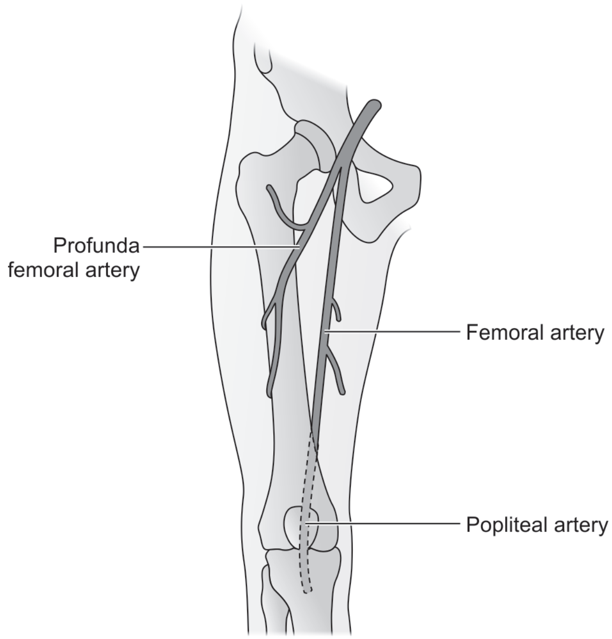


Fig. 2.15: Femoral artery

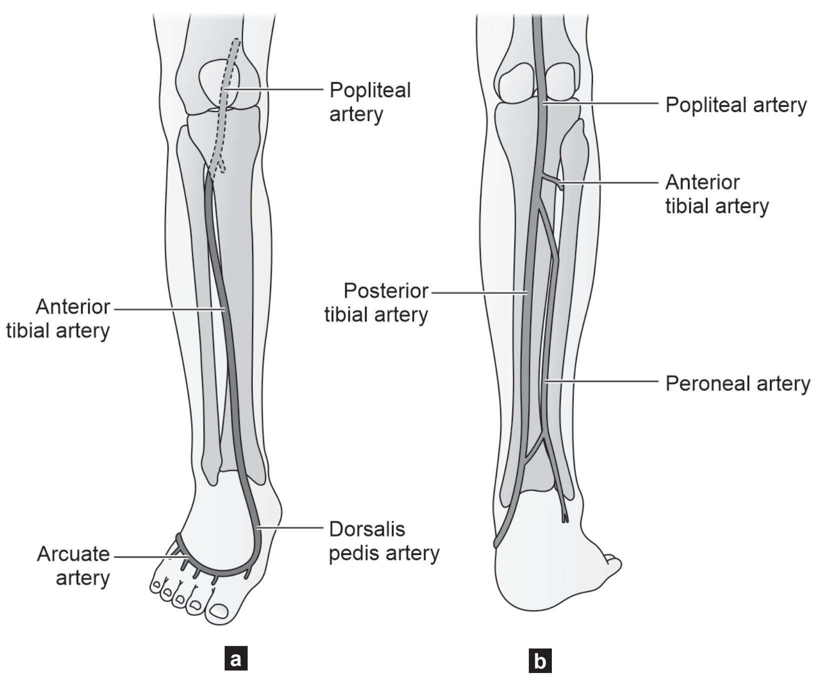


Fig. 2.16: Arteries of the leg: (a) anterior aspect, and (b) posterior aspect

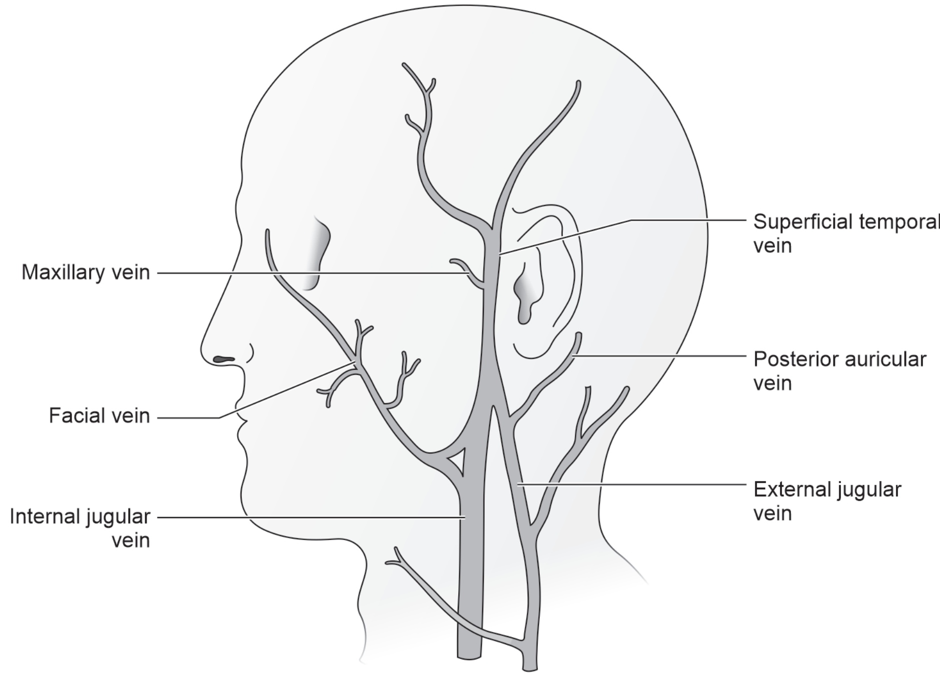


Fig. 2.17: The venous return from the head and neck

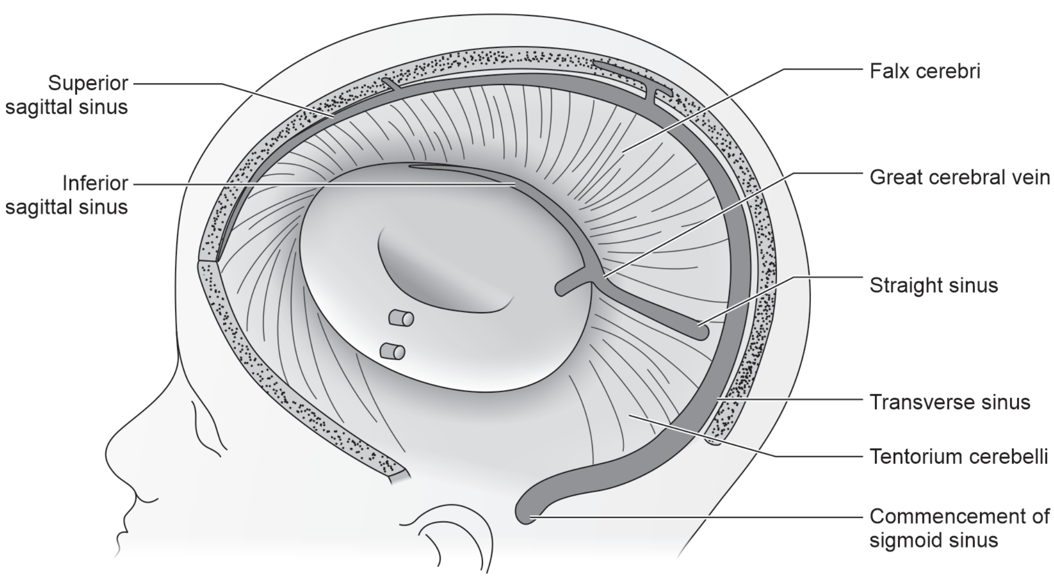


Fig. 2.18: Venous sinuses

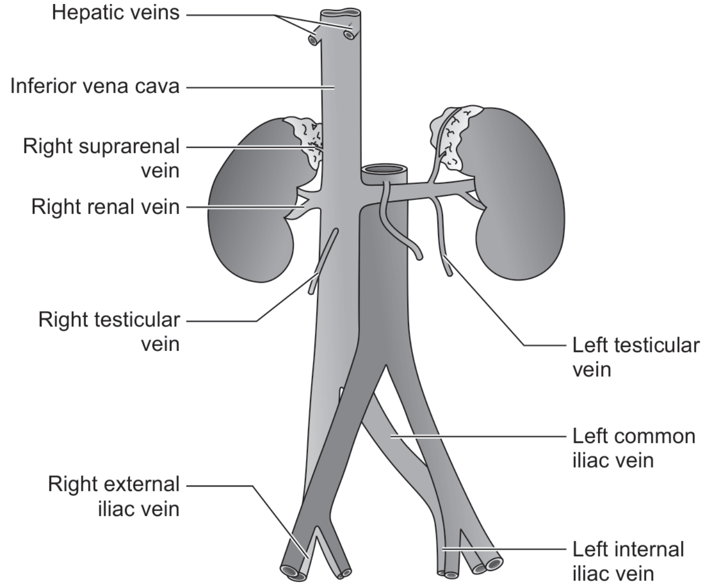


Fig. 2.19: The inferior vena cava and its tributaries

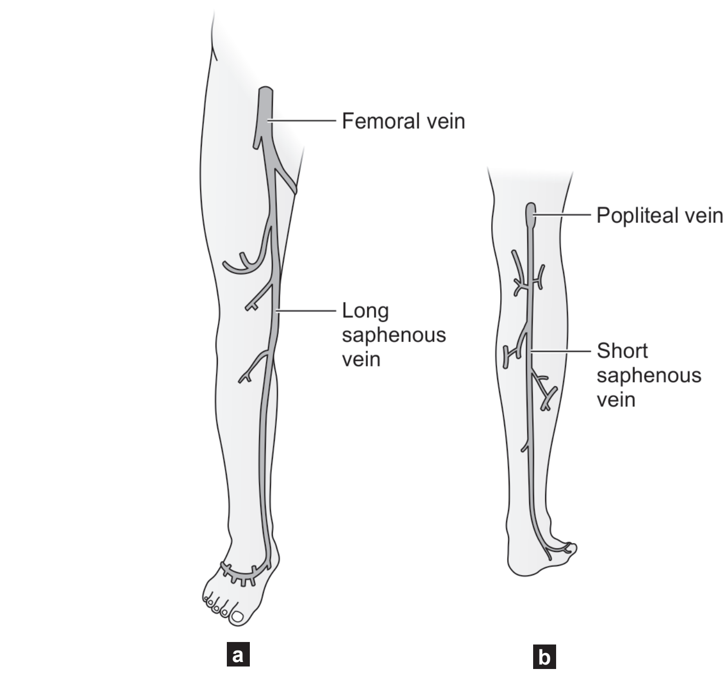


Fig. 2.20: Superficial veins of the lower limb: (a) anterior aspect, and (b) posterior aspect

THE RESPIRATORY SYSTEM

Human body is made up of billions of cells and performs a wide variety of functions. Therefore, to survive and to carry out those functions these cells requires oxygen for combustion and to provide the energy for their activities. The oxygen reaches to cells via blood which also removes the carbon dioxide produced as a waste. Product of combustion, the interchange of oxygen and carbon dioxide between the blood and the tissues is called internal respiration.

The function of respiratory system is to replenish the blood with oxygen and to remove the carbon dioxide from the blood. This interchange of gases which occurs in respiratory system between the blood and the atmospheric air is known as external respiration. The organs constituting the respiratory system are the nose, the pharynx, the larynx, the trachea, the bronchi and the lungs.

THE NOSE

The body structure of the nasal cavity has already been described. The nasal cavity is lined by ciliated epithelium containing globlets, which secrete mucus. The function of mucus is to trap dust particulates (>10 µ) and bacteria which are presented in the inhaled air. Presence of cilia is equally important as they keep on sweeping those stagnated material towards exterior. Accessory nasal sinuses are also lined by ciliated epithelium and they open into the nasal cavity. The upper part of the nose houses specific smell receptors in it.

THE PHARYNX

The pharynx is a muscular tube which in part shared by the respiratory system and the digestive system. Anatomically it lies behind the nasal cavities, mouth and larynx. It is 12–14 cm long, extending from the base of the skull to the level of the 6th cervical vertebra where it opens into the esophagus, being widest in its upper most part and gradually narrows through out its length. Anteriorly, it opens into the nasal cavity, mouth and larynx whereas separated by loose areolar tissue from the upper sixth cervical vertebrae posteriorly.

For descriptive purposes pharynx is divided into three parts—nasopharynx, oropharynx and laryngopharynx (Fig. 2.21).

The nasopharynx is the portion behind the nasal cavity and above the level of the soft palate. Anteriorly, it communicates with the nasal cavity through the posterior nares. Nasopharyngeal isthmus is an opening between the soft palate and the posterior wall of the pharynx, which connect nasopharynx and the oropharynx. This opening becomes obliterated during the act of swallowing. Opening into the lateral wall of the nasopharynx is the auditory tube. In the roof and extending posteriorly is the collection of lymphoid tissue known as pharyngeal tonsil (the adenoids). This lymphoid tissue starts to atrophy at puberty.

The oropharynx extends from the soft palate to the level of the tip of the epiglottis. It opens anteriorly into the mouth cavity through oropharyngeal isthmus, which is bounded above by soft palate, below by tongue and on either side by muscular folds, covered with mucus membrane known as pillars of the fauces. In between the folds of either side lie the palatine tonsils, which are collection of lymphoid tissue.

The laryngopharynx extends from the tip of the epiglottis to the level of 6th cervical vertebra, behind the cricoid cartilage of the larynx, where it is continuous with the esophagus. On either side of the larynx the laryngopharynx forms two pouches called the pyriform fossae.

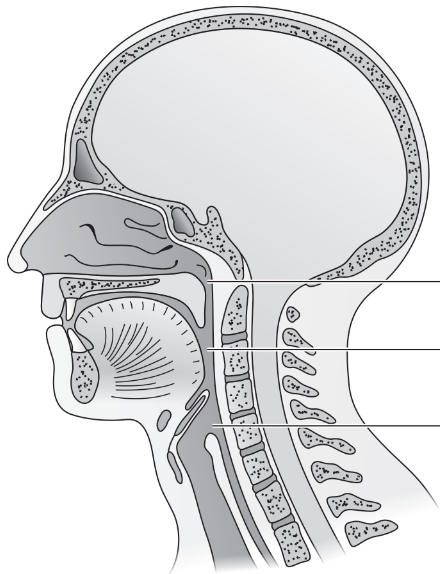


Fig. 2.21: A sagittal section through the head and neck to show the subdivisions of the pharynx

The Structure of the Pharynx

The walls of the pharynx are made up of three coats, the mucus coat, fibrous coat and the muscular coat. The arterial blood supply is from the branches of external carotid artery whereas the veins of pharynx empty into the internal jugular and the facial veins. The nerve supply derived from 9th and 10th cranial nerve and the sympathetic nervous system. The lymph vessels from the pharynx drain either directly into the deep cervical lymph node or into the retropharyngeal and paratracheal lymph nodes.

THE LARYNX

The larynx (Fig. 2.22a and b) is a box like structure which extends from the roof of the tongue to the level of the upper end of the trachea. In adult male, it lies opposite the 3rd to the 6th cervical vertebrae but it is slightly higher in children and adult females. It acts as the organ for the production of the voice and also as a valve to prevent the entry of food into trachea during the act of swallowing. It opens above into the laryngopharynx and below into the trachea.

STRUCTURE OF THE LARYNX

The larynx is consists of number of cartilages which are connected to each other by ligaments and membranes. The cartilages are *Thyroid cartilage* is the largest amongst other cartilages of larynx. It is formed of two quadrilateral plates (lamina) which are fused anteriorly in midline to form laryngeal prominence (Adam's apple). Above this there is a notch, known as thyroid notch. These two plates are widely separated posteriorly. The upper and lower angles of laminae are horn shaped and each inferior horn has a rounded facet on its inner surface which atriculates with the cricoid cartilage.

The cricoid cartilage (Fig. 2.23a) is shape like a signet ring, consisting of a quadrilateral lamina, which lies posteriorly and a narrow arch, lies anteriorly. Each lateral surface of lamina bears too articulae facets; above for the arytenoid cartilage (Fig. 2.23b) and

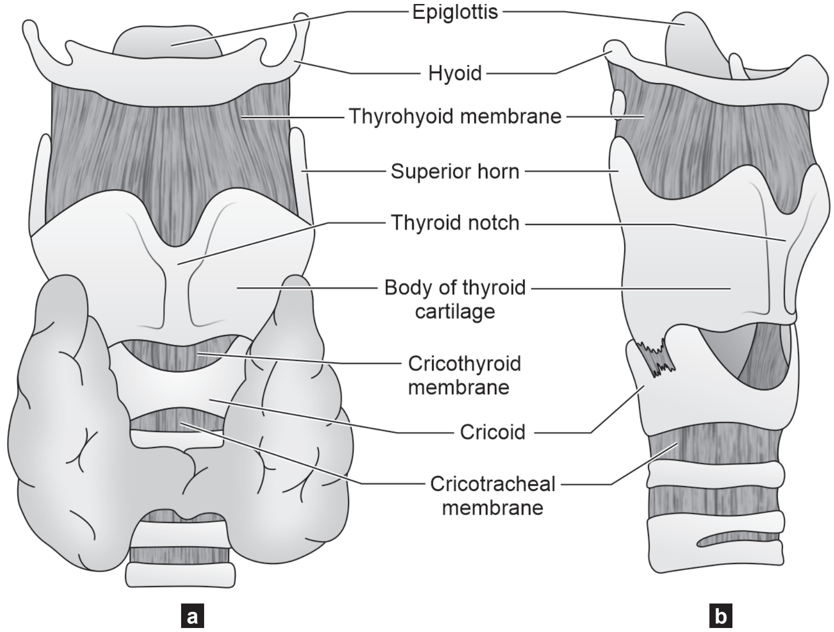


Fig. 2.22: External views of the larynx: (a) anterior aspect, and (b) lateral aspect

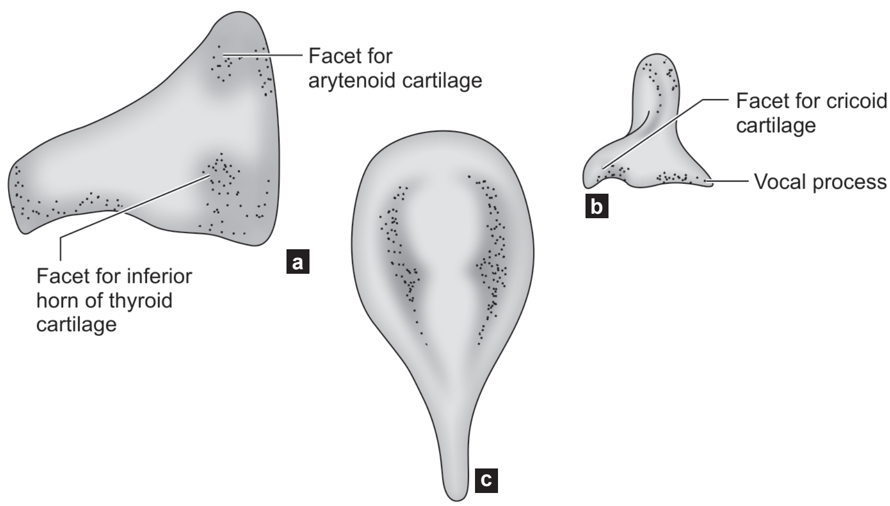


Fig. 2.23: (a) The cricoid cartilage (lateral aspect), (b) the arytenoid cartilage (lateral view) and (c) the epiglottis (posterior aspect)

below for the inferior horn of the thyroid cartilage. The arytenoid cartilage are pyramidal in shape, having an apex, a base and three surfaces as posterior, anterolateral and anteromedial.

Anterior angle is known as the vocal process and gives attachment to the vocal ligament whereas the lateral angle gives attachment to muscles. The base of arytenoid cartilage is concave and articulates with the facet on the upper part of the lateral surface of the lamina of the cricoid cartilage. The apex articulates with the corniculate cartilage. The epiglottis (Fig. 2.23c) is a leaf-shaped cartilage. Its narrow lower end is attached by the thyroepiglottic ligament, to the posterior surface of the thyroid cartilage, just below the thyroid notch. The upper end of epiglottis projects upwards behind the hyoid bone and the base of the tongue. The lower part of the anterior surface is attached to the hyoid bone by the hypoepiglottic ligament.

The Cavity of the Larynx

The larynx opens above into the pharynx and below into the trachea. The mucus membrane lining the larynx is in continuation with the mucus membrane of tongue and pharynx above. Laryngeal cavity is divided into three parts due to the two inner fold of mucus membrane. The upper fold is named as vestibular and the lower one which cover the vocal ligament forming vocal cords known as vocal folds (Figs 2.24 and 2.25).

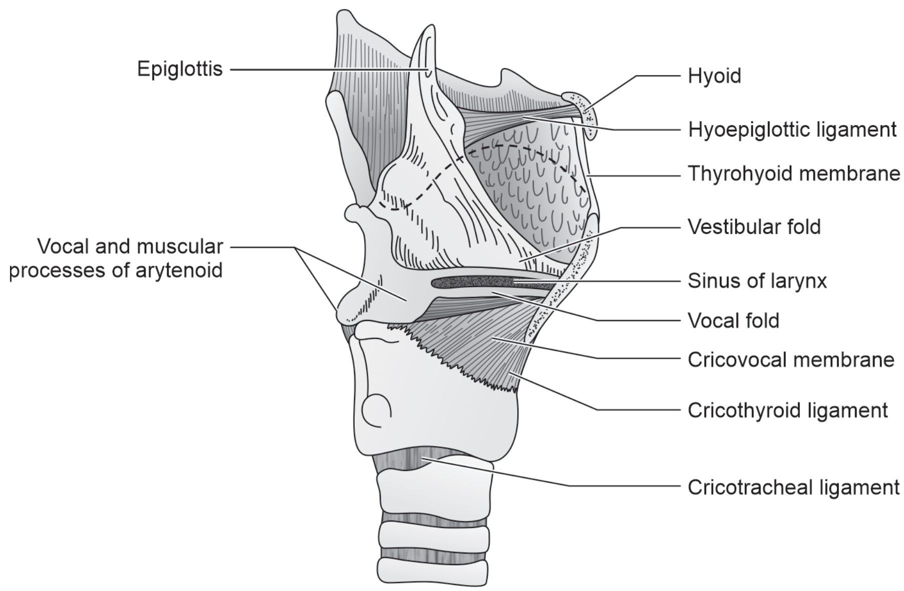


Fig. 2.24: The cartilage and ligaments of the larynx, lateral aspect

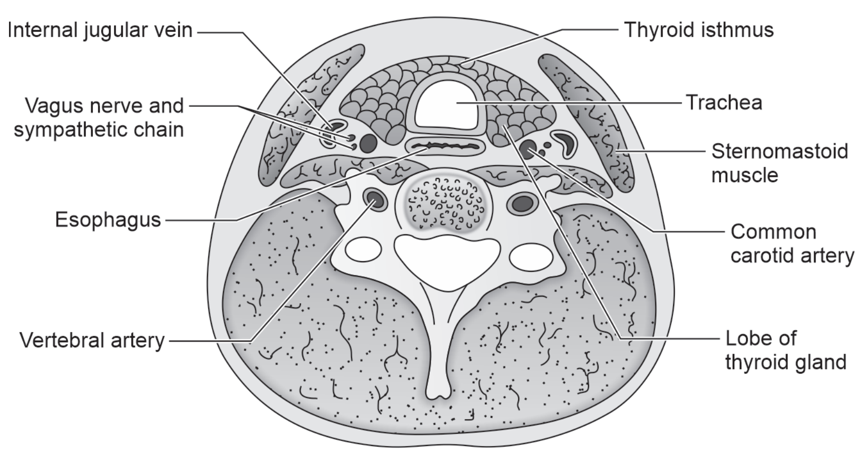


Fig. 2.25: Transverse section of the neck at the level of the lower part of the 6th cervical vertebra to show the relationship of the trachea