

Chapter 12

Circulation

At the end of this chapter students will be able to

State the location of heart in the body and define the role of pericardium.

Describe the structure of the walls of heart and rationalize the thickness of the walls of each chamber.

Describe the flow of blood through heart as regulated by the valves.

State the phases of heartbeat.

Explain the role of SA node, AV node and Purkinji fibers in controlling the heartbeat.

List the principles and uses of Electrocardiogram.

Describe the detailed structure of arteries, veins and capillaries.

Describe the role of arterioles in vasoconstriction and vasodilation.

Describe the role of precapillary sphincters in regulating the flow of blood through capillaries. Trace the path of the blood through the pulmonary and systemic circulation (coronary, hepatic-portal and renal circulation).

Compare the rate of blood flow through arteries, arterioles, capillaries, venules and veins.

Define blood pressure and explain its periods of systolic and diastolic pressure.

State the role of baroreceptors and volume receptors in regulating the blood pressure.

Define the term thrombus and differentiate between thrombus and embolus.

Identify the factors causing atherosclerosis and arteriosclerosis.

Categorize Angina pectoris, heart attack, and heart failure as the stages of cardiovascular disease development.

State the congenital heart problem related to the malfunctioning of cardiac valves.

Describe the principles of angiography.

Outline the main principles of coronary bypass, angioplasty and open-heart surgery.

Define hypertension and describe the factors that regulate blood pressure and can lead to hypertension and hypotension.

List the changes in life styles that can protect man from hypertension and cardiac problems.

Describe the formation, composition and function of intercellular fluid.

Compare the composition of intercellular fluid with that of lymph.

State the structure and role of lymph capillaries, lymph vessels and lymph trunks.

Describe the role of lymph vessels (lacteals) present in villi.

Describe the functions of lymph nodes and state the role of spleen as containing lymphoid tissue.

Introduction

Materials in the human body need to be taken from one organ to another and to the tissues from where they are distributed to each and every cell of the body. This requires movement of material called circulation. It is a vital process of the body which is accomplished by a system called circulatory system.

The **circulatory system** is an organ system that transports nutrients gases, hormones, blood cells, nitrogen waste products, etc. to and from cells in the body to help fight diseases and help stabilize body temperature and pH in order to maintain homeostasis. This system is composed of the **cardiovascular system**, which distributes blood and the **lymphatic system**, which distributes lymph. Human beings and other vertebrates possess a closed cardiovascular system. In closed system the blood never leaves the network of arteries, veins and capillaries.

12.1 Human Blood Circulatory System

The most important means of transport of food, water, wastes and gases in human body is blood. For its circulation throughout the body, blood requires a system called blood circulatory system, also known as cardiovascular system. This system consists of heart and blood vessels.

Human Heart

Human heart (Greek word kardia) is muscular pumping organ. It is conical in shape and is generally about the size of your tightened fist. It is found on the left side of the thoracic (chest) cavity. Heart is covered by a tough double membrane called pericardium. This membrane protects the heart from over extension especially when we run or take a hard exercise. Both the membranes are slightly apart and in between them present a small cavity called pericardial cavity filled with a fluid, the pericardial fluid. Which lubricates the heart to ease the movement and protect the heart from any mechanical injury.

a. Structure of Heart

Heart consists of four chambers; two auricles (also called atria) and two ventricles. Heart is composed of cardiac muscles which are specialized type of muscles keep working day and night, untiringly. Atria are smaller and thin walled, separated from each other by an inter-auricular septum. They form the anterior portion of the heart. Ventricles are larger, thick walled chambers, also separated by ventricular septum. Right atrium communicates with right ventricle through a valve called tricuspid valve (it is called tricuspid because it consists of three flaps of muscles) and left atrium opens into left ventricle through bicuspid valve (having two flaps).

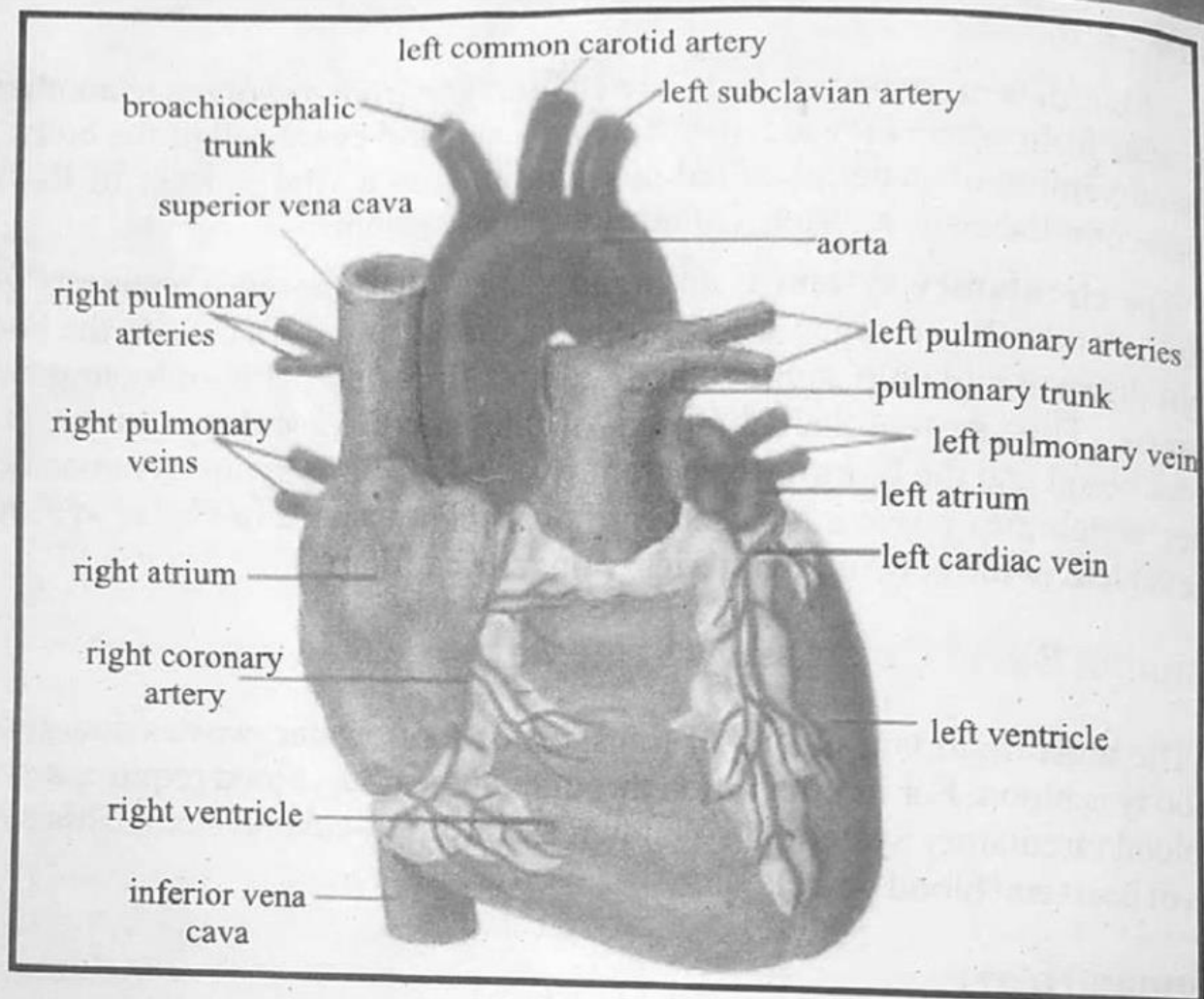


Fig: 12.1 Structure of heart

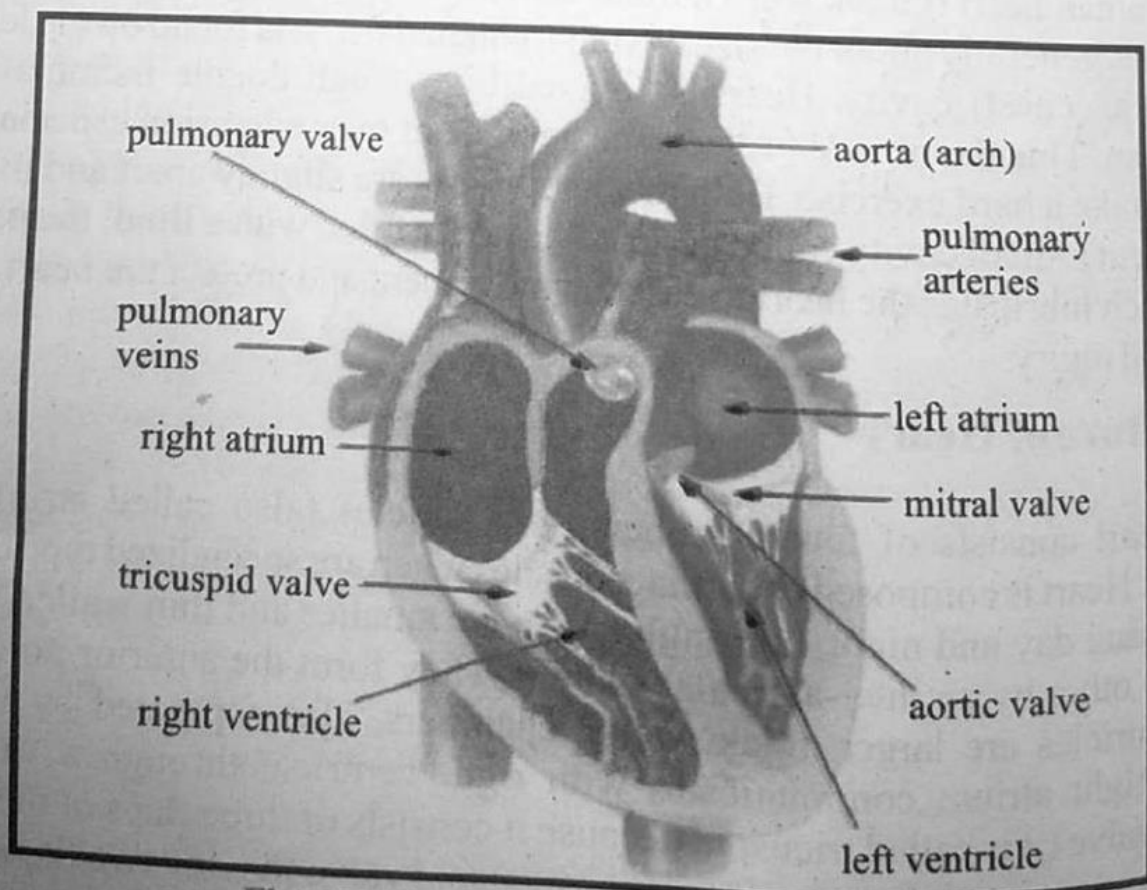


Fig: 12.2 Internal structure of heart

These valves control the blood flow and blood is allowed to flow only in one direction.

b. Function of Heart

The right atrium receives the deoxygenated blood through vena cava (largest vein) from the whole body. This happens when the heart relaxes and space is produced inside the atrium. The blood is forced to right ventricle through tricuspid valve. When the heart contracts the deoxygenated blood from right ventricle is pumped to the lungs through pulmonary arteries. (During this the tricuspid valve is kept closed preventing the back flow). After oxygenation the blood comes back to left atrium through pulmonary veins. (The semilunar valve in pulmonary vein allows the deoxygenated blood to go to lungs and prevent its back flow). From here via bicuspid valve oxygenated blood is sent to the left ventricle. On contraction the oxygenated blood is pushed with full force into aorta (the largest artery) which distributes it to whole body through the smaller and smaller arteries.

Like other mammals, in human beings as well, the oxygenated and deoxygenated blood is completely separated. Deoxygenated blood remains on the right side of the heart and oxygenated on the left side of the heart. Valves play a very important role in this regard by preventing the back flow of blood.

12.1.1 Cardiac Cycle and Phases of Heartbeat

One contraction and one relaxation is called a cardiac cycle. Contraction of heart is termed as **systole** and relaxation as **diastole**. One complete cycle takes 0.8 seconds. The contraction and relaxation are cyclic and rhythmic. In first phase called diastole blood flows in all the four chambers passively. In second phase i.e. systole both the auricles contract together for about 0.1 second filling the ventricles completely with blood. Then in third phase the ventricles contract together for about 0.3 second pouring blood in to aorta and pulmonary artery.

Normal rate of heart beat in a healthy human being is 72 beats per minute. This rate decreases when a person is resting or sleeping and increases to 120 beats per minutes during strong muscular exercise like running, swimming etc. and with some medicines like caffeine. Every time heart pours about 85 milliliters of blood into aorta with a great pressure.

Lub-dub Sound of Heart

The sound produced by heart is generally verbalized as lub-dub. Lub (first sound) is produced by closing of the AV valves during the contraction of ventricle in systole. The dub (second sound) is produced by closing of the semilunar valves in the beginning of diastole.

Blood travels, in all different types of vessels, at different speeds. Speed is fastest in arteries, slower in arterioles and slowest in capillaries. From here it starts getting collected in venules. Its speed starts increasing in venules and faster again in veins.

The continuous working of heart is due to certain specialized structures like SA node (also called pacemaker), AV node and some specific type of fibers called purkinji fibers.

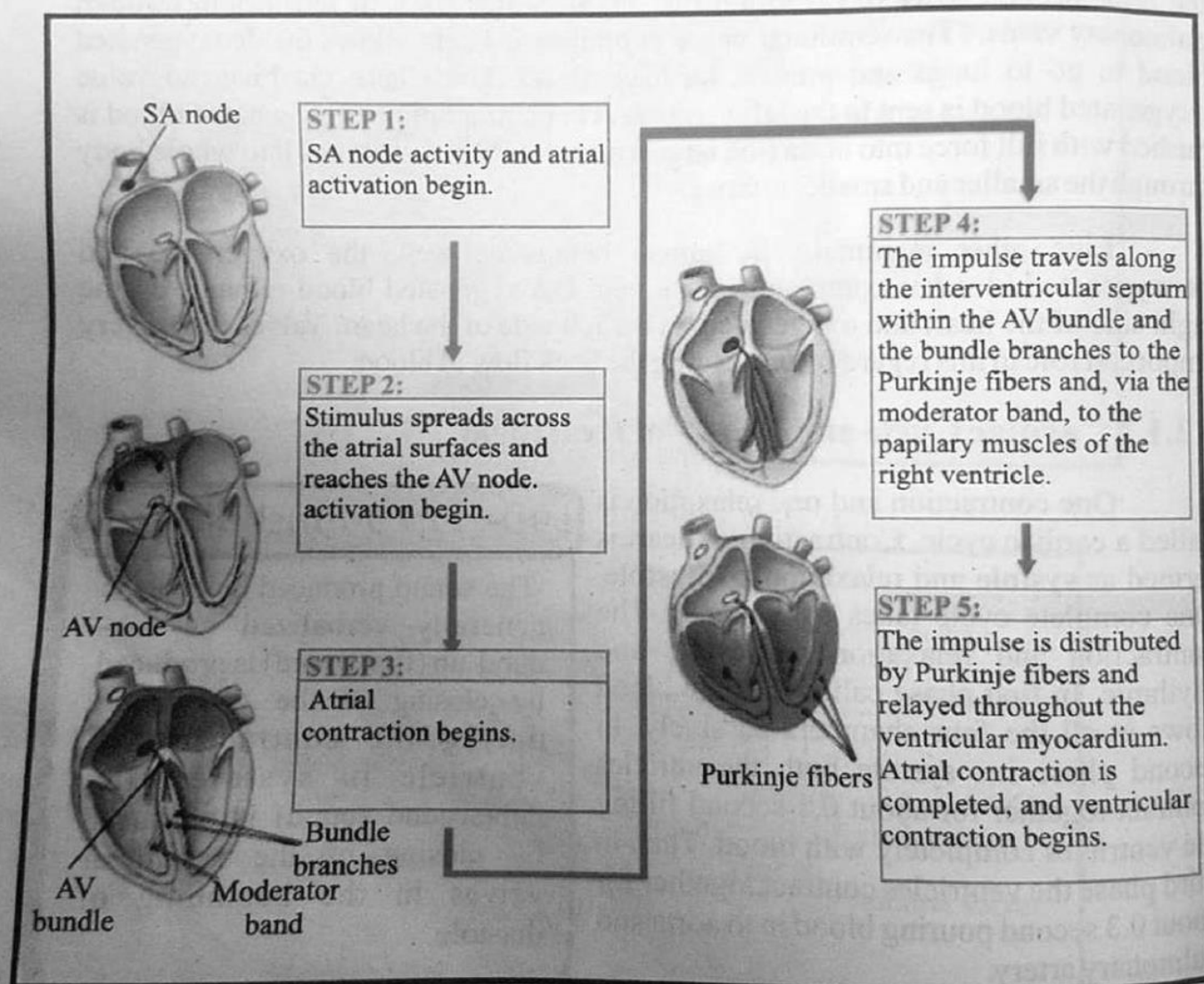


Fig: 12.3 Cardiac Cycle and phases of heartbeat

The pacemaker or SA node (sino-atrial node) is the impulse-generating (pacemaker) tissue located in the upper dorsal wall of the right atrium of the heart, near the entrance of the superior vena cava. SA node initiates the electrical impulses for heart beat and keeps the heart in motion.

The cells of the SA node generate electrical impulses faster than other cells and are responsible for the rest of the heart's electrical activity. SA node is thus sometimes called the primary pacemaker. Dysfunction of SA node causes disturbance in heart beat. Either it becomes very fast or very slow or some times a combination of both.

Another very important structure is AV node (atrio-ventricular node) which is the part of electrical control system of the heart. Its main function is to co-ordinates heart rate. It electrically connects atrial and ventricular chambers. It is an electrical relay station between the atria and the ventricles. Electrical signals from the atria must pass through the AV node to reach the ventricles. This node slows down the speed of the electrical signals to delay the contraction of ventricles until the atria are not fully contracted.

Purkinji fibers were discovered in 1839 by Jan Evangelista Purkinji. These fibers extend in the form of a branching tree in the heart and play an important role in its continuous working. Purkinji fibers are the extension of the autonomic nervous system. They are found in the inner wall of the ventricle just beneath the endocardium. These are specialized myocardial fibers which conduct electrical signals (nerve impulses) to different areas of heart to enable it to work in a coordinated way.

Artificial Pacemaker

In certain heart disorders natural pacemaker fails to generate impulses for heart beat. Then an artificial pacemaker is implanted near AV node. This pacemaker is an electronic device which automatically generates electric impulses after every 0.8 seconds.

12.1.2 Electrocardiogram (ECG)

The Electrocardiogram (ECG) is a electrocardiograph used for recording the electrical activity of the heart. For this purpose its electrodes are placed on the chest skin at specific locations. Doctors use it to monitor the electrical workings of the heart. The information is used to discover heart rate, arrhythmias, myocardial infarctions, atrial enlargements, ventricular hypertrophies, and bundle branch blocks etc.

The principle implied for recording the electrical impulse ECG is quite simple. When the overall electrical current of the heart goes towards a particular lead, it registers a positive deflection. Those that go away from the lead register a negative deflection. Those which are at 90 degrees or perpendicular to the vector of the lead registers 0, i.e. is seen as an isoelectric line.

Reading of ECG requires following conventions to be kept in mind.

Recording of the ECG is 25 mm/s which results in:

- 1 mm = 0.04 sec (or each individual block)
- 5 mm = 0.2 sec (or between 2 dark vertical lines)



Fig: 12.4 a. Heart beat recorded through Electrocardiogram (ECG)

The voltage recorded from the leads is also standardized on the paper where

1 mm = 1 mV (or between each individual block vertically) This results in:

- 5 mm = 0.5 mV (or between 2 dark horizontal lines)
- 10 mm = 1.0 mV (this is how it is usually marked on the ECG's)

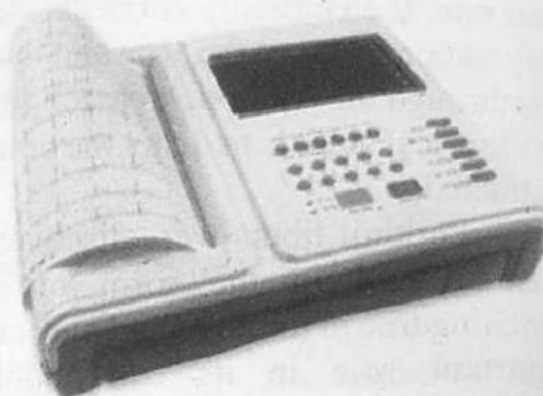


Fig: 12.4 b. Electrocardiogram

12.1.3 ECG Reading

The phases of a heart beat can also be divided into sections relating to the shape of the electrical signals produced when viewing the heart beat via an ECG (Electrocardiogram). This traces the electrical activity of the heart. The wave shape produced is called the QRS wave, with each part of the wave being labelled to help describe what is happening at each stage.

- TP Interval (Ventricular Diastole)

Atria and ventricles are relaxed; blood is flowing into the atria from the veins. As the atrial pressure increases above that of the ventricle, the AV valves open, allowing blood to flow into the ventricle

- P Wave (Atrial Systole)

The SA node fires and the atria contract causing atrial systole which forces all blood into the ventricles, emptying the atria.

- QR Interval (End of Ventricular Diastole)

The AV valves remain open as all remaining blood is squeezed into the ventricles. The electrical impulse from the SA node reaches the AV node which spreads the signal throughout the walls of the ventricles via specialised cells called bundles of His and Purkinje fibres. The R peak is the end of ventricular systole and the start of diastole.

- **RS Interval (Ventricular Systole)**

As the blood is now all within the ventricles and so pressure is higher here than in the atria, the AV valves close. The ventricles start to contract although pressure is not yet high enough to open the SL valves.

- **ST Segment (Ventricular Systole)**

Pressure increases until it equals Aortic pressure, when the SL valves open. The blood is ejected into the Aorta (and pulmonary artery) as the ventricles contract. At this time the atria are in diastole and filling with blood returning from the veins.

- **T Wave (Ventricular Diastole)**

Ventricles relax, the ventricular pressure is once again less than the aortic pressure and so the SL valves close. The cycle continues.

12.1.4 Blood Vessels:

The circulatory system consists of three types of vessels.

- Arteries
- Capillaries
- Veins

i. Arteries

The vessels which carry blood away from the heart are called arteries. All the arteries transport oxygenated blood except pulmonary artery. The only artery which carries deoxygenated blood from heart to the lungs is pulmonary artery. Arteries being very elastic resist flow of blood which is maintained through the very strong pushing force during ventricle contraction.

The wall of an artery is made of three layers.

The outer elastic layer, tunica externa, is made of areolar tissues and many layers of elastic fibers. These fibers give elasticity to the artery to expand and withstand the pressure of blood. Very large blood vessels have their own blood supply.

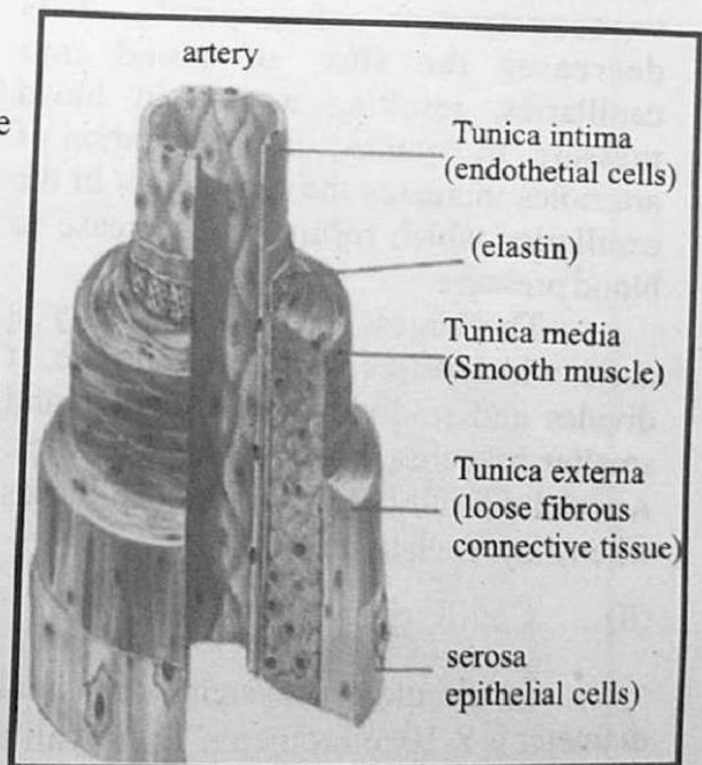


Fig: 12.5 Internal structure of artery

This is found in the form of a network of small arteries called the vasa vasorum (means vessels of vessels). This network is also found in tunica externa.

Middle layer, tunica media, is composed of circularly arranged smooth muscles and fewer elastic fibers. Inner layer, tunica interna or endothelium is comparatively thinner layer. It is composed of simple squamose epithelium and a thin layer of areolar connective tissue.

Arterioles are the smallest arteries with a diameter ranging from 3 mm to 10 micrometers. Larger arterioles have all three layers but smaller arterioles have only two; a thin layer of endothelium surrounded by a single layer of smooth muscle fibers.

Arterioles play an important role in **vasoconstriction** and **vasodilation**. Innervations (stimulus) of sympathetic nervous system cause contraction in the muscular layer of the arteriole, resulting in vasoconstriction of arteriole. This decreases the flow of blood into capillaries, resulting a rise in blood pressure. In contrast, the vasodilation of arterioles increases the blood flow in the capillaries which result in a decrease in blood pressure.

The largest artery of the body is aorta, which arises from left ventricle. It divides and re-divides into smaller and smaller branches which make arterioles. Arterioles finally break up into capillaries when they reach tissues.

(ii) Capillaries

In circulatory system, the smallest blood vessels are capillaries. Their diameter is 8-10 micrometer. Their wall is only one cell thick and is very permeable. These very thin walls of the capillaries allow the exchange of water, oxygen, dissolved nutrients and waste products etc. in between capillaries and the cells of the tissue.

Tidbit

Colour of the arteries appears to be red due to the bright red oxygenated blood flowing through them. Whereas due to deoxygenated blood veins appear to be bluish.

Do You Know?

The diameter of a capillary is little more than the RBC i.e. 7.5 μm . This decreases the blood flow and provides ample time for material exchange.

A capillary is so thin that only one RBC passes through it at a time, releasing its oxygen by diffusion to the cells. The very small diameter of the capillaries provides ample time to the blood for exchange of materials. After releasing nutrients to tissues, capillaries start joining to form venules.

Flow of blood in the capillaries is adjusted by the precapillary sphincters. A precapillary sphincter is a band of smooth muscle that encircles each capillary branch at the point where it branches off from the arteriole. Contraction of the precapillary sphincter can close off the branches stopping the blood flow. If the sphincter is damaged or can not contract, blood can flow into the capillary bed at high pressures. When capillary pressures are high, fluid passes out of the capillaries into the interstitial space and edema or fluid accumulation is resulted.

(iii) Veins

Veins are the vessels which bring the blood back from different organs of the body towards heart. All the veins transport deoxygenated blood except for pulmonary vein which brings oxygenated blood.

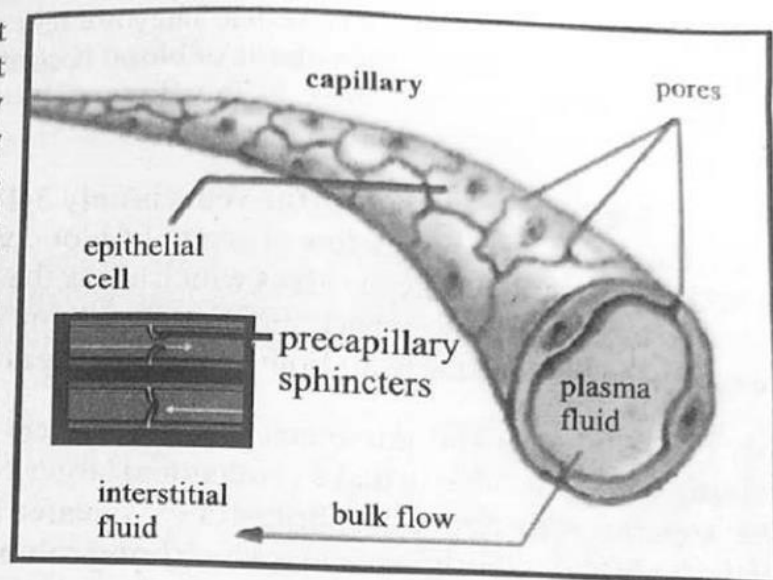


Fig: 12.6 Internal structure of capillary

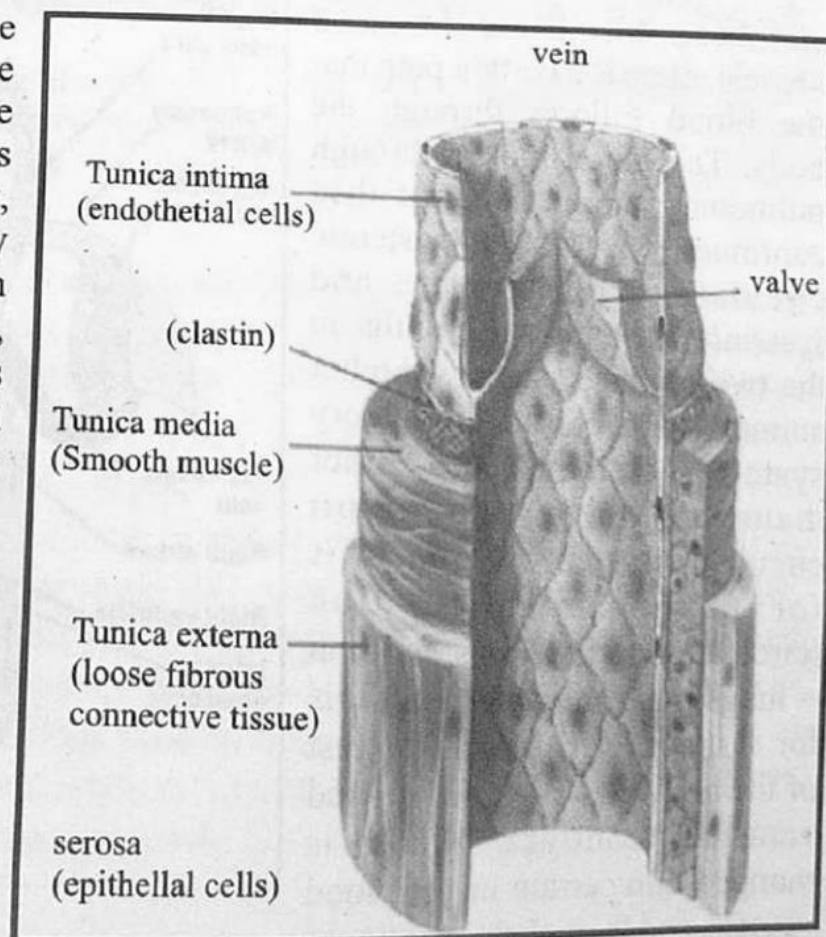


Fig: 12.7 Internal structure of a vein

Walls of the vein are composed of the same three layers but the middle layer is thinner as compared to that of arteries. They are less elastic as they do not have to bear systolic pressure. Most of the volume of blood is contained in veins. The reason is that, instead of providing resistance in the flow of blood like arteries, they expand to accumulate additional volume of blood.

The average pressure in the veins is only 5-10 mm Hg (In arteries it is 100mm Hg). The Veins have a very low pressure of blood which is not sufficient to take the blood to the heart, they keep **valves** which allow the flow of blood in one direction i.e. towards heart and prevent back flow. Veins passing through skeletal muscles get help to return the blood to the heart from the massaging action of the skeletal muscles.

Venules (8-100 micrometer in a diameter) after coming out of tissues start joining with each other to make veinlets and larger veins. The largest veins in the body are; superior vena cava which brings deoxygenated blood from head and upper region of the body and inferior vana cava which brings blood from lower parts of the body.

12.1.5 Path of Blood through Pulmonary and Systemic Circulation

When a heart contracts and forces blood into the blood vessels, there is a certain path that the blood follows through the body. The blood moves through pulmonary circulation and then continues on through systemic circulation. Pulmonary and systemic are the two circuits in the two-circuit system of higher animals with closed circulatory systems. Humans and other mammals have two-circuit circulatory systems: one circuit is for pulmonary circulation (circulation to the lungs; pulmon = lungs), and the other circuit is for systemic circulation (the rest of the body). As each atrium and ventricle contract, blood is pumped into certain major blood vessels, and from there, continues through the circulatory system.

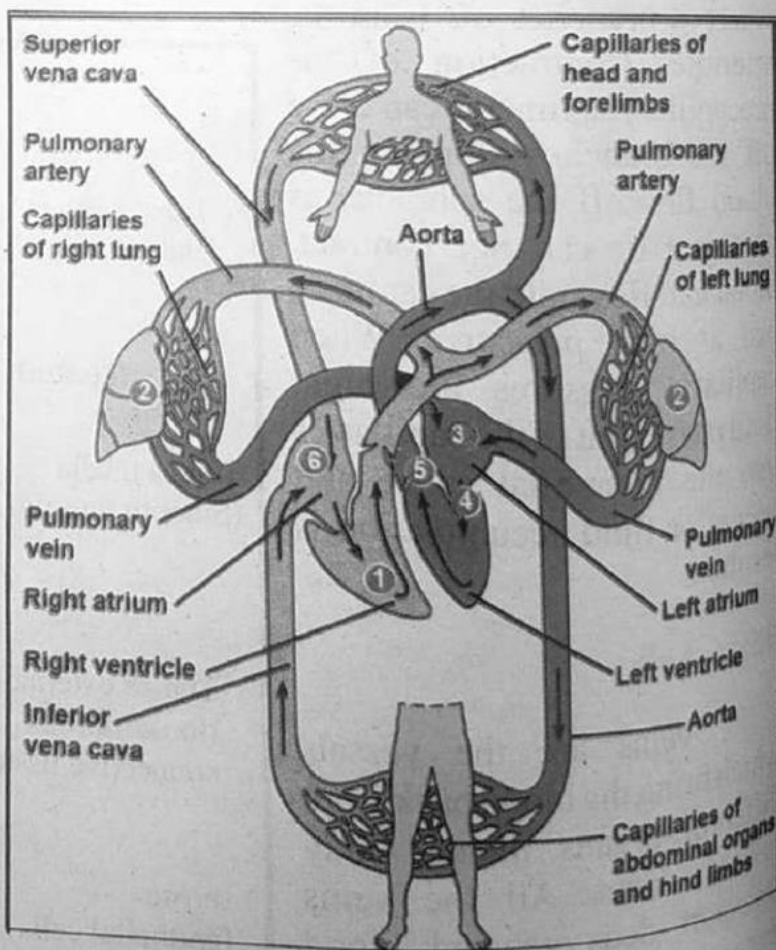


Fig: 12.8 Circulatory plan

12.1.6 Exchange of Material

The most important function of blood circulatory system is to transport oxygen and nutrients to the cells of the tissue and remove the metabolic waste products from the tissues and transport them back to the organs responsible for their excretion.

In the alveoli of the lungs oxygen binds to the heme part of the haemoglobin, filled in RBCs. Blood also absorbs nutrients, especially glucose, from villi found in the walls of the small intestine and comes back to the heart.

This blood is pumped into the aorta with full force of the contracted ventricle. From aorta it moves into branching arteries and then arterioles. When this blood, loaded with oxygen and nutrients, reaches capillaries, due to the low concentration of these materials in tissues, oxygen and nutrients diffuse out of the walls of capillaries and enter tissues. The concentration of waste material is more in tissues so they diffuse into the capillaries.

Due to the pressure of blood some water also oozes out of the capillaries as interstitial fluid. This water increases the osmotic pressure outside the capillaries. Therefore, at venous end of the capillaries water again diffuses back to the capillaries along with dissolved waste products.

12.1.7 Control of the Capillary Beds

It has been estimated that an adult human being has some 60,000 miles of capillaries with a total surface area of some 800–1000 m² (an area greater than three tennis courts). The total volume of this system is roughly 5 liters, the same as the total volume of blood in human body. However, if the heart and major vessels are to be kept filled, all the capillaries cannot be filled at once. So a continual redirection of blood from organ to organ takes place in response to the changing needs of the body. During vigorous exercise, for example, capillary beds in the skeletal muscles open at the expense of those in the viscera.

For Your Information

Blood is pumped to the body (via aorta) with great pressure to confirm its distribution to the farthest parts of the body like hairs on head and nails of feet. On the other hand the blood is pumped to the lungs (via pulmonary artery) with lesser pressure due to which it moves slowly through the alveoli of the lungs, getting sufficient time for oxygenation.

The reverse process occurs after a heavy meal. The table 12.1 shows the distribution of blood in the human body at rest and during vigorous exercise. Note the increase in blood supply to the working organs (skeletal muscles and heart). The increased blood supply to the skin aids in the dissipation of the heat produced by the muscles. The total blood flow during exercise increases because of a more rapid heartbeat and also a greater volume of blood pumped at each beat.

12.1.8 Blood Pressure (B.P)

We know that rhythmic pumping of the heart pours the blood in to the arteries. This pulsation can easily be felt in those arteries (like radial artery) which

are near the surface of the skin and we generally call it pulse. The throb we feel (as pulse) is due to the pressure of the blood which makes the elastic layer of arteries to expand rhythmically allowing blood to pass through.

The force per unit area that blood exerts on the inside walls of a blood vessel is called blood pressure. It is measured in millimeter of mercury (mm Hg). It is measured with the help of an instrument called sphygmomanometer. Blood pressure is of two types

- **Systolic blood pressure** which is felt during the ventricular contraction
- **Diastolic blood pressure** which is felt during ventricular relaxation.

Systolic B.P is greater than the diastolic pressure. The B.P is generally expressed as a ratio in which numerator shows the systolic and denominator depicts the diastolic B.P. An average, healthy adult human being has a B.P. of 120 / 80 mmHg. With increasing age the normal value of BP also increases due to decrease in the elasticity of the blood vessels.

The blood pressure is generated by the contraction of the left ventricle. Therefore, pressure is highest in the aorta. As the arteries branch and travel greater distances from the heart the blood pressure decreases. In capillaries the difference between systolic and diastolic pressure disappears. In capillaries the B.P. is about 40 mm Hg. It decreases to less than 20 mm Hg when the blood leaves arteries and further drops in venuoles. The pressure of the blood is minimum when it enters the right atrium from upper and lower vena cavae.

Table 12.1 Showing approximate blood flow in milliliter/ minute.

Organ	At Rest	During Strenuous Exercise
Heart	250	750
Kidneys	1,200	600
Skeletal Muscles	1,000	12,5000
Skin	400	1,900
Viscera	1,400	600
Brain	750	750
Other	600	400
Total	5,600	17,500

Measuring blood pressure

To measure B. P. the doctor wraps a cuff around the arm of the patient. Then this cuff is inflated with the help of a pump. This inflation compresses the brachial artery against the muscles around the humerus bone, temporarily stopping the blood flow. The doctor places a stethoscope near the compressed artery and start releasing air gradually from the cuff. Now the doctor concentrates to listen to the sound of the pulse. When the first pulsation is heard, through the stethoscope, the sphygmomanometer is read. This reading shows the systolic blood pressure. The second reading is taken when the sound of the pulsation stops (because due to further decrease in air pressure in the cuff blood start flowing evenly through the artery). This reading depicts diastolic blood pressure. Nowadays different types of automatic digital BP apparatus are also available but the manual method is more reliable for accurate reading.



Table 12.2 Blood pressure in different blood vessels

Name of Vessel	Systolic B.P.	Diastolic B.P	B.P
Aorta	120	80	
Arteries	102	60	
Arterioles	60	45	
Capillaries	-	-	40
Venules	-	-	20
Veins	-	-	10
Vena cava	-	-	0

Certain sensors (nerve endings) are located in the blood vessels of the human body called **Baroreceptors** (or baroreceptors). They detect the pressure of blood flowing through them, and can send messages (signals) to the central nervous system to increase or decrease total peripheral resistance and cardiac output. They work as short term blood pressure regulation mechanism.

Baroreceptors detect the amount of stretch of the blood vessel walls, and send the signal to the nervous system in response to this stretch.

Baroreceptors can be divided into two categories

- a) High pressure arterial baroreceptors
- b) Low pressure baroreceptors (also known as cardiopulmonary or volume receptors).

High pressure arterial baroreceptors are present in the aortic arch and the carotid sinuses of the left and right internal carotid arteries. The baroreceptors found within the aortic arch enable the examination of the blood being delivered to all the blood vessels via the systemic circuit, and the baroreceptors within the carotid arteries monitor the blood pressure of the blood being delivered to the brain.

Low pressure baroreceptors are found in large systemic venal caval veins and in the walls of the right atrium of the heart. The low pressure baroreceptors are involved with the regulation of blood volume. The blood volume determines the mean pressure throughout the system, in particular in the venous side where most of the blood is held.

The low pressure baroreceptors have both circulatory and renal effects, they produce changes in hormone secretion which have profound effects on the retention of salt and water and also influence intake of salt and water. The renal effects allow the receptors to change the mean pressure in the system in the long term.

12.2 Cardiovascular Disorders

Many disorders are associated with the circulatory system. Some of the significant are the following.

12.2.1 Thrombosis and Embolism

Thrombosis is a Greek word which means **blood clot**. It is formed by the aggregation of platelets inside the vessels. The disorder in which a person generates a thrombus in a vessel is called **thrombosis**. A thrombus in a blood vessel is very painful. A thrombus in a large blood vessel decreases blood flow through that vessel but in a small blood vessel it may completely stop the blood flow resulting in the death of tissue supplied by that vessel. Risk of thrombosis increases in certain conditions like atrial fibrillation, heart valve replacement, a recent heart attack, extended periods

Generally bed ridden patients and people like barbers who keep standing for hours as part of their daily routine suffer from this disorder. A thrombus which dislodges and becomes free-floating is termed as an embolus. The term embolus was coined by Rudolph Carl Virchow in 1848. An embolus migrates from one part of the body, through blood circulation, and causes a blockage of a blood vessel in another part of the body.

In thrombo embolism, the thrombus from a blood vessel is completely or partially detached from the site of thrombosis. The blood flow will then carry the embolus (via blood vessels) to various parts of the body where it can block the lumen and causes vessel obstruction or occlusion. One of the most commonly recognized problems caused by the embolus is called **coronary thrombosis**. In this case, the thrombus blocks a coronary artery causing myocardial infarction commonly known as a heart attack. Even worse situation appears when the thrombus blocks an artery to the brain. This is commonly called as **stroke**. A stroke may result in sudden death or paralysis of the body.

12.2.2 Atherosclerosis and Arteriosclerosis

a. **Atherosclerosis:** It (Gr. *Athere* = porridge, *skeleoris* = hardening) is the condition in which the wall of artery thickens as a result of deposition of fatty materials such as cholesterol. It develops from low-density lipoprotein molecules (LDL) becoming oxidized by free radicals.

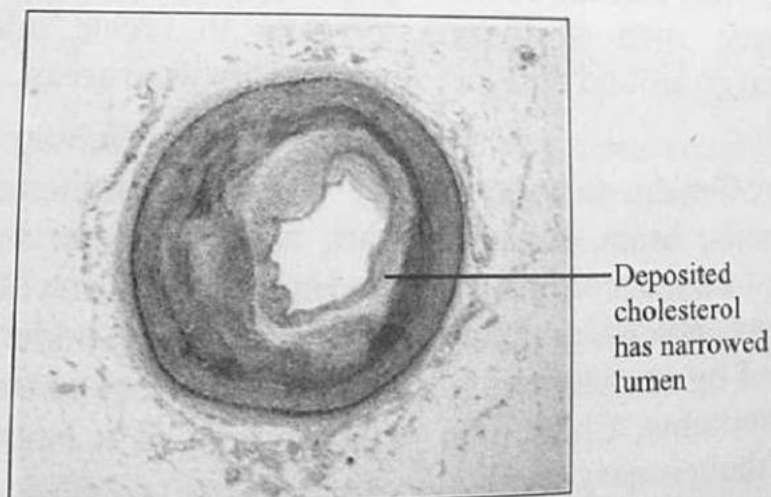


Fig: 12.9 A coronary artery with atherosclerosis. The lumen has been narrowed to a greater extent.

When oxidized LDL comes in contact with the wall of an artery, a series of reactions occur to repair the damage to the artery wall caused by oxidized LDL. The body's immune system sends specialized white blood cells called macrophages and T-lymphocytes to absorb the oxidized-LDL, forming specialized foam cells.

Unfortunately, these white blood cells are not able to process the oxidized-LDL. They grow and then rupture, depositing a greater amount of oxidized cholesterol into the artery wall. This triggers more white blood cells and the cycle continues. As a result, the artery becomes inflamed. The cholesterol plaque causes the muscle cells to enlarge and form a hard cover over the affected area. This hard cover causes the artery lumen to become narrow. Narrowing of artery reduces the blood flow and increases blood pressure. Atherosclerosis typically begins in early adolescence, and is usually found in most major arteries, yet is asymptomatic and not detected by most diagnostic methods until it grows to a serious threat to health. There are various anatomic, physiological and behavioral factors which increase the risk for atherosclerosis. Factors add to each other multiplicatively, with two factors increasing the risk of atherosclerosis fourfold. Studies show that Hyperlipidemia (High level of fats in blood), hypertension and cigarette smoking together increases the risk seven times.

Instead of medication the first method of treatment advised by the doctors, throughout the world, is to stop smoking, change feeding habits and choice of foods and practicing daily exercise or at least daily walk. If these methods do not work, medicines are usually the next step in treating cardiovascular diseases. If atherosclerosis leads to symptoms like angina pectoris then it becomes necessary to start medication.

Physical treatments which are helpful in the short term include **angioplasty** procedures that may include **stents** to physically expand narrowed arteries and major invasive surgery, such as **bypass surgery** to create additional blood supply connections that go around the more severely narrowed areas.

b. Arteriosclerosis: It is any hardening, stiffening or loss of elasticity of arterioles. It is often due to hypertension. The most common sites for arteriosclerosis are arteries in the brain, kidneys, heart, abdominal aorta or legs. Symptoms of arteriosclerosis vary according to the arteries which are affected. Leg pain when exercising might indicate peripheral arterial disease. Sudden weakness or dizziness could be caused by an obstruction in the carotid artery in the neck, which produces stroke-like symptoms. Chest pain or symptoms of a heart attack might indicate obstruction of the coronary arteries.

Risk factors for arteriosclerosis are more or less similar as that of atherosclerosis. They include smoking, obesity, high blood pressure, high serum cholesterol, stress, and diabetes. A family history of early heart disease is also a risk factor for developing arteriosclerosis.

12.2.3 Congenital Heart Problem

A congenital heart defect is a defect in the structure of the heart and large blood vessels of a newborn baby. Most of these heart defects either obstruct blood flow in the heart or vessels near it or cause blood to flow through the heart in an abnormal pattern. Defect may also occur affecting the heart rhythm.. Heart defects are among the most common birth defects and are the leading cause of birth defect-related deaths. Congenital heart disease can be categorized in to different types. In some babies right ventricle or the left ventricle fails to develop. As a result only one side of the heart pumps the blood the body and lungs. This defect is called Hypoplasia of the heart which is rare but is the most serious form of congenital heart defect.

Other type of defect may be called as Obstruction defects. Obstruction defects occur when heart valves, arteries, or veins are abnormally narrow or blocked. Common obstruction defects include blockage of pulmonary valve, aortic valve and bicuspid aortic valve. Any narrowing or blockage can cause heart enlargement or hypertension.

The most common among the congenital heart defects are the defects in the septa of the heart. The septum is a wall of tissue which separates the left side of the heart from the right side of the heart. The defect may be in the septum between the atria or the septum between the ventricles. Due to this defect the blood flows from the left side of the heart to the right side. This mixing of oxygenated and deoxygenated blood reduces the overall efficiency of the heart. Septal defects may or may not cause cyanosis depending on the severity of the defect. Some times the defect is so minor that it requires no treatment and is corrected by itself with the passage of time and increasing age. Major defects require medication and surgery.

12.2.4 Blue Baby or Cyanosis

One of the effect of congenital heart defect is the birth of blue babies, a physiological condition called cyanosis. The reason for the appearance of blue colour is the formation of carboxyhaemoglobin instead of oxyhaemoglobin in the blood because of limited availability of oxygen. During the embryonic life, heart of the foetus start beating after four month of gestation. In the heart of the foetus, an opening, "foramen ovale" connects the right atrium with left atrium. The blood passes from right atrium to the left without passing through lungs. The reason for this bypass is that the supply of oxygen to the foetus is from the blood of the mother through placenta (and not by lungs).

After the birth the foramen ovale closes spontaneously but in some babies it does not close completely. When the baby exerts force during crying and movement the deoxygenated blood from the right atrium enters the left atrium through the partially opened foramen.

When the haemoglobin of this venous, deoxygenated blood turns to carboxyhaemoglobin, it imparts blue discoloration to the skin, lips, ears and other organs of the baby, resulting in cyanosis or blue baby.



Fig: 12.10 Blue baby

12.2.5 Hypertension

Hypertension is a chronic medical condition in which a person suffers persistently from high blood pressure. As you studied under the section of blood pressure the normal BP of a healthy normal adult is 120/80 mm Hg and with increasing age the normal BP also increases. For a normal adult a mercury reading of 130/90 is considered hypertensive. For a women of above forty five years of age BP of 160/95 is considered hypertensive whereas for a man this limit is 140/95. Hypertension can be classified as

- Essential or primary hypertension
- Secondary hypertension

Primary or essential hypertension means that no medical cause is found to explain the raised blood pressure. Secondary hypertension indicates that the high blood pressure is a result of another condition, such as kidney disease, Cushing's syndrome, (a disorder in which both adrenal glands can overproduce the hormone cortisol) or tumours or due to medication such as Ibuprofen and steroids.

For Your Information

Studies have shown that reduction of the blood pressure by 5–6 mmHg can decrease the risk of stroke by 40% and of coronary heart disease by 15–20%. This also reduces the likelihood of dementia, heart failure and mortality from vascular disease to a greater extent.

Persistent hypertension is one of the risk factors for strokes, heart attacks, heart failure and arterial aneurysm, and is a leading cause of renal (kidney) failure.

Prevention and Treatment of Hypertension

Hypertension can be treated by:

- Weight reduction
- regular aerobic exercise
- Reducing dietary intake of sugar and table salt
- By taking a diet rich in fruits and vegetables and low-fat or fat-free dairy foods
- By discontinuing use of tobacco and alcohol
- Reducing stress and tensions
- severe cases antihypertensive medicines are also used.

Hypotension is the opposite of hypertension. **Hypotension** is abnormally low blood pressure. It is considered as a physiological state, rather than a disease. Not always but most often hypotension is associated with shock. Hypotension can also be life-threatening. The initial symptom of hypotension is dizziness. If the blood pressure is sufficiently low, fainting and often seizures will occur. Patients with hypotension also complain chest pain, shortness of breath, irregular heartbeat and headache.

The most common cause of producing hypotension is reduced blood volume in the body. This reduction in the volume of blood can result from hemorrhage (blood loss) insufficient fluid intake (as in starvation), excessive fluid losses from diarrhea or vomiting, or is often induced by excessive use of diuretics. Some medicines can also produce hypotension as a side effects.

12.2.6 Angina Pectoris

Angina pectoris or simply **angina** is a severe, radiating chest pain due to the lack of blood supply to the heart muscle, generally due to obstruction or spasm of the coronary arteries. Main cause of angina, is atherosclerosis of the cardiac arteries. pain of angina starts from left side of the chest and radiates to left shoulder, neck and sometimes cerebral region.

Angina is the first alarm of the body to show that something is going wrong with the heart. Those who realize and start precautionary measures and bring a change in their lifestyle and diet, they lead a successful and active life. Those who do not care and continue with their life style generally come across a heart attack. It is a common experience that people survive in first two attacks but mostly third attack is fatal and results in heart failure.

Treatment of Cardiovascular disorders:

In the above description you studied many ways to prevent and minimize different cardiovascular diseases. These ways help the patients to certain extent but sometimes doctors advise major or minor surgery or some other modern ways to provide relief to the patient. Among these methods some are

- Angiography
- Angioplasty
- Coronary bypass
- Open heart surgery

a. Angiography

Angiography is a test that uses an injection of a liquid dye to make the arteries easily visible on X-rays. An angiogram is commonly used to check the condition of blood vessels. There are alternatives nowadays to angiography, such as CT scan, MRI scans, nuclear scans, and ultrasound scans, which often produce information as accurate and useful as angiograms.

b. Angioplasty

One method of treatment of a blocked artery is angioplasty. The term angioplasty is a the combination of two Greek words; *aggeios* meaning "vessel" and *plastos* meaning "formed" or "moulded". It is the technique of mechanically widening a narrowed or obstructed blood vessel; typically as a result of atherosclerosis. In this treatment a balloon-tip catheter is passed in the artery. At the site where the lumen is narrowed due to blockage, the balloon is inflated to a fixed size using water pressures some 75 to 500 times more than normal blood pressure (6 to 20 atmospheres). This high pressure removes the blockage and opens the artery.

Sometimes, to ensure that the lumen remains open, a metallic ring called stent is placed there at the site. This stent remains there as part of the artery and ensures that the artery remain open.

The angioplasty is not restricted to the coronary arteries.

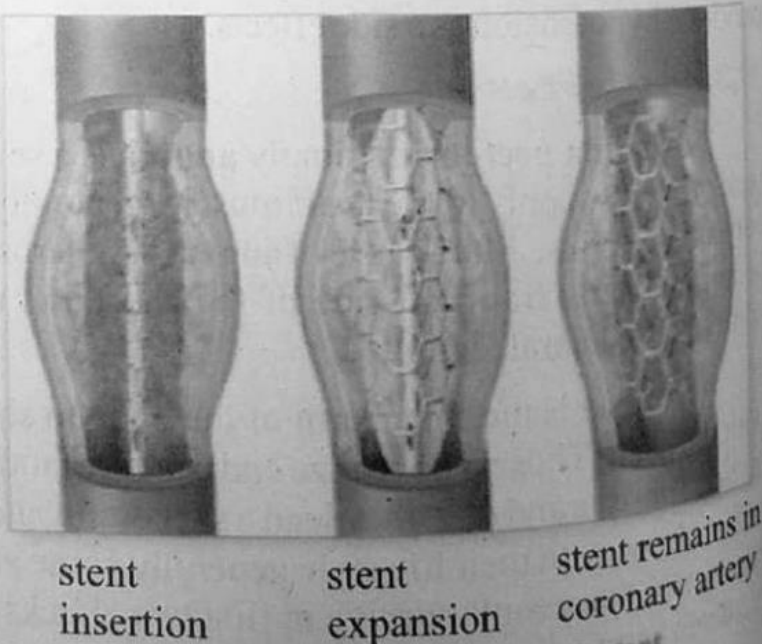


Fig: 12.11 Angioplasty through stent

Now other arteries which get narrowed by atherosclerosis are cleared and opened by this procedure generally called peripheral angioplasty. This type of angioplasty includes **renal** artery angioplasty, Carotid angioplasty, Cerebral arteries angioplasty etc.

c. **Coronary bypass or Open heart surgery**

Another treatment is called **Coronary artery bypass surgery (also called coronary by pass or simply bypass)**. In this treatment a vessel is taken from some other part of the body and is grafted from aorta to the coronary artery system. This vessel starts supplying blood to the heart muscles by passing the original blocked artery. This surgery is usually performed with the heart stopped, necessitating the usage of cardiopulmonary bypass; techniques are available to perform bypass on a beating heart, so-called "off-pump" surgery.

For Your Information

History of coronary artery bypass

The first coronary artery bypass surgery was performed in the United States on May 2, 1960 at the Albert Einstein College of Medicine, Bronx Municipal Hospital Center by a team led by Dr. Robert Goetz and the thoracic surgeon, Dr. Michael Rohman with the assistance of Dr. Jordan Haller and Dr. Ronald Dee. They used internal mammary artery as the donor vessel and was anastomosed to the right coronary artery. In 1967 Dr. René Favaloro introduced a new technique in which a saphenous vein (present in lower part of leg) was used to replace the blocked coronary artery. He later began to use the saphenous vein as a bypassing channel and become instantly successful. This is the typical bypass graft technique we know today.

A successful graft typically lasts around 10–15 years which means this process sufficiently improves the chances of survival of a patient suffering from atherosclerosis.

d. Open Heart Surgery

Any surgery where the chest is opened and surgery is performed on the heart muscle, valves, arteries, or other heart structures is termed as open heart surgery. The term "open" refers to the opening of chest and not the heart itself. The heart may or may not be opened, depending on the type of surgery. As for sometime heart is non-functional a heart-lung machine (also called cardiopulmonary bypass) is usually used during conventional open heart surgery. It helps provide oxygen-rich blood to the brain and other vital organs. The definition of open heart surgery has become confusing with new procedures being performed on the heart through smaller incisions. There are some new surgical procedures being performed that are done with the heart still beating and is generally termed as beating heart surgery.

For Your Information

The first successful surgery of the heart, performed without any complications, was by Dr. Ludwig Rehn of Frankfurt, Germany, who repaired a stab wound to the right ventricle on September 7, 1896. It was soon discovered that the surgery is better done with a bloodless and motionless environment, which means that the heart should be stopped and drained of blood. The first successful intracardiac correction of a congenital heart defect using hypothermia was performed by Dr. C. Walton Lillehei and Dr. F. John Lewis at the University of Minnesota on September 2, 1952. In all the major Govt hospitals like Lady reading Hospital, Peshawar Hayatabad Medical complex, Ayub Teaching Hospitals Abbottabad cardiology centres are providing quality treatment for cardiac patients.

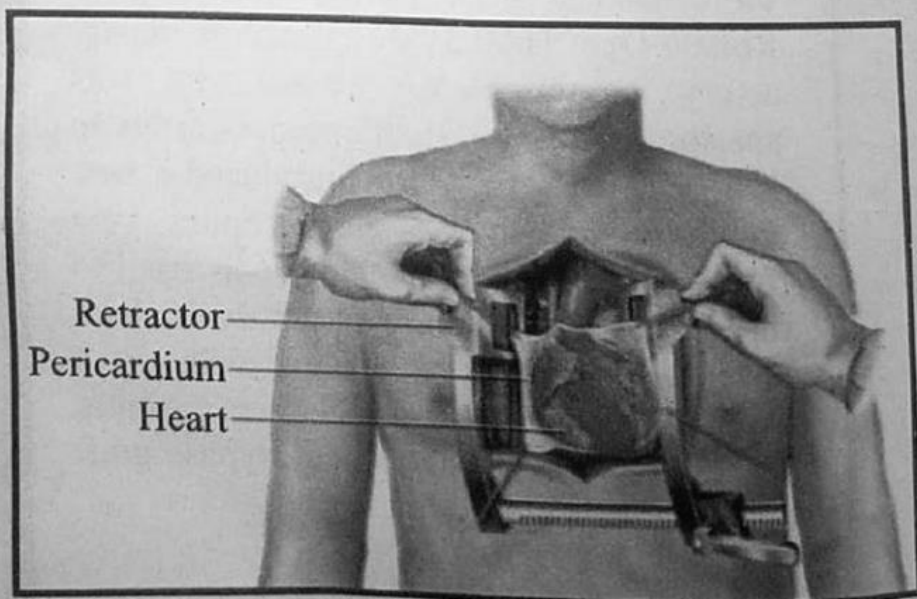


Fig: 12.12 Open heart surgery in process

12.3 Lymphatic System

The **lymphatic system** is a network of vessels found in vertebrates that carry a milky fluid called lymph. It also includes the lymphoid tissue through which the lymph travels. This system transports and returns materials from the tissues of the body to blood. In 1652 the lymphatic ducts in the liver were first described by a Swedish Olaus Rudbeck (1630–1702) and the very next year it was Thomas Bartholin who described these vessels in the whole body and gave them the name of lymphatic vessels.

Lymph vessels, at certain points, have masses of connective tissues called **lymph nodes**. These nodes (more than 100 in human body) are present in the armpits, groin and neck region. These are the sites of lymphocyte production and storage. They act as barriers to infection by filtering out and destroying toxins and germs. The largest body of lymphoid tissue in the human body is the spleen.

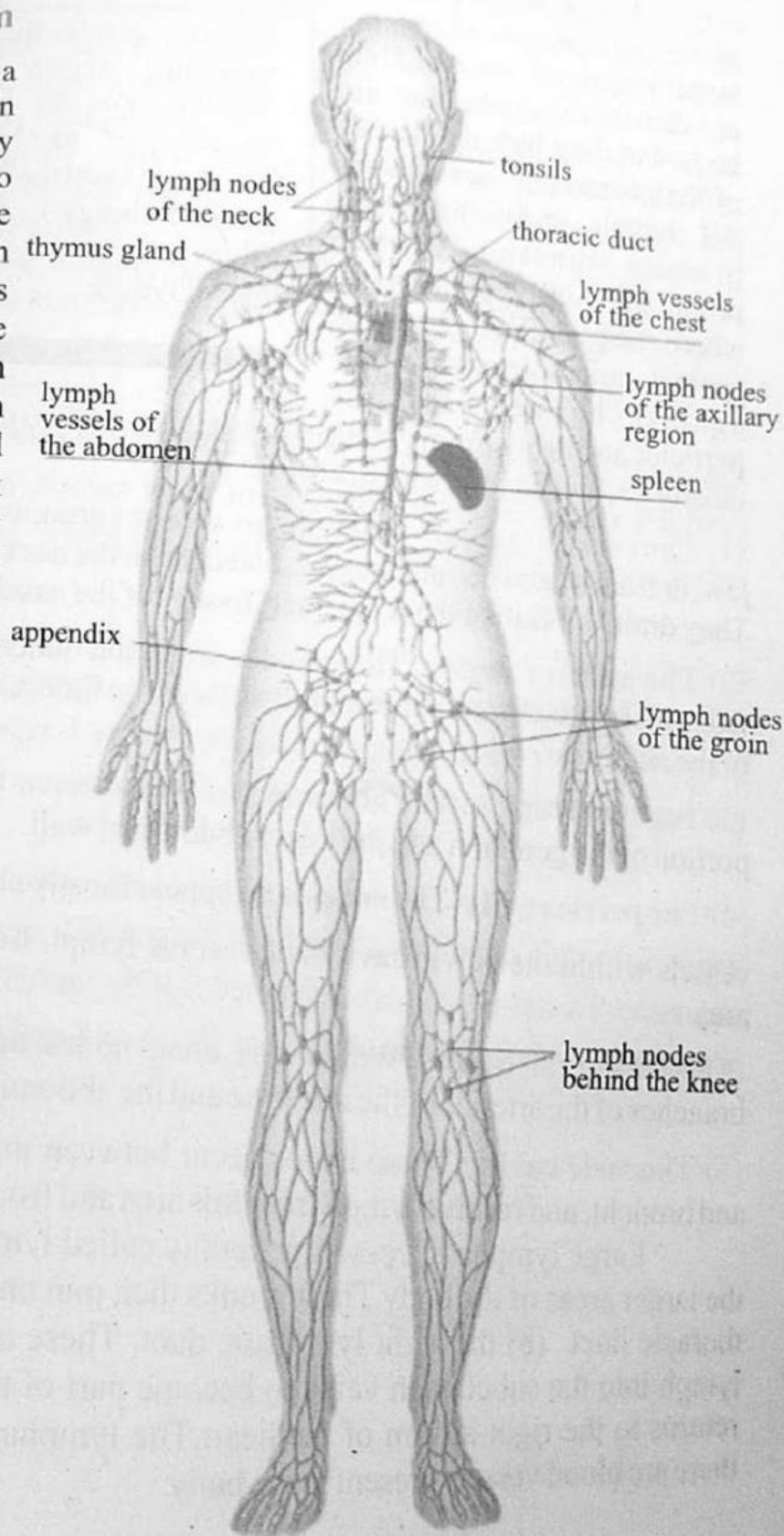


Fig: 12.13 Lymphatic System in a Human body

a. Position of lymph node

Lymph nodes generally occur in groups along the larger lymphatic vessels. They are distributed throughout the body, but they lack the tissues of the central nervous system. All lymph nodes have the primary function of the production of lymphocytes, which help defend the body against microorganisms and against harmful foreign

particles and debris from lymph before it is returned to the blood stream. The nodes are mostly located in following six areas:

For Your Information

Although lymphatic system does not possess any pumping organ like heart to provide pressure/force to transport material but the activity of skeletal muscles, breathing movements and movement of the viscera provide it ample energy to move the fluid upward. The valves present in lymph vessels prevent the back flow of lymph.

(1) **The cervical region:** Nodes in this area are grouped along the lower border of the jaw, in front of and behind the ears, and deep in the neck along the larger blood vessels. They drain the skin of the scalp, face, tissues of the nasal cavity, and the pharynx.

(2) **The axillary region:** These nodes are in the underarm region and receive lymph from vessels that drain the arm, the walls of the thorax, the breast, and the upper walls of the abdomen.

(3) **Inguinal region:** The nodes in this area receive lymph from the legs, the outer portion of the genitalia and the lower abdominal wall.

(4) **The pelvic cavity:** The nodes here appear mostly along the paths of the blood vessels within the pelvic cavity and receive lymph from the lymphatic vessels in the area.

(5) **Abdominal cavity:** Within this area, nodes occur in chains along the main branches of the arteries of the intestine and the abdominal aorta.

(6) **Thoracic cavity:** These nodes occur between the lungs and along the windpipe and bronchi, and receive lymph from this area and from the internal wall of the thorax.

Large lymphatic vessels generally called lymphatic trunks drain lymph from the larger areas of the body. These trunks then join one of two collecting ducts: (a) the thoracic duct (b) the right lymphatic duct. These collecting ducts finally drain the lymph into the subclavian veins to become part of the plasma, just before the blood returns to the right atrium of the heart. The lymphatic vessels are present wherever there are blood vessels present in the body.

They are joined by a capillary system. When the blood passes through arteries, veins and capillaries the water along with certain salts, some plasma proteins etc ooze out in tissue spaces. This fluid is called **interstitial fluid**. Interstitial fluid bathes the cells in the tissue space. From here this fluid is collected in the fine, very permeable, blind ended capillaries of lymphatic system in the form of lymph which join to make larger vessels. The lymphatic vessels transport this excess fluid to the end vessels without the assistance of any "pumping" action. This system is very important for the distribution of fluids and nutrients in the body, because it drains excess fluids and protein so that tissues do not swell up. Our body also eliminates the products of cellular breakdown and bacterial invasion through this system. It filters out organisms like bacteria, viruses and fungi that cause disease, produces certain white blood cells called lymphocytes.

b. **Spleen as lymphatic organ**

The spleen is an effective in protecting the body by clearing worn out red blood cells and other foreign bodies from the bloodstream. The spleen contains lymphocytes and macrophages, which can engulf and destroy bacteria, dead tissue, and foreign matter.

c. **Lymphatic system and cancer**

The study of lymphatic drainage of various organs is important in diagnosis, prognosis, and treatment of cancer. Lymph nodes can trap the cancer cells. If they are not successful in destroying the cancer cells the nodes may become sites of secondary tumors.

d. **Diseases of lymphatic system**

Problems with the system can impair the body's ability to fight infections. Hodgkin's disease is an enlargement of the lymph nodes in the neck. Pressure on adjoining organs and nerve endings can result in a dysfunction of vital organs or in paralysis.



KEY POINTS

- The circulatory system is an organ system that transports nutrients, gases, hormones, blood cells, nitrogenous waste products, etc. to and from cells in the body to help fight diseases and help stabilize body temperature and pH to maintain homeostasis.
- One contraction and one relaxation is called a cardiac cycle. Contraction of heart is termed as systole and relaxation as diastole.
- The pacemaker or SA node is the impulse-generating tissue located in the upper dorsal wall of the right atrium of the heart, near the entrance of the superior vena cava.
- Electrocardiograph (ECG) is a medical device used for recording the electrical activity of the heart.
- A capillary is so thin that only one RBC passes through it at a time, releasing its oxygen by diffusion to the cells. The very small diameter of the capillaries provides ample time to the blood for exchange of materials.
- Most of the volume of blood is contained in veins. The reason is that, instead of providing resistance in the flow of blood like arteries, they expand to accumulate additional volume of blood.
- The force per unit area that blood exerts on the inside walls of a blood vessel is called blood pressure.
- Blood pressure is of two types: Systolic blood pressure which is felt during the ventricular contraction. Diastolic blood pressure which is felt during ventricular relaxation.
- Certain sensors (nerve endings) are located in the blood vessels of the human body called Baroreceptors (or baroreceptors). They detect the pressure of blood flowing through them.
- Thrombus is a blood clot which is formed by the aggregation of platelets inside the vessels. The disorder in which a person generates a thrombus in a vessel is called thrombosis.
- Hypertension is a chronic medical condition in which a person suffers persistently from high blood pressure.
- Angina is a severe, radiating chest pain due to the lack of blood (and oxygen) supply to the heart muscle, generally due to obstruction or spasm of the coronary arteries.
- A surgery where the chest is opened and surgery is performed on the heart muscle, valves, arteries, or other heart structures is termed as open heart.
- The lymphatic system is a network of vessels found in vertebrates that carry a milky fluid called lymph. Lymph vessels, at certain points, have masses of connective tissues called lymph nodes.



The foramen ovale in the fetal heart is located in the:

1. The foramen ovale
a. Right atrium
b. Left atrium
c. Interventricular septum
d. Interatrial septum
2. Colouration of the skin of a baby turns bluish shortly after birth. The reason may be:
a. Increased level of anesthesia was administered to her/his mother
b. Baby has an unclosed foramen ovale.
c. Some hormonal disturbance has caused discolouration.
d. Blood capillaries in the liver are not working efficiently.
3. Lymph is poured back to the circulatory system in
a. pulmonary vein
b. hepatic portal vein
c. subclavian vein
d. renal vein
4. The interventricular septum and the intra-atrial septum separate the:
a. chambers of the heart
b. chambers of the lungs
c. aorta and pulmonary artery
d. bicuspid and tricuspid valves
5. The systemic circuit of the cardiovascular system extends:
a. from the heart to the lungs.
b. from heart to the coronary arteries.
c. from the heart to the body's organs and tissues.
d. from the gastrointestinal tract to the liver.
6. The only vein in the body that transports oxygen-rich blood is the:
a. coronary vein
b. hepatic portal vein
c. pulmonary vein
d. aortic vein
7. The semilunar valves prevent blood from flowing backwards:
a. into the atria
b. into the ventricles
c. into the aorta
d. into the vena cava

EXERCISE



8. All the following apply to the bicuspid valve EXCEPT:

- a. It is also called the mitral valve
- b. It is a semilunar valve
- c. It is found on the left side of the heart
- d. It prevents blood from backing into the left atrium

9. The condition called arrhythmia is characterized by:

- a. rapid heart contraction.
- b. irregular heart rhythms.
- c. mitral valve prolapse.
- d. semilunar valve dysfunction.

10. Intercalated disks are found:

- a. between the right side and right side of the heart.
- b. between the flaps of the tricuspid valve.
- c. where the aorta joins the pulmonary artery.
- d. between the cardiac muscle cells.

11. Blood flowing through a vein tends to:

- a. pulse.
- b. collect blood.
- c. carry oxygen to the body cells.
- d. flow at a faster rate than in the artery.

B. Write short answers to the following questions.

- 1. How the interstitial fluid is formed?
- 2. Why the normal value of BP increases in old age? Explain your answer.
- 3. If the baroreceptors are removed from an artery what would be the effect?
- 4. What changes occur in BP and cardiac output during a strenuous exercise?
- 5. If we don't take water the whole day in the month of June, what would be the effect on volume of lymph?

C. Write in detail the answers of following questions.

- 1. Draw the internal structure of a human heart and show the blood circulation with the help of arrows.
- 2. Name major arteries and veins and discuss the organs to which they target.
- 3. Define blood pressure and explain its periods of systolic and diastolic pressure.

EXERCISE



4. Describe the principles of angiography.
5. Describe the functions of lymph nodes and state the role of spleen as containing lymphoid tissue.
6. List the changes in life styles that can protect man from hypertension and cardiac problems.
7. Identify the factors causing atherosclerosis and arteriosclerosis.

Projects:

- Conduct a survey to identify major hospitals of cardiology working in your area. In case of no such facility available, identify the nearest cardiac centre and its utility or otherwise for cardiac patients in case of emergency situation.
- Record an interview with a patient who has undergone coronary bypass surgery. Collect information regarding his/her past life style, dietary habits and genetic history. Draw a conclusion from this data for preventing cardiac issues and for sustaining healthy life.