CHAPTER 12

CIRCULATION

Number of allotted teaching periods: 14

Major Concepts:

INTRODUCTION

All organisms must exchange materials with their environment and distribute materials within their bodies. Most animals have a system of internal transport - a **circulatory system** that transports oxygen and carbon dioxide, distributes nutrients to the body cells and conveys the waste products of metabolism to specific site for disposal.

12.1 BLOOD CIRCULATORY SYSTEM OF MAN

The circulatory system of man is divided into **cardiovascular system** and **lymphatic system**. The cardiovascular system consists of a strong muscular heart, three kinds of blood vessels: arteries, capillaries, veins and blood.

12.1.1 HEART

The heart functions as a pump and is responsible for the circulation of the blood through the blood vessels. The heart `produces the pressure responsible for making blood flow through the blood vessels by contracting forcefully. The human heart is a hollow, fibromuscular organ. The Greek name for the heart is *cardia* from which we have the adjective **cardiac**. The Latin name for the heart is *cor* from which we have adjective **coronary**. The adult heart has the shape of a cone. The blunt, rounded point of the cone is the apex and the larger flat part at the opposite end of the cone is the base.

12.1.2 STRUCTURE OF HUMAN HEART

The heart is located in the thoracic cavity between the lungs. The heart, trachea, oesophagus and associated structures form a middle portion called **mediastinum**. The heart lies deep and obliquely in the mediastinum and slightly to the left of the sternum. The base of heart deep to the sternum, extends to the second intercostals space and the apex of the heart is in the fifth intercostals space, approximately 9 cm to the left of the midline.

Pericardium

The **pericardium** is a closed sac that surrounds heart. It consists of two parts; the out part and inner part. The outer part consists of inelastic white fibrous tissue. The inner part is made up of two membranes. The inner membrane is attached to the heart and the outer one is attached to the fibrous tissue. Pericardial fluid is secreted between them and reduces the friction between the heart wall and surrounding tissues when the heart is beating. The inelastic nature of the pericardium as whole prevents the heart from being overstretched or overfilled with blood.

Science Titbits

Pericarditis is an inflammation of the serous pericardium. It can be extremely painful, with sensations of pain referred to the back and the chest which can be confused with the pain of myocardial infarction (heart attack).

Q. What are the functions of pericardium?

Anatomy of the Heart

The heart consists of four chambers: two atria (meaning, entrance chamber) and two ventricles (meaning, belly)

External Features

The atria lie above and behind the ventricles. On the surface of the heart they are separated from each other by an **atrioventricular groove** or **sulcus** (meaning ditch). The atria are separated from each other by an **interatrial groove**. The ventricles are separated from each other by an **interventricular groove**. In normal intact heart the **sulci** are covered by fat and only after this fat is removed the actual sulci can be seen.

Structure of the Walls of the Heart

The heart wall is composed of the three layers of tissue. The epicardium, the myocardium, and the endocardium. The **epicardium** is a thin serous membrane comprising of the smooth outer surface of the heart. The thick middle layer of the heart, the **myocardium**, is composed of cardiac muscle cells and is responsible for the ability of the heart to contract. The smooth inner surface of the heart chambers is the **endocardium**, which consists of simple squamous epithelium over a layer of connective tissue. The smooth inner surface allows blood to move easily through the heart. The **heart valves** are formed by a fold of the endocardium, making a double layer of endocardium with connective tissue in between.

Thickness of the Walls of each Chamber

The right ventricle has thinner walls than the left ventricle in a ratio of 1:3, it pumps blood to the lungs, which are at a short distance from the heart. The atria have comparatively thin walls as they only have to force blood into the ventricles and this does not require much power. On the other hand, the ventricles have to force blood out of the heart hence they have relatively thick walls, especially the left ventricle which has to pump blood round the whole body.

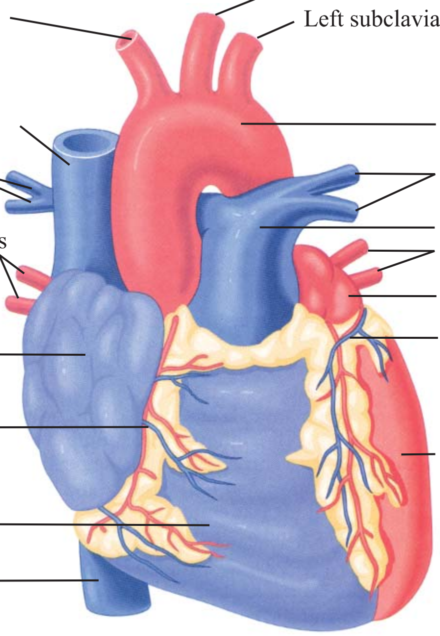


Fig: 12.1 Human Heart, External view

Heart Chambers and Valves

The **right atrium** receives three veins: the superior vena cava, the inferior vena cava, and the coronary sinus. The **left atrium** receives the four pulmonary veins. The two atria are separated from each other by the **interatrial septum**. The atria open into the ventricles through **atrioventricular canals**. The **right ventricle** opens into the pulmonary trunk, and the **left ventricle** opens into the aorta. The two ventricles are separated from each other by the **interventricular septum.**

Atrioventricular Valves

An **atrioventricular valve** is on each atrioventricular canal and is composed of **cusps**, or flaps. These valves allow blood to flow from the atria into the ventricles, but prevent blood from flowing back into the atria. The atrioventricular valve between the right atrium and the right ventricle has three cusps and is called the **tricuspid valve**. The atrioventricular valve between the left atrium and left ventricle has two cusps and is therefore called the **bicuspid** or **mitral** (meaning, resembling a bishop's miter, a two-pointed hat), **valve**. Each ventricle contains cone-shaped muscular pillars called **papillary** (meaning, pimple-shaped) **muscles**. These muscles are attached by thin, strong connective tissue strings called **chordae tendineae** (meaning, heart strings) to the cusps of the atrioventricular valves. The papillary muscles

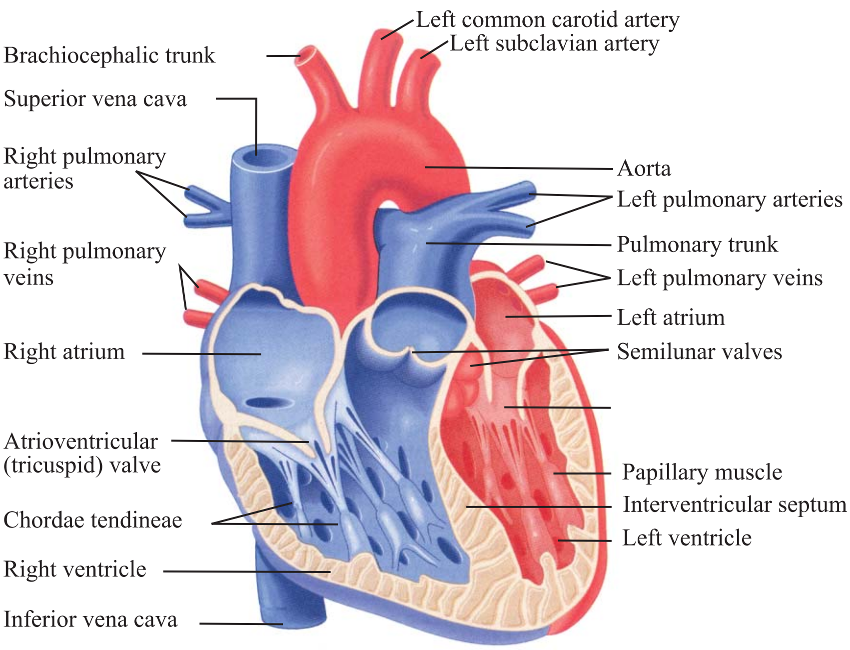


Fig: 12.2 Dissection of a human heart, as seen from the front, with the ventral part of both atria and both ventricles removed

contract when the ventricles contract and prevent the valves from opening into the atria by pulling on the chordae tendineae attached to the valve cusps. Blood flowing from the atrium into the ventricle pushes the valve open into the ventricle, but, when the ventricle contract, blood pushes the valve back towards the atrium. The atrioventricular canal is closed as the valve cusps meet.

Q. What is the function of chordae tendineae?

Semilunar Valves

The aorta and pulmonary trunk possess **aortic** and **pulmonary semilunar** (meaning halfmoon-shaped) **valves**. Each valve consists of three pocketlike semilunar cusps, the free inner borders of which meet in the centre of the artery to block blood flow.

12.1.3 PASSAGE OF BLOOD THROUGH HEART

The **superior vena cava** and the **inferior vena cava**, both carrying deoxygenated blood, enter the right atrium. The **right atrium** sends blood through an atrioventricular valve (the **tricuspid valve**) to the right ventricle. The right ventricle sends blood through the **pulmonary semilunar valve** into the **pulmonary trunk** and the two **pulmonary arteries** to the lungs. Four **pulmonary veins**, carrying oxygenated blood from the lungs, enter the left atrium.The **left atrium** sends blood through an atrioventricular valve (the **bicuspid valve**) to the **left ventricle**. The left ventricle sends blood through the **aortic semilunar valve** into the **aorta** to the body proper. The heart is a **double pump** because the right ventricle of the heart sends blood through the lungs, and the left ventricle sends blood throughout the body.

12.1.4 HEARTBEAT AND ITS CONTROL

The heart is the hub of the circulatory system. In a continuous, rhythmic cycle it passively fills with blood from the large veins and then actively contracts, propelling the blood throughout the body. Its alternating relaxations and contractions make up the **cardiac cycle**. The cardiac cycle is a sequence of one heartbeat.

Phases of Heartbeat

The term systole means to contract and diastole means to dilate. **Atrial systole** is contraction of the atrial myocardium and **atrial diastole** is

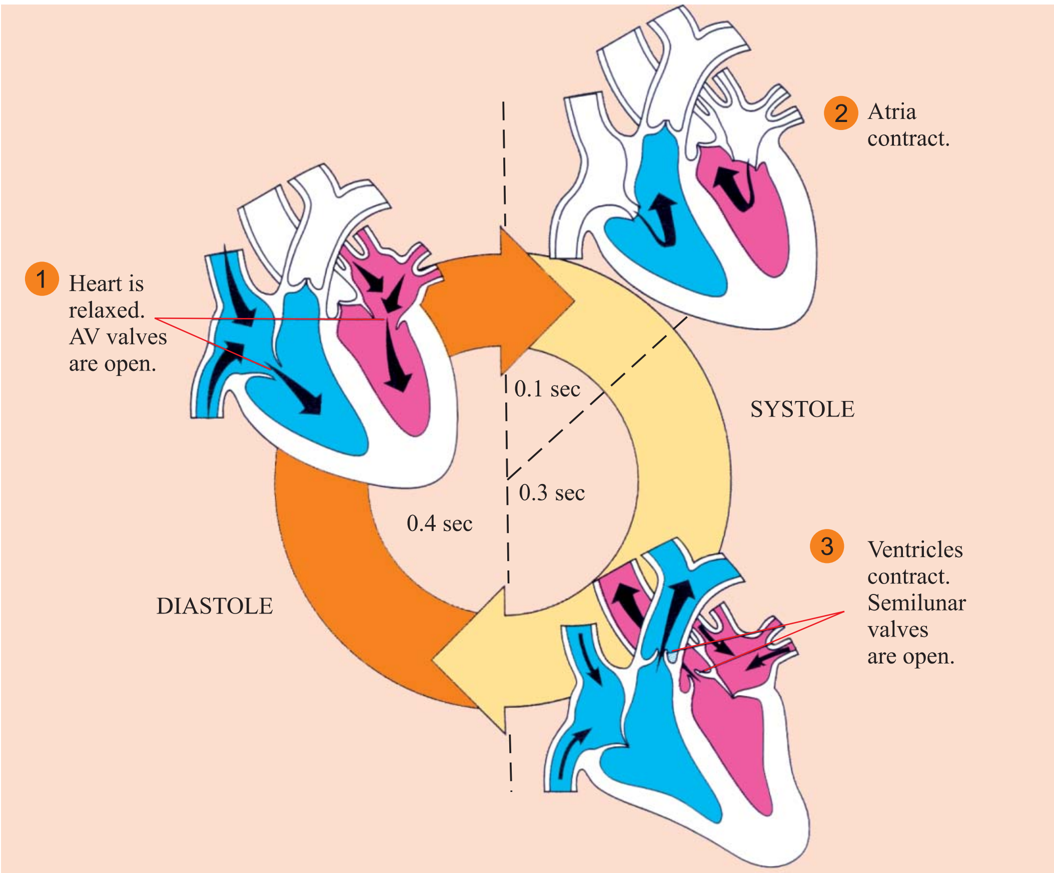


Fig 12.3 Cardiac Cycle

relaxation of the **atrial myocardium**. Similarly **ventricular systole** is contraction of the ventricular myocardium and **ventricular diastole** is the relaxation of the **ventricular myocardium**. When the word “systole” and “diastole” are used without reference to specific chambers, they mean ventricular systole or diastole.

Atrial Diastole : Blood enter the right atrium from the body through the vena cavae. At first the bicuspid and tricuspid valves are closed, but as the atria fill with blood, pressure in them rises. Eventually it becomes greater than that in the relaxed ventricles and the valves are pushed open.

Atrial Systole: The two atria contract simultaneously and blood is pushed through the **atrio-ventricular** valve into the still relaxed ventricles. At this phase semilunar valve is closed, tricuspid and bicuspid valves are open.

Ventricular Systole: Almost immediately the **ventricle** contract. When this occurs the pressure in the ventricles rises and closes the atrioventricular valves, preventing blood from returning to the atria. This pressure forces, open semilunar valves of the aorta and the pulmonary artery and blood enters these vessels. In this phase the tricuspid and bicuspid valves are closed.

Ventricular Diastole: The high pressure developed in the aorta and pulmonary artery tends to force some blood back towards the **ventricles** and close the **semilunar valves** of the aorta and pulmonary artery. Hence back flow in the heart is prevented. In this phase **bicuspid valve** and **tricuspid valve** are open, **aortic semilunar valve**, and **pulmonary semilunar** are closed. The normal cardiac cycle of 0.7 to 08 second depending on the capability of cardiac muscle to contract. The heart muscle rests 0.1 to 0.3 second between the beats.

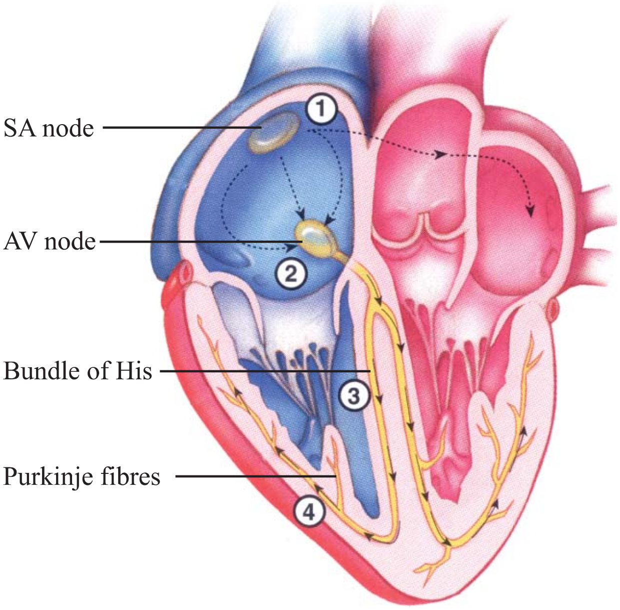
Heart Sounds

When a stethoscope is used to listen to the heart sounds, distinct sounds normally are heard. The **first heart sound** is a low-pitched sound, often described as a **“lubb”** (lub) sound. It is caused by vibration of the atrioventricular valves which close near the beginning of ventricular systole. The **second heart sound** is a higher pitched sound often described as a **“dupp”** (dub) sound. It results from closure of the aortic and pulmonary valves, near the end of systole.

> **Critical Thinking**
>
> Where are the sounds lub and dub produced in heart during cardiac cycle?

Conducting System of the Heart

Most muscles contract as a result of impulses reaching them from nerves. This is not, however true of the heart, which will continue beating



1. Action potentials originate in the sinoatrial (SA) node and travel across the wall of the atrium (arrows) from the SA node to the atrioventricular (AV) node.

2. Action potentials pass through the AV node and along the atrioventricular (AV) bundle, which extends from the AV node, through the fibrous skeleton, into the interventricular septum.

3. The AV bundle divides into right and left bundle branches, and action potentials descend to the apex of each ventricle along the bundle branches.

4. Action potentials are carried by the Purkinje fibres from the bundle branches to the ventricular walls.

Figure 12.4 Conducting System of the Heart

rhythmically even after its nerve supply has been severed. The heart will go on beating after it has been cut right out of the body. Cardiac muscles are therefore **myogenic** (*myo*: muscle, *genic*, giving rise to) i.e. its rhythmic contraction arise from within the muscle itself. Cardiac muscle has an intrinsic rhythmicity that allows the heartbeat to originate in and be conducted through the heart without extrinsic stimulation. Specialized strands of interconnecting cardiac muscle tissue that coordinate cardiac contraction constitute the **conduction system**. The conduction system constitutes the cardiac cycle. The components of the conduction system are the (a) Sinoatrial node, (b) Atrioventricular node, (c) Atrioventricular bundle (d) Conducting myofibrils.

Sinoatrial Node: In short it is called **SA node**. It consists of specialized plexus of cardiac muscles embedded in the upper wall of the right atrium. It is close to where vena cavae enter the atrium. The SA node has been developed from the sinus venosus and has become a part of the atrium, so it is called sinoatrial node.

Atrioventricular Node: There is another specialized group of cardiac muscle fibres called atrioventricular node. In short it is called **AV node**. It is present near the junction of right atrium and right ventricle.

Atrioventricular Bundle: AV node is connected to a strand of specialized muscles (in the ventricular septum) known as **AV bundle** or

bundle of His (pronounced as "hiss"). This bundle passes through a small opening in the fibrous skeleton to reach the interventricular septum, where it divides to form right and left bundle branches, which extend beneath the endocardium on either side of the interventricular septum to the apices of the right and left ventricles respectively.

The inferior, terminal branches of the bundle branches are called **Purkinje fibres**, which are large-diameter cardiac muscle fibres. They have fewer myofibrils than most cardiac muscle cells and do not contract forcefully. **Intercalated disks** are well developed between the Purkinje fibres and contain numerous gap junctions. As a result of these structural modifications, action potentials travel along the Purkinje fibres much more rapidly than through other cardiac muscle tissue. Cardiac muscle cells have the capacity to generate spontaneous action potentials, but cells of the SA node do so at a greater frequency. As a result, the SA node is called the **pacemaker** of the heart. When the heart beats under resting conditions, approximately 0.04 second is required for action potentials to travel from the SA node to the AV node. Within the AV node action potentials are propagated slowly compared with the remainder of the conducting system. As a consequence, there is a delay of 0.11 second from the time action potentials reach the AV node until they pass to the AV bundle. The total delay of 0.15 second allows completion of the atrial contraction before ventricular contraction begins.

Q. Why action potentials travel along the Purkinje fibres more rapidly than through other muscle fibres?

Reason for the slight delay between the atrial and ventricular contraction

The wave does not immediately spread to the ventricles from SA node. Almost 0.1 second passes before the ventricles start to contract. The reason for the delay is that the atria of the heart are separated from the ventricles by connective tissues, which cannot propagate a wave of electrical excitation. Secondly the cells that carry wave of impulse from the atria to the ventricle have smaller diameter. Thus they propagate the depolarization slowly, causing the delay of contraction of ventricles. This delay permits the atria to finish the emptying the contents into the corresponding ventricles before the ventricles start to contract.

Pacemaker

A **cardiac arrythmia** is a disturbance in electrical rhythm of heart. It may be **bradycardia** (heart beat less than 40 beats per minute) or **tachycardia** (heart beat more than 100 beats per minute). Pacemaker supplies electrical initiation to myocardial contraction. The pacemaker is put surgically under the skin where it may be programmed. It generates electrical rhythm at a set rate, so in this way arrythmia are controlled.

Science, Technology and Society Connections

Rationalize the use of artificial pacemaker in patients of cardiac arrhythmias.

12.1.5 ELECTROCARDIOGRAM

The electrical impulses that pass through the conduction system of the heart during the cardiac cycle can be recorded as an electrocardiogram (ECG). The electrical changes result from depolarization and repolarization of cardiac muscle fibres and can be detected on the surface of the skin using an instrument called the **electrocardiograph**.

The principal aspects of an ECG are shown in fig. 12.5. The wave deflections, designated P, QRS, and T, are produced as specific events of the cardiac cycle occur. Any heart disease that disturbs the electrical activity will produce characteristic changes in one or more of these waves, so understanding the normal wave-deflection patterns is clinically important. Depolarization of the atrial fibres of the SA node produces the **P wave**.

The ventricles of the heart are in diastole during the expression of the P wave. On the ECG recording, the **P-R interval** is the period of time from the start of the P wave to the beginning of the QRS complex. This interval indicates the amount of time required for the SA depolarization to reach the ventricles.

The **QRS complex** begins as a short downward deflection (Q), continues as a sharp upward spike (R), and ends as a downward deflection (S). The QRS complex indicates the depolarization of the ventricles. During this interval, the ventricles are in systole and blood is being ejected from the heart. The time duration known as the **S-T segment** represents the period between the completion of ventricular depolarization and initiation of repolarization. The **T wave** is produced by ventricular repolarization.

A normal ECG indicates that the heart is functioning properly. The P wave represents excitation and occurs just prior to contraction of the atria. The second wave, or the QRS complex, occurs just prior to ventricular contraction. The third, or T, wave occurs just before the ventricles relax.

Q. How is an ECG related to cardiac cycle?

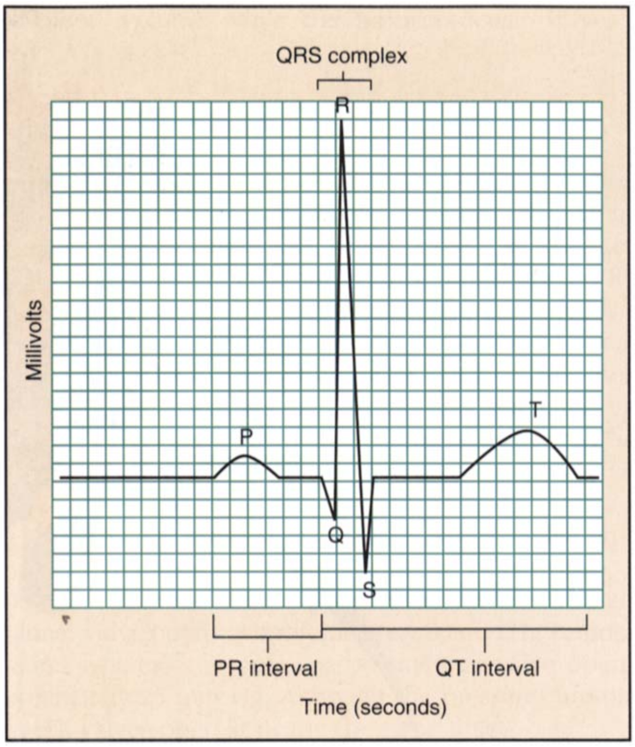


Figure 12.5 Electrocardiogram (ECG)

Uses of Electrocardiogram

ECG is used to detect cardiac arrythmias and conduction defects. It is used to diagnose and localize myocardial hypertrophy (increase in size of heart), ischemia or infarction (decrease in oxygen content) . It may also give information about electrolyte imbalance and toxicity of certain drugs.

12.2 BLOOD VESSELS

The heart provides the major force that causes blood to circulate, but the blood vessels carry blood to all tissues of the body and back to the heart. In addition, the blood vessels take part in the regulation of blood pressure and help to direct blood flow to tissues that are most active. The circulatory system has three types of blood vessels, the **arteries** (and arterioles), which carry blood away from the heart, the **veins**, which return blood to the heart, and **capillaries**, which permit exchange of materials with the tissues. Now we will discuss a detailed structure of blood vessels i.e. arteries, veins and capillaries.

Arteries

Arteries carry blood away from the heart. All arteries carry oxygenated blood except the pulmonary arteries, which carry deoxygenated blood. Arteries are pink in colour and are situated within the muscles. Arteries vary in size. Aorta is approximately 23 mm and arterioles are about 0.2 mm in diameter. Arteries have thick muscular walls.

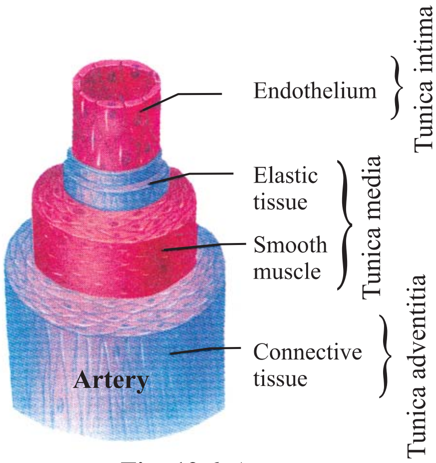


Fig: 12.6 Artery

These branch into **arterioles** and **capillaries**. Arteries are distributing vessel and carry blood under pressure. The lumens of arteries have no valves. The wall of an artery consists of three coats or tunics: tunica adventitia or tunica externa, tunica media, tunica intima.

The outermost layer is called **tunica adventitia** or tunica externa. It is composed of white fibrous connective tissue. The middle layer is called **tunica media**, and has variable amount of elastic fibres. It is many layered in thickness. The innermost layer of the artery is called **tunica intima**. It is composed of simple squamous epithelium and elastic fibres composed of elastin. Arterioles transport blood from small arteries to capillaries and are the smallest arteries in which the three tunics can be identified. The tunica intima has no internal elastic membrane and the tunica media consists of one or two layers of circular smooth muscle cells.

Capillaries

All blood vessels have an internal lining of simple squamous epithelial cells called the **endothelium**, which is continuous with the endocardium of the heart. The capillary wall consists primarily of endothelial cells, which rest on a basement membrane. Outside the basement membrane a delicate layer of loose connective tissue called the **adventitia** that merge with the connective tissue surrounding the capillary. Most capillaries range from 7 to 9 μm in diameter, and thus branch without a change in their diameter.

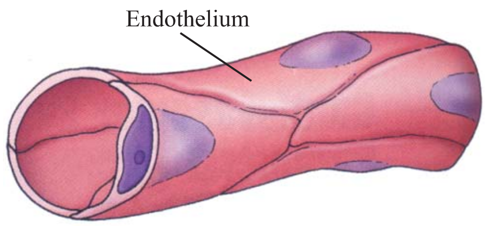


Fig: 12.7 Blood Capillary

Capillaries are approximately 1 mm long. Red blood cells flow through most of capillaries in a single file.

Capillary Network

Arterioles supply blood to each capillary network, (fig. 12.8) blood then flows through the capillary network and into the venules. Blood flows from arterioles through **metarterioles**. From a metarteriole blood flows into a **thoroughfare channel.** Several capillaries branch from the thoroughfare channels. Flow in these capillaries is regulated by smooth muscle cells called **precapillary sphincter**, which are located at the origin of the branches. (see fig. 12.8). This sphincter can open and close the entrance to the capillary.

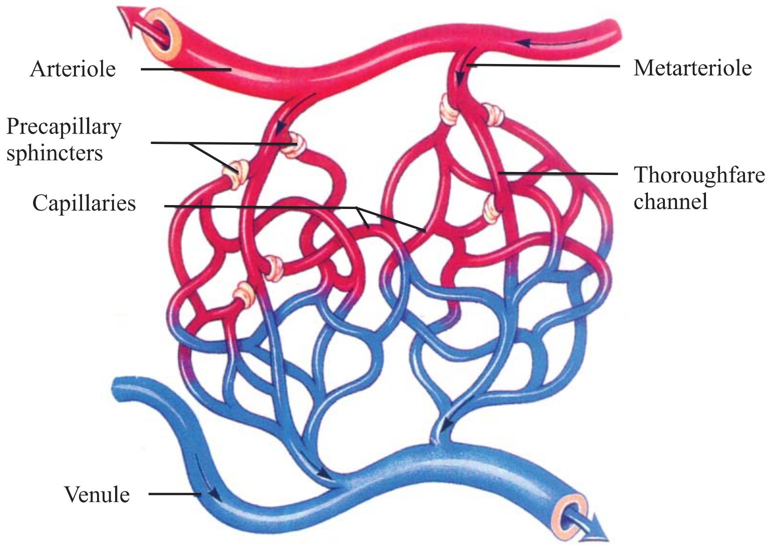


Fig. 12.8 Capillary Network

Veins

The blood vessels that bring blood back to the heart are called veins. Veins are relatively not deep in the muscles. Veins can be seen as blue vessels under the skin. A vein also consists of tunica adventitia, tunica media and tunica intima.

Tunica adventia is composed of collagenous connective tissue. **Tunica media** is a composed of a thin layer of circularly arranged smooth muscle cells, collagen fibres and a few sparsely distributed elastic fibres. **Tunica intima** is a thin layer and consists of endothelial cells, a relatively thin layer of collagenous connective tissue and a few scattered elastic fibres. Venules with a diameter of 40 to50 μm are tubes composed of endothelium resting on a delicate basement membrane.

Their structure, except for their diameter is very similar to that of capillaries. As the vessels increase to 0.2 to 03 mm in diameter, the smooth muscle cells form a continuous layer; the vessels then are called small veins. The **venules** collect blood from the capillaries and transport it to the small veins, which in turn transport it to the medium sized vein. Medium and large veins collect blood from small veins and deliver it to large veins. The large veins transport blood from medium veins to the heart.

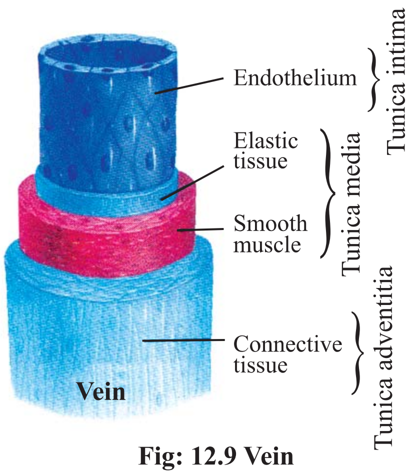


Fig: 12.9 Vein

Valves in Veins

Veins having diameters greater then 2mm contain valves that allow blood flow toward the heart but not in the opposite direction (fig. 12.10). The valves consists of fold in the tunica intima that form two flaps that are shaped and function like the semilunar valves of the heart. The two fold overlap in the middle of the vein, when blood attempts to flow in a reverse direction. Valves are present only in the lower part of the body especially in the abdomen and hind limbs. In the upper region above the heart there is no valve. As the blood pressure in the veins is comparatively low, so the flow of blood in the veins is helped by gravity, semilunar valve and muscular contraction.

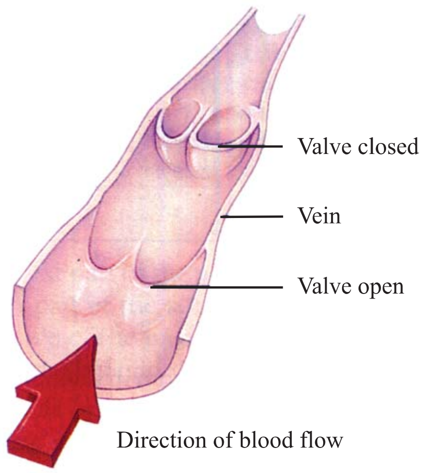


Fig: 12.10 Valves in veins

Critical Thinking

Blood in arteries flows with jerks, while that in veins flows continuously. Why?

Q. What factors assist venous return of the blood?

Role of Arterioles in Vasoconstriction and Vasodilation

The amount of blood flowing through a blood vessel can be regulated by contraction or relaxation of smooth muscle in the tunica media. A decrease in blood flow results from vasoconstriction, a decrease in blood vessels diameter caused by smooth muscle contraction whereas an increase in blood flow is produced by vasodilation an increase in blood vessel diameter because of smooth muscle relaxation.

Vasoconstriction Agents

Blood circulation is also controlled by hormones (vasoconstriction agents) acting on arterioles. Norepinephrine is an especially powerful vasoconstriction hormone, and epinephrine is less.

Vasodilator Agents

Several substance called **kinins** (vasodilator agents) can cause powerful vasodilation are formed in the blood and tissue fluids of some organs. e.g histamine. Most of the prostaglandins are vasodilator agents though some of the prostaglandins are vasoconstrictor.

Skills: Analyzing and Interpreting

- **Justify how Vasoconstriction and Vasodilation is Reflective of Emotions?**

During emotional rage such as apprehension and rage vasodilation occurs due to secretion of **epinephrine**. It is a hormone that is responsible for fear, flight and fright conditions. The sympathetic vasodilator fibres are part of a regulatory system that originates in cerebral cortex and ends at postganglionic neurons in blood vessels on skeletal muscles, activate them to release acetylcholine, and vasodilation occurs.

Blood discharge through thoroughfare channels rather than capillaries so heat loss occurs and the skin becomes hot and red. While in vasoconstriction blood supply becomes less to skin, so heat is preserve and the skin becomes cold. Situations such as shock, hypotention and tachycardia occur by stimulation of arterial stretch receptors and production of hypertension and bradycardia occur by increased intracranial pressure.

Role of Precapillary Sphincter in Regulating the Flow of Blood Through Capillaries

At the point where true capillaries originate from the metarterioles a smooth muscle fibre usually encircles the capillary. This is called **precapillary sphincter** (fig. 12.8). This sphincter can open and close the entrance to the capillary. Precapillary sphincters are normally either completely open or completely closed, and the degree of constriction of the metarteriole also varies. The number of precapillary sphincters that are open at any given time is about proportional to the requirements of the tissue for nutrition. In addition the precapillary sphincters and metarterioles often open and close cyclically several times per minute,with the duration of the open phases being about proportional to the metabolic needs of the tissue. The cyclic opening and closing is called **vasomotion**.

12.2.1 VASCULAR PATHWAY

Cardiovascular system (fig 12.11) includes two circuits, the **pulmonary circuit** which circulates blood through lungs and **systemic circuit** which circulates blood to all other parts of the body.

Pulmonary Circulation

The path of blood through the lungs can be traced as follows: The left atrium receives oxygenates blood from the lungs through a pair of **pulmonary veins**, which open by common aperture into it. From left atrium the blood flows into the left ventricle. The superior and inferior vena cavae bring deoxygenated and open into the right atrium. From right atrium blood flows into the lungs for oxygenation by a **pulmonary arch** or **trunk** which divides into two **pulmonary arteries**, each going to the lung of its own side. This part of circulation is called **pulmonary circulation** or **circuit**. The pulmonary arteries carry deoxygenated blood and pulmonary veins carry oxygenated blood.

Q. What are the advantages of supplying blood to the pulmonary circulation at a low pressure than that of the systemic circulation?

Systemic Circulation

The systemic circuit includes all the **arteries** and **veins** other than involved in pulmonary circuit. The largest artery in the systemic circuit is the **aorta** and the largest veins are the **superior** and **inferior venae cavae**. The path of systemic blood to any organ in the body begins in the **left ventricle** which pumps blood in the aorta.

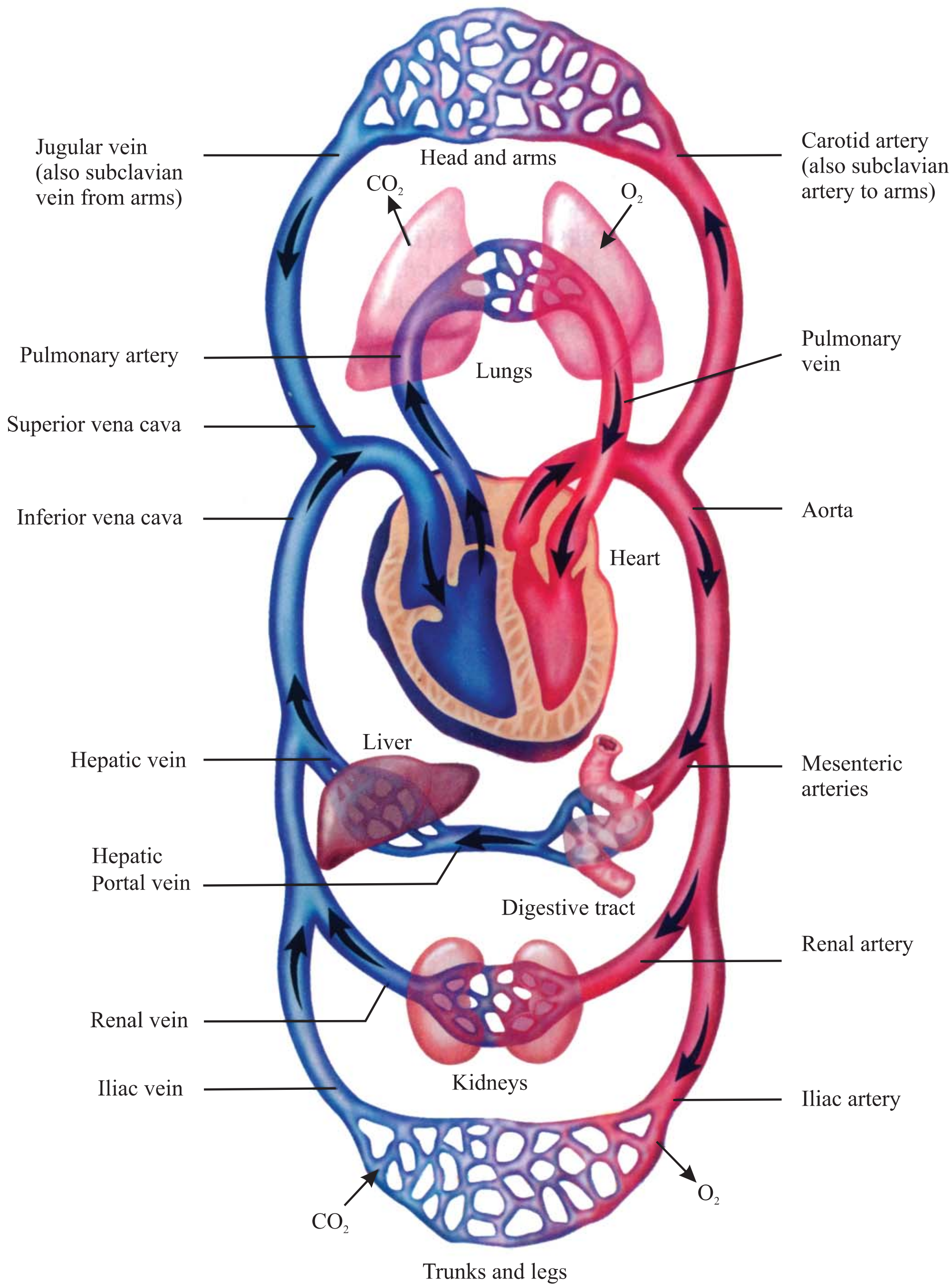


Fig: 12.11 Cardiovascular System

Branches from **aorta** go to the organs and major body regions. The **superior vena cava** collects blood from the head and the chest and the arms and the **inferior vena cava** collects blood from the lower body regions. Both enter the right atrium. The aorta and the vanae cavae are the major pathways in the systemic circuit. In most instances the artery and the vein that serve the same organ are given the same name.

Coronary Circulation

The wall of the heart has its own supply of blood vessels to meet its vital needs. The myocardium is supplied with blood by the **right** and **left coronary arteries** (fig. 12.1).

From the capillaries in the myocardium, the blood enters the **cardiac veins**. The course of these vessels parallels that of the coronary arteries. These cardiac veins converge to form the **coronary sinus channel** on the posterior surface of the heart. The coronary venous blood then enters the heart through an opening into the right atrium.

Hepatic Portal System

Blood from the capillaries within most of the abdominal viscera such as the stomach, intestines, and spleen drains through a specialized system of blood vessels to the liver. Within the liver the blood flows through a series of dilated capillaries called **sinusoids**. A **portal** (meaning door) system is vascular system that begins and ends with capillary beds and has no pumping mechanism such as the heart.

The **portal system** that begins with capillaries in the viscera and ends with the sinusoidal capillaries in the liver is the hepatic (meaning, relating to the liver) portal system. The **hepatic portal vein**, the largest vein of the system, is formed by the union of the **superior mesenteric vein**, which drains the small intestine and the **splenic vein**, which drains the spleen. The splenic vein receives the **inferior mesenteric** and **pancreatic veins**, which drain the large intestine and pancreas, respectively. The hepatic portal vein also receives gastric veins before entering the liver. Blood from the liver sinusoids is collected into **central veins**, which empty into **hepatic veins**. Blood from the cystic veins also enters the hepatic veins. The hepatic veins join the inferior vena cava.

Critical Thinking

How does the sequence of blood vessels of the hepatic portal system differ form that in most other circulatory roots?

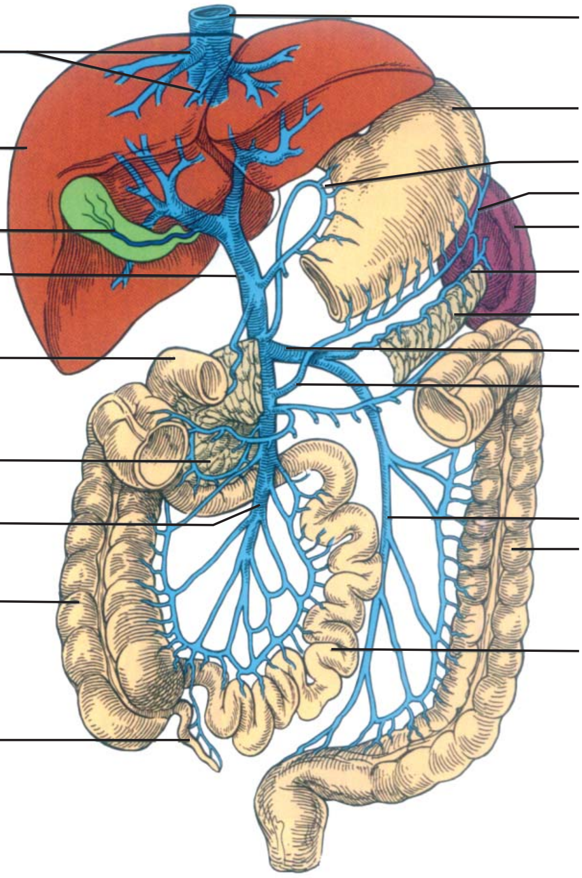


Fig: 12.12 Hepatic Portal System

Renal Circulation

Arterial blood enters the kidney at the hilum through **renal artery**, which divides, into **interlobar arteries**, **arcuate arteries** branch from the interlobular arteries at the boundary of renal cortex and **renal medulla**. Small interlobular arteries radiate from the arcuate arteries and project into the renal cortex. Microscopic **afferent glomerular arterioles** arise from the branches of the interlobular arteries. From

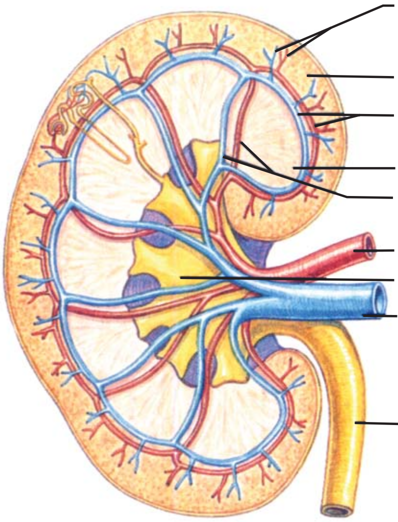


Fig. 12.13 Principal Arteries and Veins of Kidney

here blood enters either the **peritubular capillaries** or **vasa recta**. From these capillary networks the blood is drained into interlobular veins and arcuate veins which leave the kidney as a single **renal vein**.

Q. What is the function of hepatic portal system?

12.2.2 RATE OF BLOOD FLOW IN BLOOD VESSELS

Blood flow means simply the quantity of blood that passes through a given point in the circulation in a given period. Ordinarily, blood flow is expressed in milliliter or liter per minute, but can be expressed in milliliter, per second or any other unit of flow. The over all blood flow in the circulation of an adult at rest is about 5000 ml/min. This is called **cardiac output**. It is the amount of blood pumped by the heart in a unit period.

The velocity of blood flow is greatest in the aorta, but the total cross-sectional area for the capillaries is large, but the velocity of blood flow is low. As the veins become larger in diameter, their total cross-sectional area decreases, and the velocity of blood flow increases. The relationship between blood vessel diameter and velocity of blood flow is much like a stream that flows rapidly through a narrow gorge, but flows slowly through a broad plane.

12.3 BLOOD PRESSURE AND ITS MEASUREMENT

Blood pressure is the force exerted by the blood against any unit area on the inner walls of the blood vessel. The standard reference for the blood pressure is the mercury (Hg) manometer, which measures pressure in millimetres of mercury (mm Hg). If the blood pressure is 100 mm Hg the pressure is great enough to lift a column of mercury 100 mm. When the ventricles of the heart contract the arterial blood pressure is the highest. It is called **systolic pressure**. When the ventricles of the heart relax, the arterial blood pressure is the lowest. It is called **diastolic pressure**.

Baroreceptor Reflexes

Baroreceptors, or pressoreceptors, are sensory receptors sensitive to stretch. They are scattered along the walls of most of the large arteries of the neck and the thorax and are most numerous in the area of the carotid sinus at the base of the internal carotid artery and in the walls of the aortic arch (fig: 12.15). Stimulation of baroreceptors produces reflexes which control blood within a narrow range of values.

Table: 12.1 Velocities of Blood Flow			
Vessels	**Approximate Cross Sectional Area**	**Volume/Ccm^2**	**Velocity/cm s^{-1}**
Aorta	2.5 cm^2	100	40 cm / second
Arteries	20 cm^2	300	40-10 cm / second
Arterioles	40 cm^2	50	10-0.1cm / second
Capillaries	2.500 cm^2	250	0.1 cm / second
Venules	250 cm^2	300	0.3 cm / second
Veins	80 cm^2	2200	0.3-5 cm/ second
Venae Cavae	8 cm^2	300	5-20 cm / second
Velocity values with two numbers represent changes in velocity as blood passes through that part of the circulatory system. For example, 40-10 indicates a decrease in velocity from 40cm /second to 10cm/second.			

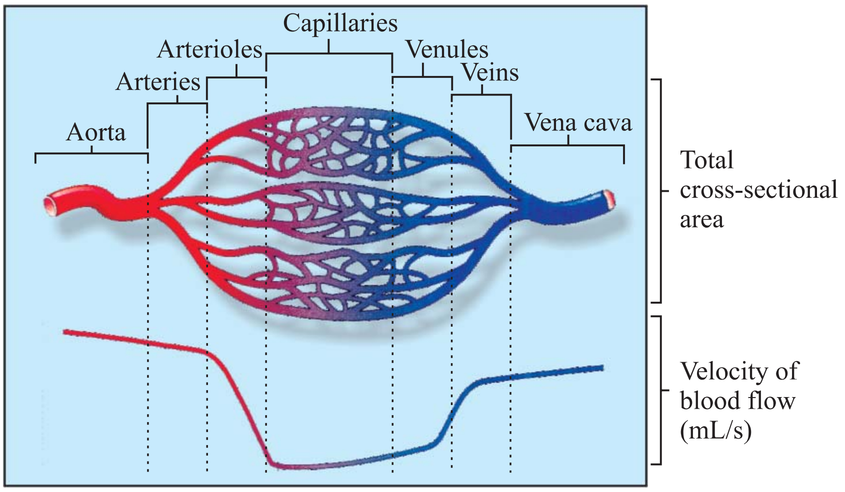


Fig: 12.14 Blood Vessel Types and Velocity of Blood Flow: Total cross-sectional area for each of the major blood vessel types is the space through which blood flows, measured in square centimeters. The cross-sectional area of the aorta is about 5 cm^2. The cross-sectional area of each capillary is much smaller, but there are so many that the total cross-sectional area is more than that of the aorta. The line at the bottom of the graph shows that blood velocity drops dramatically in arterioles, capillaries, and venules. As the total cross-sectional area increases the velocity of blood flow decreases.

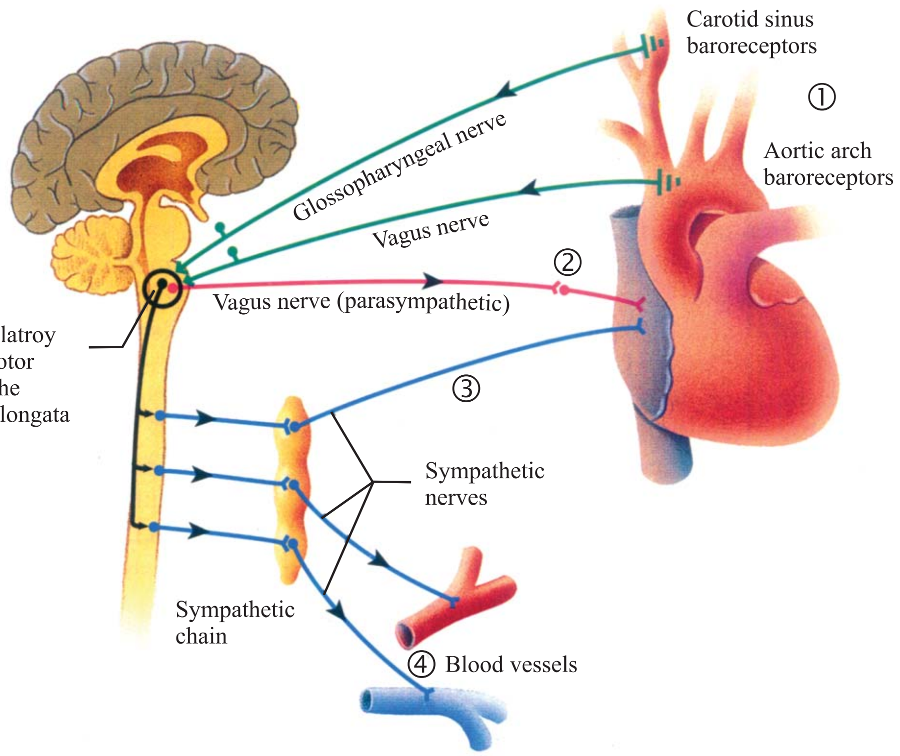


Figure 12.15 Baroreceptor Reflex Control of Blood Pressure (1) Baroreceptors in the carotid sinus and aortic arch monitor blood pressure. (2) Increased parasympathetic stimulation of the heart decreases the heart rate. (3) Increased sympathetic stimulation of the heart increases the heart rate and stroke volume. (4) Increased sympathetic stimulation of blood vessels increase vasoconstriction.

In the carotid sinus and the aortic arch, normal blood pressure partially stretches the arterial wall so that a constant, but low, frequency of action potentials are produced by the baroreceptors. Increased pressure in the blood vessels stretches the vessel walls and results in an increased frequency of action potentials generated by the baroreceptors. Conversely, a decrease in blood pressure reduces the stretch of the arterial wall and results in a decreased frequency of action potentials. The carotid sinus and aortic arch baroreceptor reflexes are important in regulating blood pressure moment to moment.

Volume Receptors

Stretch of the atria also causes **reflex dilation** of the afferent arterioles in the kidneys. Also, signals are transmitted simultaneously to the **hypothalamus** to decrease the secretion of antidiuretic hormone, thereby indirectly effecting kidney function. The decreased afferent arteriolar resistance causes the **glomerular capillary pressure** to rise, with resultant increase in filtration of fluid into the kidney tubules. The diminution of **antidiuretic hormone** diminishes the re-absorption of water from tubules. The combination of these two effects causes rapid loss of fluid into the urine, which serves as a powerful mean to return the blood volume back to normal.

All these mechanisms that tend to return the blood volume back towards normal after a volume overload act indirectly as pressure controller as well as volume controller, because axcess volume drives the heart to greater cardiac output and lead, therefore to greater arterial pressure.

Science, Technology and Society Connections

Hypothesize the role and effects of diuretic drugs in regulating blood pressure.

12.4 CARDIOVASCULAR DISORDERS

Cardiovascular disorders or disease (CVD) are the diseases of the heart and blood vessels. The CVD are the leading cause of untimely death.

12.4.1 THROMBOSIS

The formation of a clotted mass of blood within a vessel or the heart during life in called **thrombosis**. The clotted mass of blood within a vessel or the heart during life is called **thrombus**. Morphologically there are two types of thrombi: Pale or white thrombi and red thrombi. **Pale thrombi** are composed of platelets and fibrin and few R.B.C.

They are dry easily breakable, develop in arterial circulation and are attached to vessel wall. **Red thrombi** are composed of platelets fibrin and large number of R.B.C, develop in venous circulation. There are three types of clinical thrombi, arterial thrombi, cardiac thrombi, and venous thrombi.

The occlusion of some part of the cardiovascular system by any mass transported to the site through the blood stream is called **embolism**. **Embolus** is a detached intravascular solid, liquid or gaseous mass that is carried to a site distant from its point of origin. About 99% emboli arise from dislodgement of thrombi and are therefore called **thromboemboli**. The emboli may be solid, gas and liquid. Thrombus and embolus cause death.

12.4.2 HEART PROBLEMS

In this section we will discuss diseases related to heart, such as: Atherosclerosis, angina pectoris, heart attack, heart failure.

Atherosclerosis

Atherosclerosis is characterized by formation of yellow fatty streaks containing high proportion of cholesterol in the intima of large and medium sized arteries resulting in the narrowing of the vascular lumen. Later, fibres are deposited in the cholesterol and these often start to calcify and become hard, a process known as **arteriosclerosis**. The deposits are called **athromatous plaques**. As a **plaque** increases in size it protrudes into the lumen of the artery and begins to block it. The plaque first forms thrombus and may form embolus.

Factors Causing Atherosclerosis and Arteriosclerosis

The major risk factors are: (a) Hypercholesterolemia (hyperlipidemia) (b) Hypertension (c) Cigarette smoking (d) Diabetes mellitus (e) Male sex (f) Familial predisposition (occurring in or affecting more members of a family than would be exposed by chance). The other minor risk factors are:(a) Increasing age (b) Lack of exercise, (c) Stressful competitive life (d) Obesity (e) High carbohydrate diet, (f) Hyperuricemia (g) Oral contraceptives.

Angina Pectoris

Due to atherosclerosis a person may feel occasional pain, a condition known as **angina pectoris** (Latin *angere* to choke and *pecto* breast). **Angina** is most likely to occur when the heart is labouring hard because of physical or emotional stress. Angina is a signal that part of the heart is not receiving a sufficient supply of oxygen and that part of the heart attack could occur in future. There are three types of angina pectoris: Typical angina pectoris, variant angina pectoris, unstable angina pectoris.

Heart Attack

Many heart attacks occur without warning. A blood clot may completely block a coronary artery, or atherosclerosis may reach a critical level causing massive damage to the heart muscle. All of a sudden, the person feels a heavy squeezing ache or discomfort in the centre of the chest. The pain may radiate to shoulder, arm neck or jaw. Other symptoms may include sweating, nausea, shortness of breath and dizziness or fainting. The whole process is called **myocardial** (heart muscle) **infarction** (death due to lack of oxygen). When heart muscle die, they are not replaced because cardiac muscle do not divide. When a person survives a heart attack scar tissue (a type of connective tissue) grows into the areas where the heart muscles has died. The scar tissue cannot contract as cardiac muscle. As a result the damaged heart is permanently weakened.

Heart Failure

Congestive heart failure is a clinical syndrome resulting from deficient cardiac stroke volume, relative to body need, with inability of the cardiac output to keep pace with the venous return i.e. heart is unable to pump all the blood coming to it.

Congenital heart problem: it is related to the malfunctioning of cardiac valves includes: Valvular Stenosis, Regurgitation, Patent Ductus Arteriosus (PDA), Fallot's Tetralogy.

Valvular Stenosis: Scaring of the valve leaflets may cause reduction in diameter of the valve orifice.

Regurgitation: Severe destruction of valve apparatus may cause valve ring dilation, with thickening and shortening of chordae tendinae resulting in regurgitation of blood through the valve when it is closed i.e. valve closed is incomplete.

Patent Ductus Arteriosus (PDA)

PDA is most often diagnosed in childhood. During fetal life, before the lungs begin to function most of the blood from pulmonary artery passes through the **ductus arteriosus** into the aorta. Normally the ductus closes soon after birth but sometimes it fails to do so. This causes blue babies due to mixing of oxygenated and deoxygenated blood.

Fallot's Tetralogy

It is the most common cause of congenital cyanotic heart disease. e.g. Ventricular hypertrophy (increase in the size of ventricle).

12.4.3 DIAGNOSIS OF CARDIOVASCULAR DISORDERS

Modern research efforts have resulted in improved diagnosis of CVD their treatment and prevention.

Principles of Angiography

Cardiac catheterization is a technique in which specially designed catheter is inserted into a vein or artery and advanced into the heart under radiographic fluoroscopic guidance. This allows the operator to obtain angiograms by injecting contrast media into an area of interest. It is used to evaluate disease of the mitral valve, aortic valve and aorta, to determine the

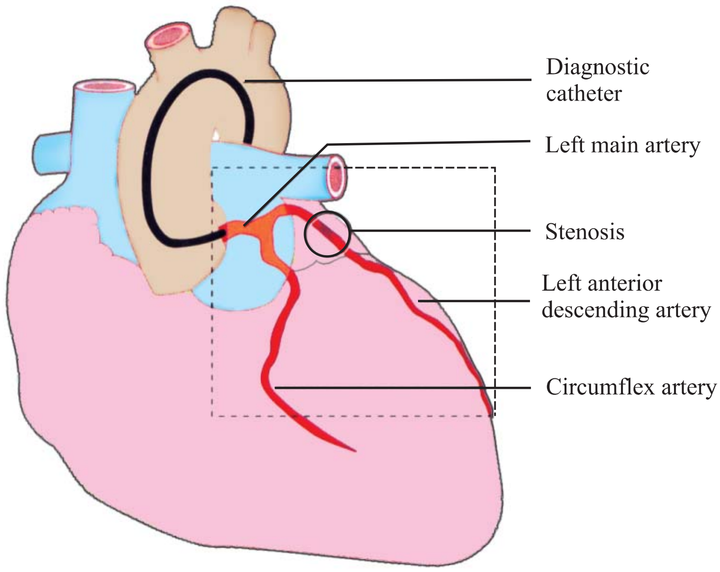


Figure.12.16 Coronary Angiogram-Schematic of the Vessels and Branches

size and function of the left ventricle. Coronary angiography is used to detect stenosis (constriction, narrowing of a tube or passage) and guide revascularisation procedures such as balloon angiography and stenting (fig. 12.18).

12.4.4 TREATMENT AND PREVENTION OF CVD

In this section we will discuss the range of advances that have been made for the treatment and prevention of CVD such as coronary bypass, angioplasty, open heart surgery.

Coronary Bypass

A coronary bypass is a surgical procedure that relieves the effects of obstruction in the coronary arteries. The technique involves taking healthy segments of blood segments of blood vessel from other parts of the patient's body usually a vein from the leg called **great saphenous vein** and an artery of thorax called **internal thoracic artery** and using them to bypass obstructions in the coronary arteries. The technique is common for those who suffer from severe occlusion of parts of the coronary arteries.

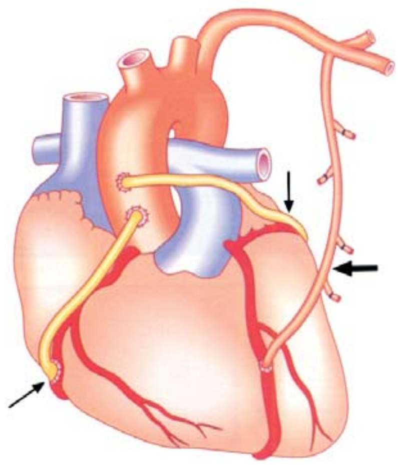


Fig: 12.17 A triple Coronary Artery Bypass Graft Operation

The advantages of coronary artery bypass grafting are: (1) procedure is safe, (2) angina is abolished or greatly reduced in almost 90% of the patients, (3) it is used in the patients with: (a) 2 to 3 vessel diseases (b) disease of left main coronary artery (c) impaired left ventricular function (d) diabetic patients (e) lesion not suitable for angioplasty. The disadvantages of coronary artery bypass grafting are: (a) defused left ventricular damage, (b) peroperative (during operation), myocardial infarction. (c) Infection (d) wound pain (e) longer hospital stay.

Science, Technology and Society Connections

List the advantages and disadvantages of coronary by pass.

Angioplasty

In angioplasty a cardiologist threads a plastic tube into an artery of an arm or a leg and guides it through a major blood vessel toward the heart. When the tube reaches the region of plaque in a coronary artery a balloon is attached to the end of the tube is inflated forcing the vessel open. However, the artery may not remain open, so slotted tubes called **stents** are expanded inside the artery to keep the artery open. Stent are coated with heparin to prevent blood clotting and chemicals to prevent arterial closing.

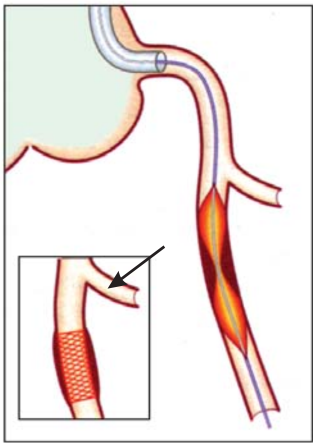


Fig: 12.18 Coronary Angioplasty and Stenting

Open Heart Surgery

This is a surgery in which the patient's chest is opened. The surgery is performed on the heart. The term "open" refers to the chest, not to the heart itself. The heart may or may not be opened depending on the particular type of surgery. Heart surgery is used to correct heart problems in children and adults. An open heart bsurgery is performed under , which requires that the patient be on a ventilator during surgery. The chest is opened by making an incision along the sternum, or breastbone. The surgeon then cuts the sternum, allowing the chest cavity to be opened, giving the surgeon access to the heart. At this time the heart-lung machine does the work of the heart and the lungs, and the ventilator is not used. Once the surgery is complete, the heart beat is started and provides blood and oxygen to the body. The sternum is returned to its original position and closed using surgical wire, to provide strength the bone needs to heal, and the incision is closed.

12.4.5 HYPERTENSION AND HYPOTENSION

Hypertension

Sustained high blood pressure is known as hypertension. Blood pressure 140/90, at least two different readings six hours apart is considered hypertension.

Factors Regulating Blood Pressure

Pressure difference between the two ends of the vessels (also frequently called pressure gradient) which is the force that pushes the blood through the vessels. Blood flows directly proportional to the pressure difference but indirectly to proportional resistance. The circulatory system is provided with an extensive system for controlling the arterial pressure. For instance if at any time the pressure falls significantly below its normal level of about 100mmHg a barrage of nervous reflexes within seconds elicits a series of circulatory changes to raise the pressure back to normal. Nervous control of the circulation provides additional specific attributes to tissue blood flow control.

Postural Hypotension

In some individuals, sudden standing causes a fall in blood pressure, dizziness, dimness of vision, and even fainting. The causes of this **orthostatic** (**postural**) **hypotension** are multiple. It is common in patients receiving sympatholytic drugs. It also occurs in diseases such as diabetes, syphilis, and Parkinson's disease, in which there is damage to the sympathetic nervous

Table: 12.2 Classification and Follow up of Blood Pressure Measurements

Category	Systolic Blood Pressure (mm Hg)	Diastolic Blood Pressure (mm Hg)	Follow up recommended
Normal	< 130	< 85	Recheck in 2 years
High Normal	130-139	85-89	Recheck in 1 year
Hypertension Stage 1 *(Mild)*	140-159	90-99	Confirm within 2 months
Stage 2 (moderate)	160-179	100-109	Evaluate or refer within 2 months
Stage 3 (severe)	180-209	110-119	Evaluate refer within 1 week
Stage 4 (very severe)	> 210	>120	Evaluate refer immediately

system. This underscores the importance of the sympathetic vasoconstrictor fibres in compensating for the effects of gravity on the circulation. Mineralocorticoids are used to treat patients with postural hypotension.

Prevention of Cardio Vascular Diseases

All of us can take steps to prevent the occurrence of CVD. One should pay particular attention to these guidelines for a heart-healthy-life-style. When a person **smokes**, the drug nicotine causes arterioles to constrict and blood pressure to rise. **Stimulants** such as cocaine and amphetamines can cause an irregular heart attack and stroke. Hypertension occurs more often in persons who are **obese**. So one should try to maintain normal body weight. It is recommended and one should take **diet** having low cholesterol and low in saturated fats, and take low salt diet. The LDL-cholesterol level together with other risk factors such as age, family history general health and whether the patient smokes will determine who need dietary therapy to lower their LDL.

12.5 LYMPHATIC SYSTEM OF MAN

The lymphatic system includes lymph, lymphocytes, lymphatic vessels, lymph nodes, tonsils, spleen and thymus gland.

Interstitial Fluid

About one sixth of the body consists of spaces between the cells, which collectively are called the **interstitium**. The fluid in these spaces is the **interstitial fluid** or **intercellular fluid**.

Formation: The fluid in the interstitium is derived by filtration and diffusion from the capillaries.

Composition: It contains almost the same constituents as plasma except for much lower concentrations of proteins because proteins do not pass outward through the walls of the capillaries with ease. The interstitial fluid is mainly entrapped in the minute space among the proteoglycan filaments. This combination of proteoglycan filaments and the fluid entrapped within them has the characteristics of gel and therefore is called **tissue gel**.

Function: Instead of flowing, fluid mainly **diffuse** through the gel. Diffusion through the gel occurs about 95 to 99 percent as rapidly as it does through free fluid. For the short distances between the capillaries and the tissue cells, this diffusion allows rapid transport through the interstitium not only of water molecules but also of electrolytes, nutrients, cellular excreta, oxygen, carbon dioxide etc. Materials are exchanged between the blood and interstitial fluid and between the interstitial and the body cells. In other words, to get from the blood to body cells or vice versa, materials must pass through the interstitial fluid.

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Comparison: Composition of Interstitial Fluid and Lypmph

Approximately 30 litres of fluid pass from the blood capillaries into the interstitial space each day, whereas only 27 litres pass from the interstitial

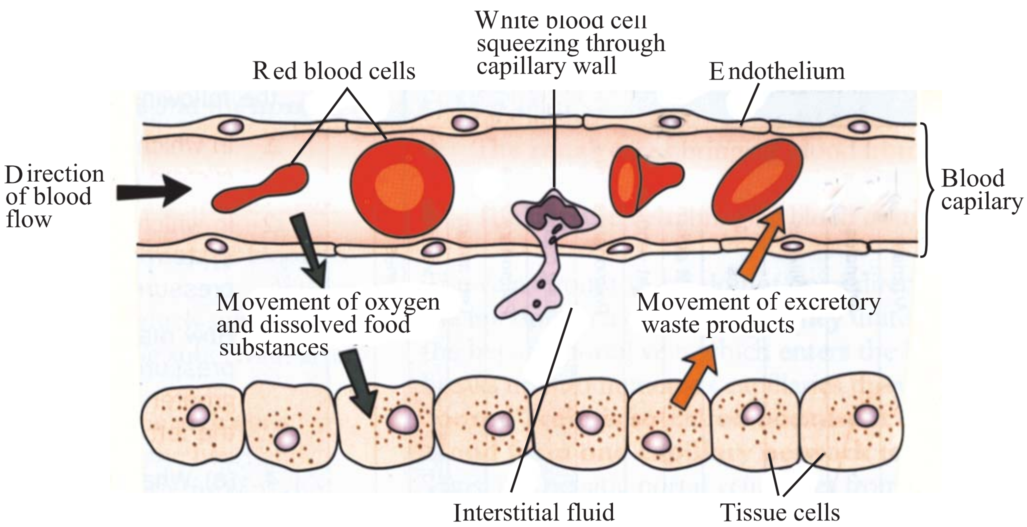

Fig: 12.19 Relationship between a Blood Capillary, Interstitial Fluid and Tissue Cells

space back into blood capillaries. The remaining 3 litres of fluid enters the lymphatic capillaries, where the fluid is called **lymph** (meaning clear spring water) and passes through the lymphatie vessels back to the blood.

In addition to water lymph contains solutes derived from two sources: (a) substances in plasma such as ions, nutrients, gases and some proteins, pass from blood capillaries into the interstitial space and become part of the lymph and (b) substances derived from cells, such as hormones, enzymes and waste products are also found in the lymph.

12.5.1 LYMPHATIC VESSELS

The lymphatic system (figure 12.20) unlike the circulatory system only carries fluid away from tissue. The lymphatic system begins in the tissues as **lymph capillaries**, which differ from capillaries as they lack a basement membrane. The lymph capillaries are far more permeable than blood capillaries, and nothing in the interstitial fluid is excluded from the lymph capillaries, Second, the lymph capillary epithelium functions as a series of one-way valve that allows fluid to enter the capillary but prevent it from passing back into the interstitial spaces.

The lymph capillaries join to form larger **lymph vessels** that resemble small veins.Small lymphatic vessels have a beaded appearance because of the presence of one-way valves along their lengths that are similar to the valves of veins. Lymph nodes are round, oval, or bean–shaped bodies distributed along the various lymphatic vessels. The lymph nodes function to filter lymph.

Critical Thinking

What causes lymph to move through the lymph vessels?

Thoracic Duct

The thoracic duct drains the lower limbs, abdomen, the left thorax, the left upper extremity, and the left side of the head and neck (fig.12.21). The duct ends by entering the left subclavian vein.

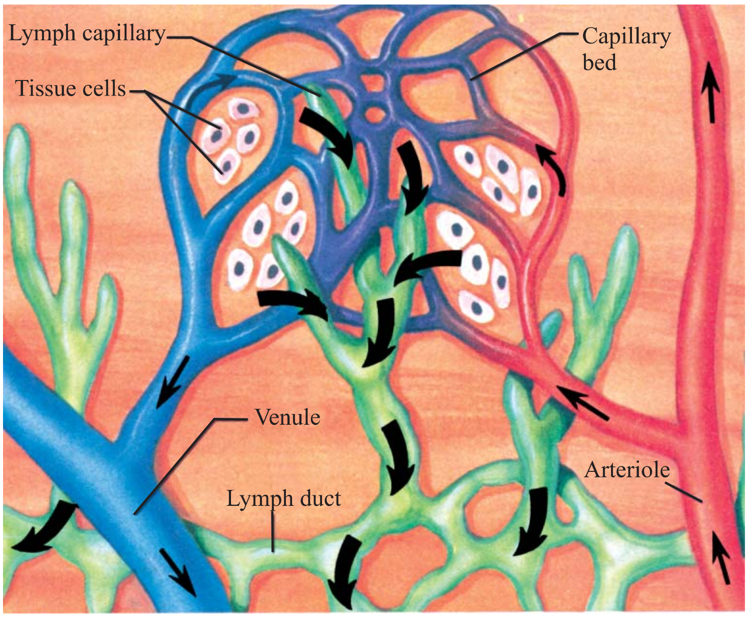

Fig: 12.20 Lymphatic Vessels

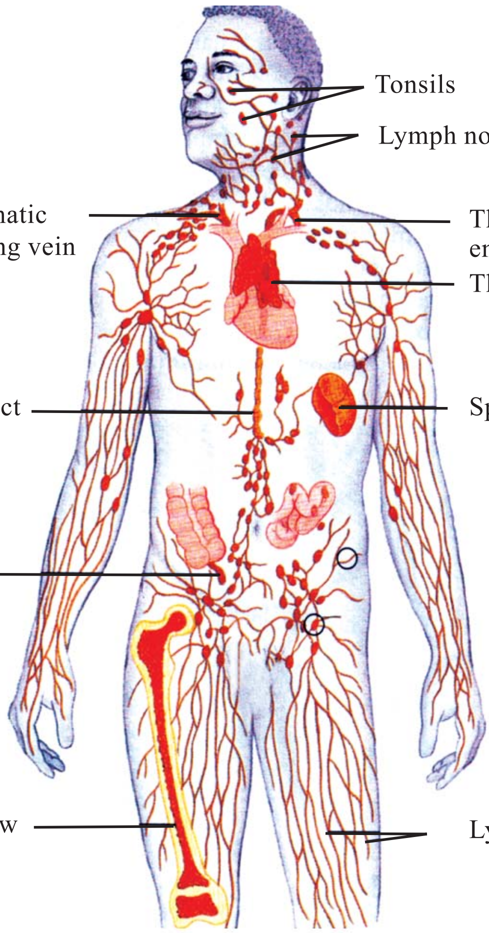

Fig: 12.21 Human Lymphatic System

Right Lymphatic Duct

The **right lymphatic duct** is much short and smaller in diameter than the thoracic duct. It drains the right thorax, right upper limb, and right side of the head and neck and opens into the right subclavian vein.

Role of Lacteal Present in Villi

Each villus contains a **lymph capillary** called **lacteal**. The lymphatic system absorbs fats and other substances from the digestive tract. Fat enters the lacteals and pass through these lymphatic vessels to venous circulation. The lymph passing through these lacteals has a milky appearance because of its fat contents. **Chylomicrons** (these are proteins, triglycerol 90% phospholipids 4% and cholesterol 5%) enter the lacteal. Chylomicrons enter the lymph capillaries because lymph capillaries lack basement membrane and are more permeable to large particles.

Lymph Nodes

Lymph nodes are small, round or bran-shaped structures, ranging in size from 1 to 25 mm long, and are distributed along the course of the lymphatic vessels. They filter the lymph, remove bacteria and other materials. In addition, lymphocytes congregate (assemble), function and proliferate within lymph nodes. Lymph nodes are found throughout the body.

Skills: Analysing and Interpreting

- Trace the path of lymph from lymph capillary until it is returned to the blood.

12.5.2 SPLEEN

The spleen, which is roughly the size of a clenched fist, is located on the left side in the extreme superior, posterior part of the abdominal cavity. The spleen detects and responds to foreign substances in the blood, destroys worn-out erythrocytes, and acts as a blood reservoir. Foreigen substances in the blood passing through the white pulp can stimulate lymphocytes in the periarterial sheath or the lymph nodules in the same manner as in lymph nodes. Before blood leaves the spleen through veins, it passes into the red pulp. Macrophages in the red pulp remove foreign substances and worn-out erythrocytes through phagocytosis. In emergency situations such as haemorrhage, smooth muscle in splenic blood vessels and in the splenic capsule contract in response to sympathetic stimulation. The result is the movement of a small amount of blood from the spleen into the general circulation.

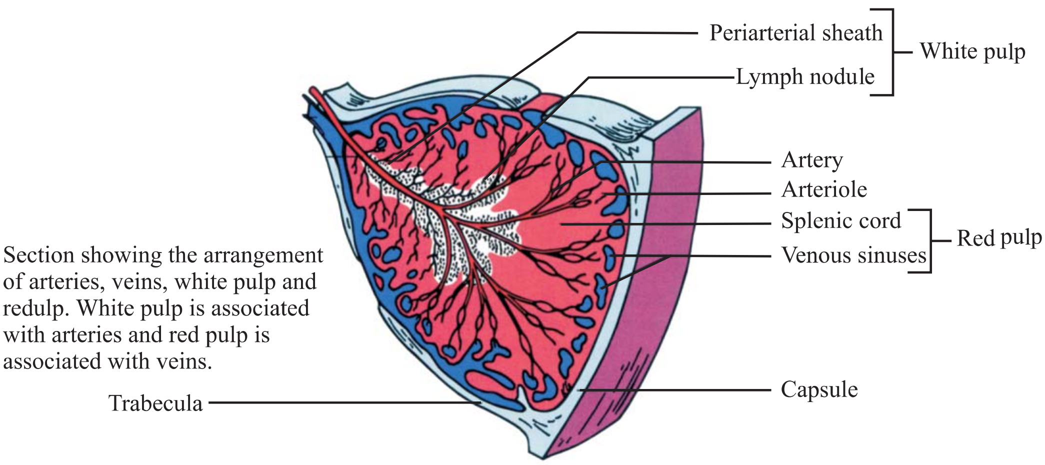

Fig: 12.22 Spleen

Table: 12.4 Differences Between Blood Capillaries and Lymphatic Capillaries

	Blood Capillaries		Lymph Capillaries
1	These are reddish and easy to locate.	1	These are colourless, thus difficult to locate.
2	These are joined to arterioles at one end and to venules at the other end.	2	These are joined to arterioles at one end and to venules at the other end.
3	These have no free end.	3	Their free ends are blind and expanded into a knob.
4	These are narrower than lymphatic capillaries.	4	These are wider than blood capillaries.
5	These have a uniform diameter.	5	These are not of uniform thickness.
6	These carry blood received from arterioles to the venules.	6	These carry colourless lymph received from tissue spaces by lymphatic vessels.
7	Blood flows through them under high pressure.	7	Lymph flows through them under low pressure.
8	Provide tissue fluid to intercellular spaces.	8	These absorb tissue fluid from intercellular spaces.

Table: 12.5 Differences Between Blood and Lymph

	Blood		Lymph
1	It is a red fluid tissue.	1	It is a colourless fluid tissue.
2	It circulates and flows through the arteries, capillaries and veins.	2	It flows in the tissue-spaces and through the lymphatic capillaries and vessels enter the subclavian veins.
3	It consists of erythrocytes leucocytes and platelets.	3	It consists of leucocytes only.
4	It appears red because of the presence of erythrocytes.	4	Due to the absence of erythrocytes it appears colourless.
5	It is rich in plasma proteins calcium and phosphorus.	5	It has fewer plasma proteins and less calcium and phosphorus.
6	It flows rapidly.	6	Its flow is very slow.

Science, Technology and Society Connections

List major hospitals of cardiology working in your province.

Skills: Initiating and Planning

- **Justify in what ways blood circulatory system is dependent on the lymphatic system.**

The lymphatic system represents an accessory route by which fluid can flow form the interstitial spaces into the blood. And, the most important, the lymphatic system can carry proteins and large particulate matter away from the tissue spaces, neither of which can be removed by absorption directly into the blood capillary. This removal of proteins from the interstitial spaces is an essential function, without which we would die within 24 hours. Thus blood circulatory system is dependent on lymphatic system.

- **Interpret why the swelling of the lymph nodes is a cause of concern.**

Lymphatic flow is determine by the interstitial fluid pressure and activity of lymphatic pump. Lymph node swelling is a cause of concern because lymph node swells in different diseases, e.g. in pyrexia (fever) of unknown origin enlarged lymph nodes appear. Enlargement of anterior and tonsillar nodes is usually associated with tonsillitis or pharyngitis, posterior lymphoadenopathy may suggest a glandular fever syndrome or HIV infection. The causes of lymphoadenopathy (swelling of lymph node) are bacterial (streptococcal, tuberculosis), viral, protozoal, fungal (histoplasmosis), leukeemias, lymphomas etc.

Exercise

Select the correct answer

1. The rhythmic beating of cardiac muscle in the mammalian heart is initiated by the.
   A) atrio-ventricular node
   B) parasympathetic nervous system

C) Purkinje tissue

D) sino-atrial node

2. A red blood cell, entering the right side of the heart, passes by or through the following structures:

1. atrioventricular valve, 2. semilunar valve, 3. right atrium, 4. right ventricle, 5. sinoatrial node

In which order will the red blood cell passes the structures?

A) $2 \longrightarrow 3 \longrightarrow 1 \longrightarrow 4 \longrightarrow 5$

B) $3 \longrightarrow 1 \longrightarrow 5 \longrightarrow 2 \longrightarrow 4$

C) $3 \longrightarrow 5 \longrightarrow 1 \longrightarrow 2 \longrightarrow 4$

D) $5 \longrightarrow 3 \longrightarrow 1 \longrightarrow 4 \longrightarrow 2$

3. What effect would be caused by cutting the sympathetic nerve fibres to the heart?

A) a decrease in the heartbeat rate

B) a decrease in the length of the diastole phase

C) a decrease in the length of the systole phase

D) a decrease in the stroke volume

4. What produces systolic blood pressure?

A) contraction of the right atrium B) contraction of the right ventricle

C) contraction of the left atrium D) contraction of the left ventricle

5. Human heart is

A) myogenic B) neurogenic

C) cardiogenic D) digenic

6. Typical lub-dup sounds heard in heart in heartbeat are due to

A) closing of bicuspid and tricuspid valves.

B) closing of semilunar valves

C) blood under pressure through aorta.

D) closure of bicuspid –tricuspid valves followed by semilunar valves.

7. Bicuspid valve connects
   - A) left atrium and left ventricle
   - B) left atrium and right ventricle
   - C) right atrium and left ventricle
   - D) right atrium and right ventricle

8. Pace maker is situated in heart
   - A) in the wall of right atrium
   - B) on interauricular septum.
   - C) on interventricular septum
   - D) in the wall of left atrium.

9. During ventricular systole in a mammalian heart the
   - A) ventricular pressure increases
   - B) atrioventricular valves open
   - C) semilunar valves close
   - D) aortic pressure decreases

10. Lymph returns------------ to blood
   - A) oxygen
   - B) carbon dioxide
   - C) interstitial fluid
   - D) white blood cells

11. Lymph most closely resembles which of the following?
   - A) blood
   - B) urine
   - C) water
   - D) interstitial fluid

12. Which of these factors has little effect on blood flow in arteries?
   - A) total cross sectional area of vessels
   - B) blood pressure
   - C) skeletal muscle contraction
   - D) heartbeat

13. The Sino Atrial node (SA node)
   - A) regulates the rhythm of contraction
   - B) is also called AV node
   - C) regulates the rate of contraction
   - D) is also called bundle of His

SECTION II : SHORT QUESTIONS

1. Which side of the human heart contains oxygenated blood?
2. What are the contraction and relaxation of human heart called?
3. Name two circulatory systems in the body of man.

4. Where are SA node, AV node, Purkinje fibre, Bundle of His located?
5. Name the artery supplying blood to the heart.
6. What is blood pressure?
7. Name the instrument used in measuring blood pressure.
8. Why is SA node called pacemaker of the heart.
9. What is a cardiac cycle?
10. What is the major feature of human lymphatic system?
11. What is an arterial pulse? How much is the normal human pulse rate?
12. Why is AV node essential for the conduction of cardiac impulse?
13. What is the function of the valves in lymph vessel?
14. What are the risks associated with atherosclerosis?
15. Why can you feel your pulse in arteries but not in veins? If there is no pulse in your veins what pushes the blood in veins back to the heart?
16. List the risk factors in your family history and life style for cardiovascular disease. Which factors can be changed? Which cannot? What can you do to lower your risk of heart disease?
17. What is the difference between the lymph capilleries and blood capilleries?

SECTION III : EXTENSIVE QUESTIONS

1. Describe the external and internal structure of human heart.
2. Write a comprehensive note on electrocardiogram.
3. Explain how the structure of each type of blood vessel is suited to its function?
4. Define blood pressure. How it is measured?
5. Discuss cardiovascular diseases. List the ways to prevent it.
6. Write notes on: Angiography, angioplasty, open-heart surgeries, and hypertension.
7. Describe the lymphatic system is man.

ANSWER MCQS

1. D 2. D 3. A 4. D 5. A 6. D 7. B 8. A 9. A 10. C 11. D
12. C 13. A

SUPPLEMENTARY READING MATERIAL

1. Madar S.S. Human Biology, Mcgraw-hill, USA, 1998
2. Taylor, D.J., Green, N.P.O. and Stout, G.W. Biological science 3rd Ed. Cambridge university press, reprint, 2004.
3. Campbell N.A. Mhchell, L.G. & Reece J.B., Biology Concepts and connections, 2nd edition Benjamin/Cummings Company California, 2003

USEFUL WEBSITES

1. en.wikipedia.org/wiki/blood
2. www.fi.edu/biosci/blood.htm
3. texasheart.org/HIC/Ana tomy/Anatomy
4. www.worlddinvisible.com/apologet/humbody/heart
5. en.wikipedia.org/wiki/atherosclerosis.