<u>Circulatory System</u>

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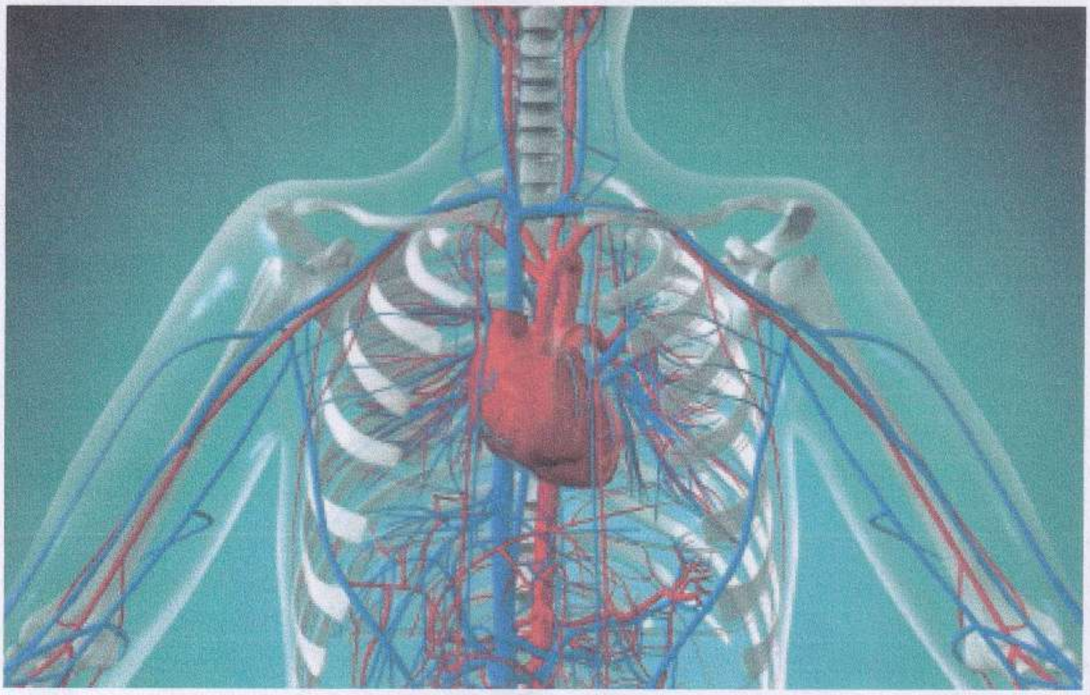
<u>What is circulation?</u>

The movement of body fluids (blood and lymph) from one part of the body to the other parts is called **circulation**. It is the continuous movement of blood through the heart and blood vessels, which is maintained chiefly by the action of the heart, and by which nutrients, oxygen and internal secretions are carried to and wastes are carried from the body tissues.

Simple diffusion allows some water, nutrient, waste and gas exchange into primitive animals that are only a few cell layers thick. Bulk flow is the only method by which the entire body of larger more complex organisms is accessed.

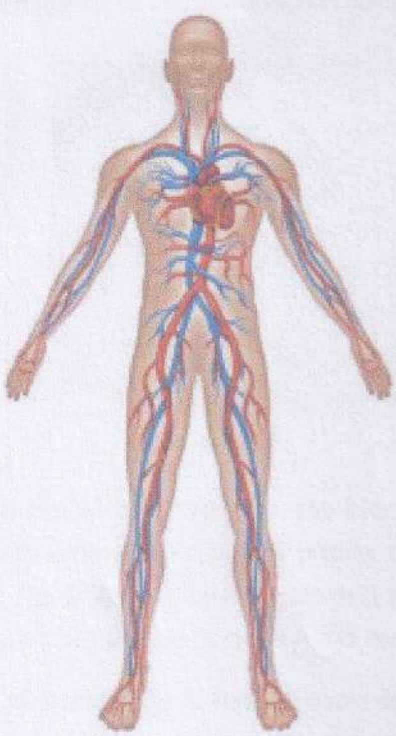


What is Circulatory System?

In all animals, except a few simple types, the circulatory system is used to transport nutrients and gases through the body. The circulatory system is effectively a network of cylindrical vessels: the arteries, veins, and capillaries that emanate from a pump, **the heart**.

Not all animals have a circulatory system. If they are small, nutritive molecules, respiratory gases, and waste metabolites diffuse readily through the intracellular spaces and no special arrangements are required for their transport. Even rather large animals may lack a circulatory system because of their primitive organization.

The circulatory system (cardiovascular system) pumps blood from the heart to the lungs to get oxygen. The heart then sends oxygenated blood through arteries to the rest of the body. The veins carry oxygen-poor blood back to the heart to start the circulation process over.



Variation in circulatory system:

In unicellular organisms such as *Amoeba*, *Paramecium*, etc., there is no need of a circulatory system because O_2 and food can easily diffuse to all parts of the cytoplasm from environment, while waste products such as CO_2 and NH_3 can easily be eliminated from surface.

The **coelenterates** and **flatworms** have achieved considerable size and complexity with little more than a highly branched and ramifying gut or gastrovascular cavity which combines some of the functions of a circulatory system with the digestive machinery; the **echinoderms** have such a low rate of metabolism that an active circulation does not appear to be essential.

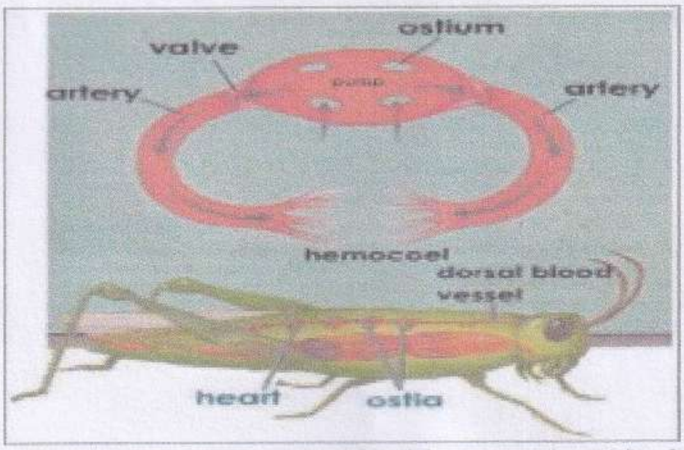
However, the majority of multicellular animals because of bulk, activity, and associated metabolic demands require continuous and reliable circulation of body fluids, specialized to transport nutrients and gases to tissue remote from the source of supply. The evolution of a transport system was essential to the phylogeny of the highly complex organ systems of the higher animals.

Intracellular transport is a unique feature of unicellular organisms because their cytoplasm constantly shows streaming movements in a definite course.

Transport through external medium in some lower animals such as sponges and coelenterates, the water in which they live acts as the medium of transport. The circulation of water through channels of these organisms is assisted by ciliary, flagellar or muscular activity.

Transport in fluid filled body spaces is a unique feature of animals having a primary body cavity. The fluid contained in these primary cavities is made to move by muscular movements of the body. As the fluid moves, the food and oxygen contained in it also move from one place to another and is picked up by the cells. Pseudocoelom and pseudocoelomic fluid is found in nematodes, entoprocts and rotifers, while haemocoel and haemocoelomic fluid or the haemolymph is found in arthropods and molluscs.

Other major types of circulation are: **Open and Closed**



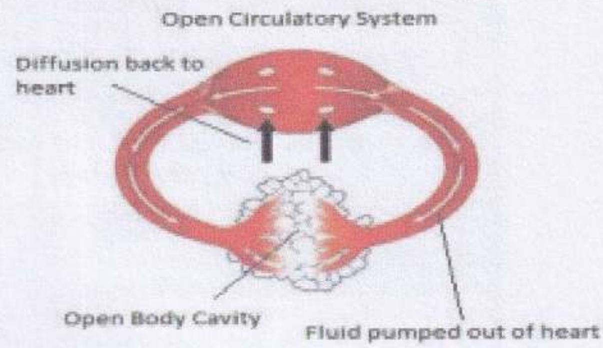
In an **open circulatory system**, the blood is not enclosed in the blood vessels but is pumped into a cavity called a hemocoel and is called hemolymph because the blood mixes with the interstitial fluid. As the heart beats and the animals moves, the hemolymph circulates around the organs within the body cavity and then reenters the hearts through openings called **ostia**.

This type of circulation is seen in most of the invertebrates. Here the vessels are not closed but interrupted by slits, lacunae, etc. Most arthropods and many molluscs have this type of circulation. Blood vessels are very much reduced or absent. The volume of the hemolymph or the blood is more, while blood pressure is low in animals that have and open type of circulation.

Although, a rudimentary heart is present but the hemolymph circulates mainly by virtue of muscular movements of the appendages.

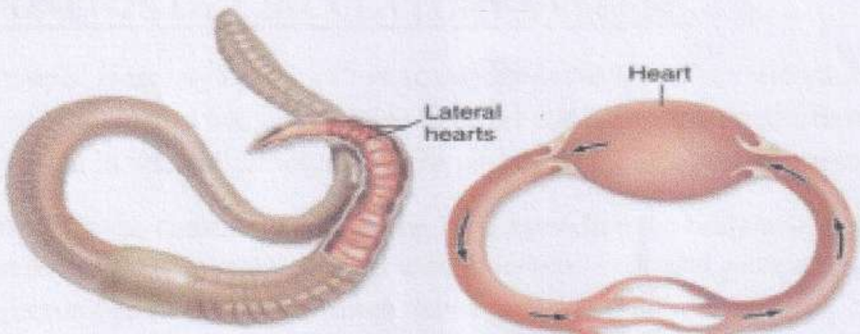
Organisms that are more complex but still only have two layers of cells in their body plan, such as jellies (Cnidaria) and comb jellies (Ctenophora) also use diffusion through their epidermis and internally through the gastrovascular compartment. Both their internal and external tissues are bathed in an aqueous environment and exchange fluids by diffusion on both sides.

In **Closed circulatory system** type of circulatory system, the blood remains in the blood vessels. It does not come out of the blood vessels. The blood flows from the arteries to veins through small blood vessels called capillaries. The closed type of circulatory system is found Annelids, Phoronids, Nematodes, Cephalopods, some Molluscs, Holluthurians and Vertebrates.

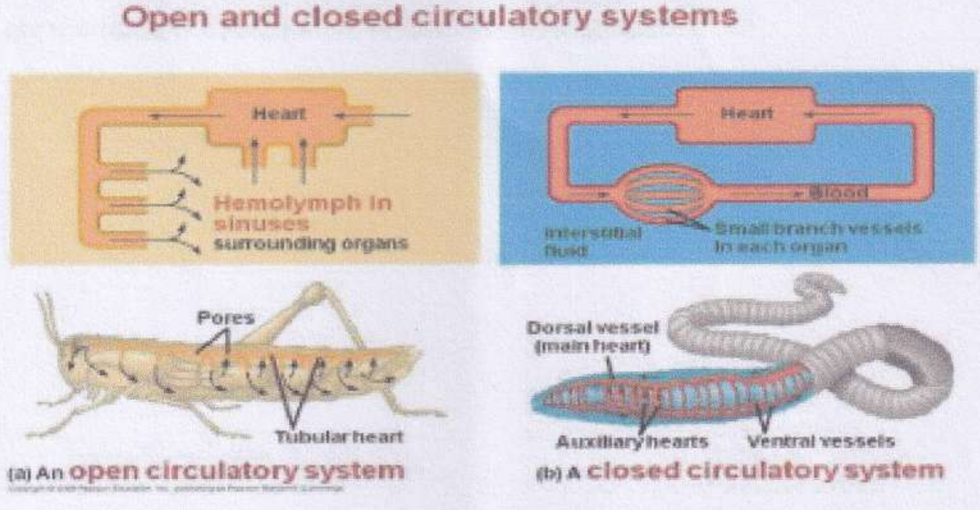


Interesting separations of vessels in this system is a unique feature of the evolution of the circulatory apparatus. Another important feature in the development of cardiovascular system is the progressive differentiation of a special muscular organ whose contractions impart motion to the fluid.

In worms and certain lower Chordata there are no true hearts but dorsal vessels contract rhythmically. This pulsating vessels evolved and were replaced by specialized muscular organ, **the Heart**.



Open and closed circulatory systems



	Open system of circulation		Closed system of circulation
1.	In this system, blood is pumped by the heart, through large vessels, into body cavities called sinuses.	1.	In this system, blood is pumped by the heart, through a closed network of vessels.
2.	The body tissues are in direct contact with blood.	2.	The body tissues are not in direct contact with blood.
3.	Blood flows at low pressure. Hence, it is a slower and less efficient system of circulation.	3.	Blood flows at high pressure. Hence, it is a faster and more efficient system of circulation.
4.	The flow of blood is not regulated through the tissues and organs.	4.	The flow of blood can be regulated by valves.
5.	This system is present in arthropods and molluscs.	5.	This system is present in annelids, echinoderms, and vertebrates.

COMPONENTS OF CIRCULATORY SYSTEM:

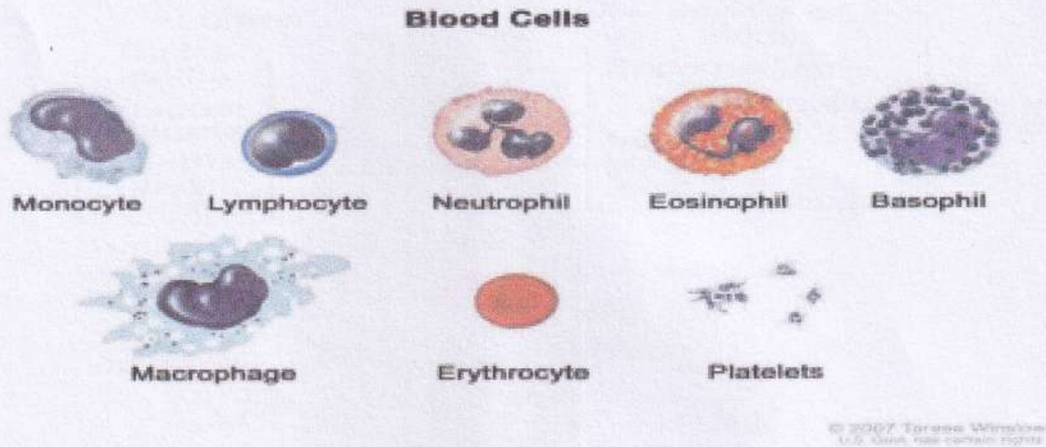
Haemolymph: Haemolymph is a fluid analogous to the blood in vertebrates, that circulates in the interior of arthropod body, remaining in direct contact with animal's tissues. It is composed of fluid plasma in which haemolymph cells are called haemocytes are present.

Blood: Blood is the constantly circulating fluid providing the body with nutrition, oxygen and waste removal. Blood is mostly liquid with numerous cells and proteins suspended in it. The average person has about 5 litres (more than a gallon) of blood.

A liquid plasma makes up about half of the content of blood. Plasma contains proteins that help blood to clot, transport substance through the blood, and perform other functions. It also contains glucose and other dissolved nutrients.

There are many other components of blood besides plasma:

White blood cells (WBCs): These cells help the to body fight any infection. They are the part of the immune system. WBCs are of different types like- Neutrophils, Eosinophils, Basophils,



Lymphocytes and Monocytes.

Red blood cells (RBCs): Erythrocytes (RBCs) are disc shaped cells that gives the reddish color to the plasma. These carry oxygen from lungs throughout the body.RBCs have a component called as **Haemoglobin** (Hb), which actually binds to the oxygen and carry it to all parts of the body. It is a protein heme surrounded by globin group. It has iron (Fe), that actually gives the red color to the blood.

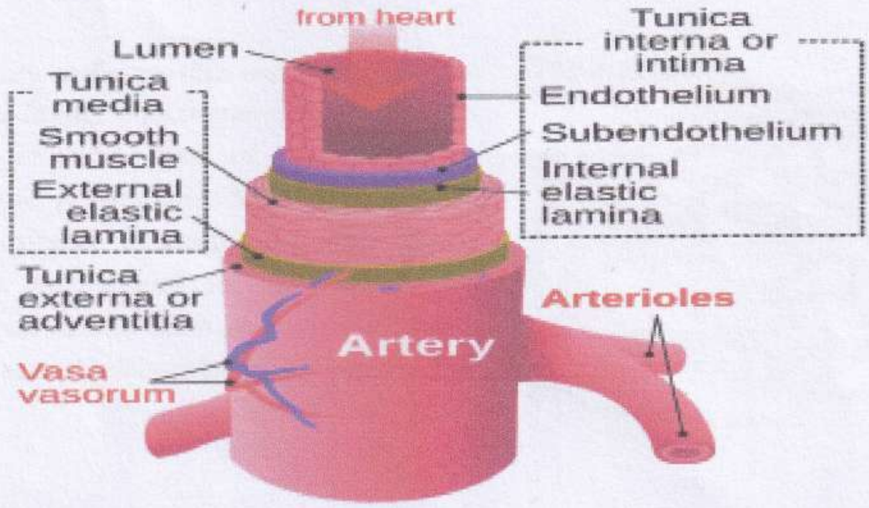
Platelets: These help the blood to clot. They stick together to stop bleeding in case of any wound.

The Blood Vessels:

There are three types of blood vessels: ***Arteries, Veins and Capillaries.***

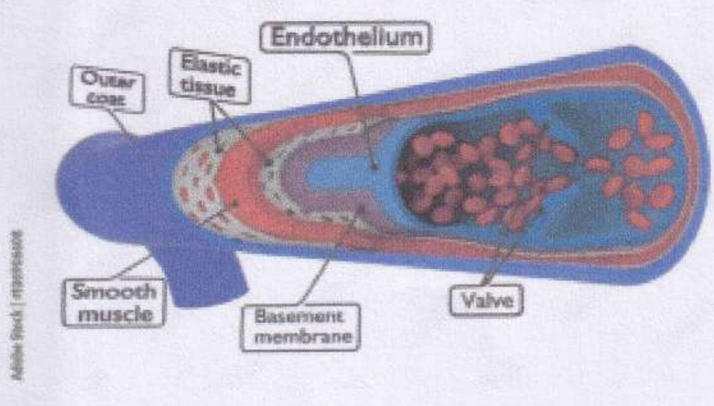
Arteries: They are thick-walled structures which carry blood away from the heart to the tissues. The blood flowing through the arteries is always at high pressure. There are 3 coats of which arteries are made. The ***tunica intima*** is the innermost and is composed of the endothelial cells. ***Tunica media*** constitutes the middle layer and is composed of elastic and simple muscle fibres. The amount of elastic fibres is very high in larger arteries such as aorta, while the amount of the muscle fibres is higher in smaller arterioles. The outermost layer, the ***tunica externa*** is composed of loose areolar connective tissue. One of the most characteristic features of arteries is that their wall thickness is well developed as compared to that of the veins.

During systole, the entire arterial system expands as the blood is ejected into it by the left ventricle as the walls of the arteries are elastic, this helps in the absorption of the part of the rise in pressure. And during diastole, as no blood is ejected the pressure of blood circulating in the arteries tends to fall considerably and tries to approach zero. The blood is flowing at very high pressure in the arteries (B.P. 120/70 mm Hg), the rate of blood flow in the arteries is about 65 km/hour. When they contract under nervous or hormonal influences, the lumen of the vessel is considerably decreased. This system is used to increase or decrease the blood supply to a part by increasing decreasing its diameter.



Veins: The veins are thin-walled structures which carry blood from the tissues to the heart. The blood flowing through the veins is at a very low pressure, and consequently their walls are not well developed. The walls of veins have all the three layers, as described for arteries. There is not much change between the ***tunica intima*** of the structures, but the ***tunica media*** is less thick and contains less elastic and much less muscular tissue, being occupied partly by bundles of loose-connective tissue. ***Tunica adventitia*** is relatively better developed in the veins than in the arteries. The external elastic lamina which lies between tunica media and tunica adventitia is less developed.

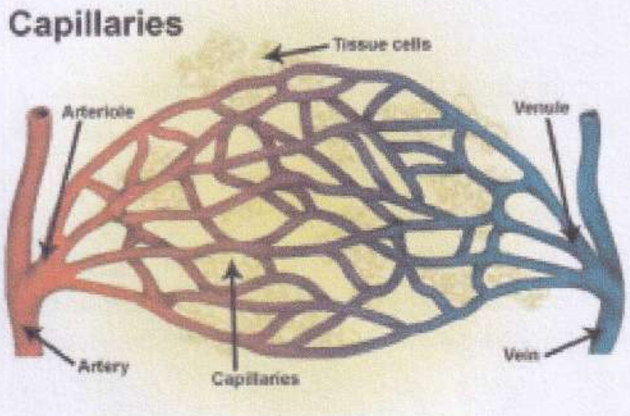
In veins valves are present that prevent the backflow of blood towards the heart. The mechanism by which voluntary muscles supplement in the venous return to the heart is called the muscle pump mechanism.

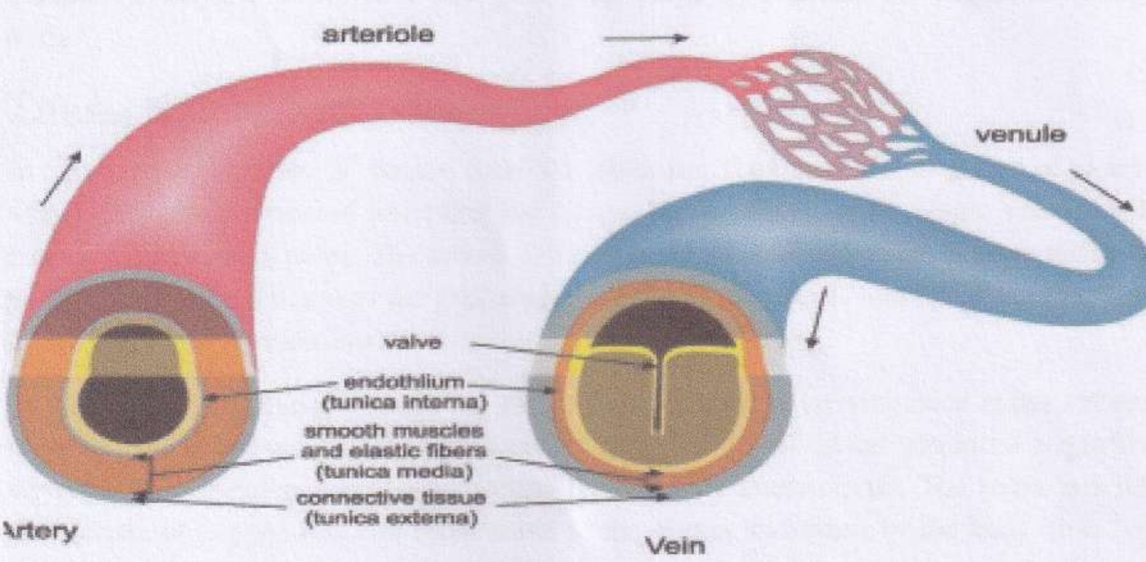


Capillaries: Capillaries are smallest of vessels and barely allow the passage of red blood cells. They are visible only under microscope. The lumen of the capillaries vary on an average of 0.0075 mm in diameter. The length of capillary does not exceed 0.5mm. The number of capillaries in the body are immense. Active tissues have more capillaries than of inactive ones.

The number of capillaries in muscle tissues are 1,500,000 per 2.54 sq cm. Less active tissues such as fatty tissue, have much less capillaries, while the lens of eye has none at all.

The capillary walls are thin and have only the endothelial lining. Functionally, the capillaries are most important part of the circulatory system. Here, in capillaries blood is actually at work as oxygen, nutrients and other useful substances are passed to the tissues and injurious substances such as carbon dioxide, ammonia, urea, lactic acid, etc., are removed.





Comparison of hearts/circulation:

In invertebrates, the circulatory system is a network of channels and spaces in the connective tissue, which is continuous around and between all epithelial layers of the body. Invertebrate blood or haemal channels range widely in size. Small tubular channels are called vessels; large sacs like spaces are sinuses; small spaces are lacunae; and in case where the connective tissue compartment enlarges to form a voluminous, blood-filled cavity, is called haemocoel.

During the evolution the cardiovascular system has undergone several anatomical changes. The tubular structures were developed into a muscular organ called as heart. The heart of the earliest vertebrates, possibly represented by amphioxus, was probably a one chambered contractile vessel where peristaltic movements provide the perfusion of the vasculature of the low pressures.

A heart with the single trabeculated ventricle and a single atrium (two chambered) evolved later among fish where blood first perfuses the gills and then the systemic vasculature. A pulmonary circulation along with the partial intracardiac separation of systemic pulmonary blood flows also evolved in fishes, resembling modern day lung fishes and developed further in amphibians, and particularly among reptiles where partial division of the ventricles exist (three chamber). Both birds and mammals evolved hearts with full ventricular septation and a thick compact left ventricular wall that allowed for a considerable rise in systemic blood pressures (four chamber).

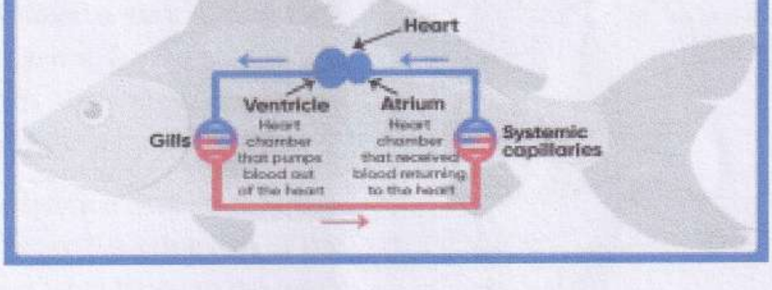
<u>Single chambered heart of amphioxus:</u>

In amphioxus (primitive chordate), a true heart is not found. The blood vessels are contractile in nature and show peristaltic waves. A part of ventral aorta beneath the pharynx is muscular and contractile and acts as a heart. The peristaltic activity of vessel actually squeezes the blood column and imparts motion to it. This pushes the blood forward and it is circulated through the body.

<u>Two chambered heart of fishes:</u>

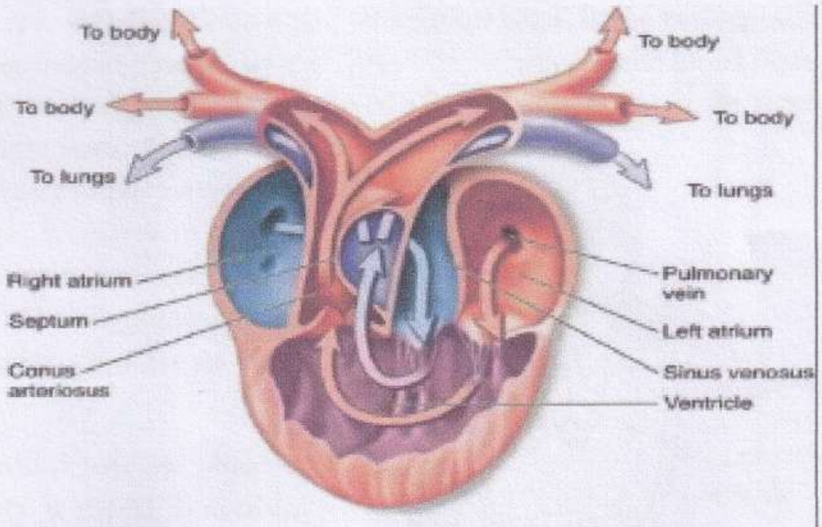
In fishes, the heart is an 'S' shaped tube-like structure. They have single circuit of blood flow within this two chambered heart that has only a single atrium and a single ventricle. These chambers lie in same plane. The atrium collects the blood that has returned from the body and ventricle pumps the blood to the gills where gas exchange occurs and blood is reoxygenated; this is called **gill circulation**.

The blood then continues through the rest of the body before arriving back at the atrium; this is called **systemic circulation**. This unidirectional flow of blood produces a gradient of oxygenated to deoxygenated blood around the fish's systemic circuit. The result is a limit in the amount of oxygen that can reach some of the organs and tissue of the body, reducing the overall metabolic capacity of fish.



Three chambered heart:

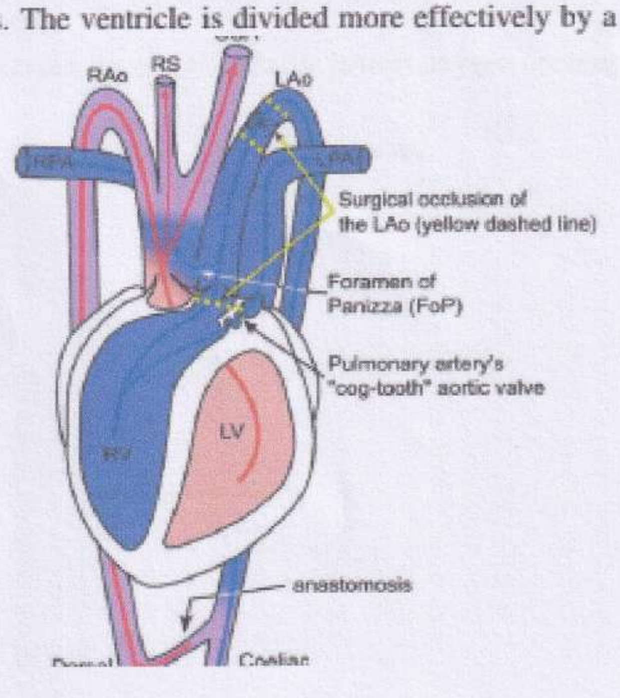
Amphibians have a three chambered heart that has two atria and one ventricle. The atria are divided into right and left atrium by means of atrial septum, while ventricle is undivided single chambered. The two atria (superior heart chambers) receive blood from the two different circuits- the lungs and the systems- and then there is some mixing of the blood in the hearts ventricle (inferior heart chamber) which reduces the efficiency of oxygenation. The advantages to this arrangement are that high pressure in the vessels pushes blood to the lungs and body. The mixing is mitigated by a ridge within the ventricle that diverts oxygen rich blood through the systemic circulatory system and deoxygenated blood to the pulmocutaneous circuit. For this reason, amphibians are often described as having **double circulation**.



(a) Amphibian heart

Advanced three chambered heart of reptiles:

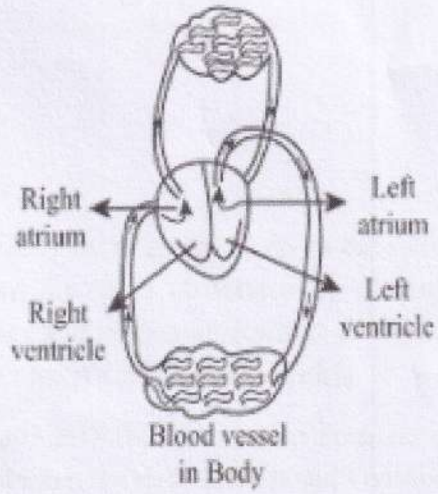
Most reptiles also have a three chambered heart similar to the amphibian heart that directs blood to the pulmonary and systemic circuits. The ventricle is divided more effectively by a partial septum which result in less mixing of deoxygenated and oxygenated blood. Some reptiles like alligators and crocodiles are the most primitive animals to exhibit a four chambered heart. Crocodilians have a unique circulatory mechanism where the heart shunts blood from the lungs towards the stomach and other organs during long periods of submergence, for instance, while the animal waits for preys or stays underwater waiting for prey to rot.



The important adaptation that place is that two arteries that leave the same part of the heart on which one takes blood to the lungs and the other provides an alternate route to the stomach and other parts of the body. Other adaptation includes a hole in the two ventricles called as foramen of Panizza, which allows blood to move from one side of the heart to the other, and specialized connective tissue that slows the blood flow to the lungs. Together these adaptations made the crocodiles alligators one of the most evolutionary successful animal groups on earth.

Four chambered heart of birds and mammals:

In birds and mammals, the heart is developed into a four chambered heart. It has two atriums and two ventricles which are separated by valves by each other. The deoxygenated blood from different parts of the body returns to the right atrium, from where it is pumped to the right ventricle. The blood from the right ventricle is pumped to the lungs by means of pulmonary arteries where it is oxygenated. After oxygenation, it returns to the left atrium through the pulmonary vein. From here, it is pumped into the left ventricle. The oxygenated blood from the left ventricle is carried to the different parts of the body.

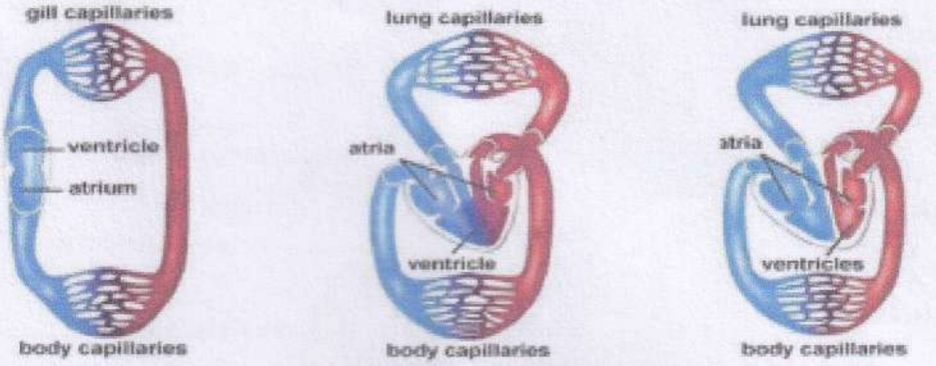


The system of blood vessels which supplies blood to the different parts of the body is called systematic circulation or arterial circulation, while the one supplying the lungs is called as pulmonary circulation or venous circulation. Both together form as double circulation.

Separate circuits have a several advantages:

1. Oxygenated and deoxygenated blood cannot mix; therefore, the systemic circuit always receives the blood with highest oxygen content.
2. Respiratory gas exchange is maximized because the blood with the lowest oxygen content highest co2 content is sent to the lungs.
3. Separate systemic and pulmonary circuits can operate at different pressures.

Various Closed Circulatory Systems



Fish
2-chambered heart

Amphibian and Reptiles
3-chambered heart

Mammal
4-chambered heart

HUMAN HEART:

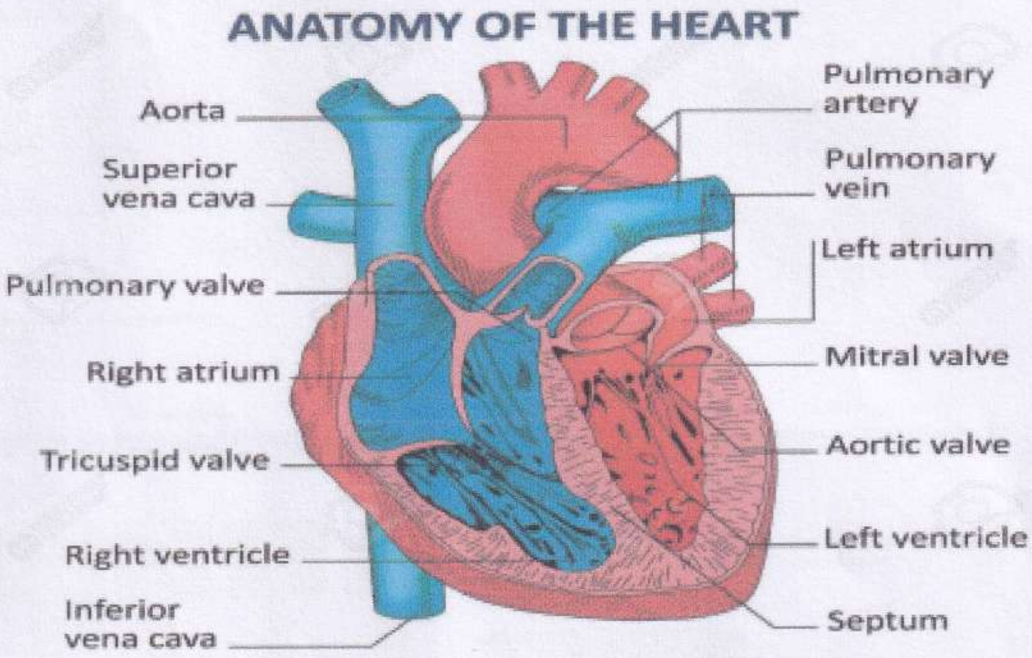
The human heart is located within the thoracis cavity, medially between the lungs in the space known as the **mediastinum.** The heart is separated from the other structures by a tough membrane known as pericardium and sits in its own space called the pericardial cavity. A typical heart is approximately the size of your fist; 12 cm in length and 8 cm in width.

Human heart has four chambers (two auricles and to ventricles). The heart also consists of valves that prevent the backflow of the blood. The valve between the right atrium and ventricle has three flaps or cusps and is called the **tricuspid valve** while that between the left atrium and ventricle has only two flaps and cusps and is called the **bicuspid** or **mitral valve**. The right atrium and right ventricle are called as *right heart*. The left atrium and left ventricle are called the *left heart*. These are two distinct but linked circuits in the human circulation called **the pulmonary and systemic circuits**. The pulmonary circuit transports blood to and from the lungs, where it picks up oxygen and delivers carbon dioxide for exhalation. The systemic circuit transports oxygenated blood to virtually all the tissues of the body and returns relatively deoxygenated blood and carbon dioxide to the heart to be sent back to the pulmonary circulation. There is another valve called as semilunar value or pulmonic valve that opens up when the right ventricle pumps the blood to the lungs for reoxygenation.

The heart is composed of three layers: the **epicardium**, the **myocardium** and the **pericardium**. The endocardium forms the inner lining of the heart, the myocardium forms the middle layer of the heart. The outer layer of the cells is called as epicardium, of which the second layer is a membranous layered structure called the pericardium that surrounds and protects the heart.

The heart has its own blood vessels that supply that heart muscle with blood. The **coronary arteries** branch from the aorta surrounding the outer surface of the heart. They diverge into capillaries where the heart muscle is supplied with oxygen before converging again into the

coronary veins to take the deoxygenated blood back to the right atrium where the blood will be reoxygenated through the pulmonary circuit.



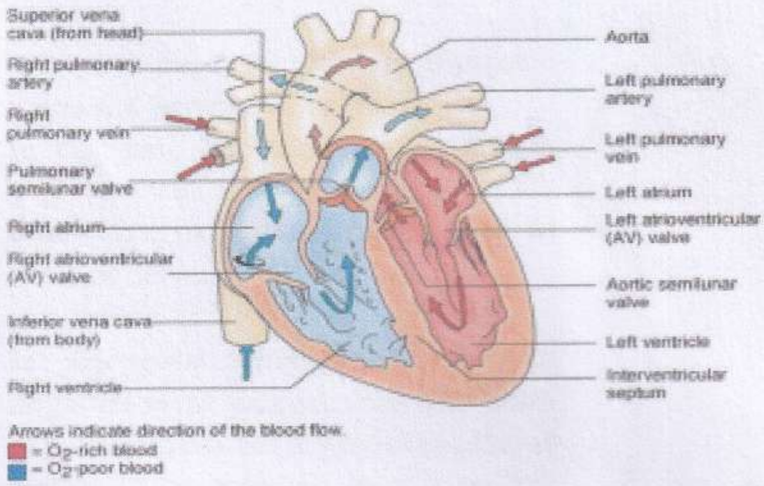
Blood flows from right heart to lungs:

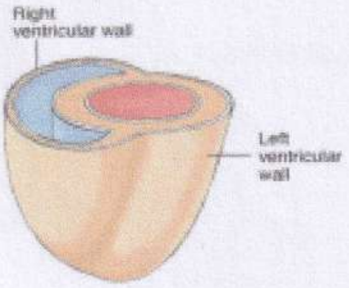
Superior (upper) and inferior (lower) vena cava are large veins that collect deoxygenated blood into the right atrium from the upper and lower body parts, respectively. Blood flows from right atrium, to the right ventricle. Most of the ventricular filling takes place passively during ventricular relaxation. Atrium contracts at the end of ventricular diastole, and put a modest amount of blood into the ventricular volume. After ventricular filling, the right ventricle contracts and pumps the deoxygenated blood into the **pulmonary artery**, which carries blood towards the lungs.

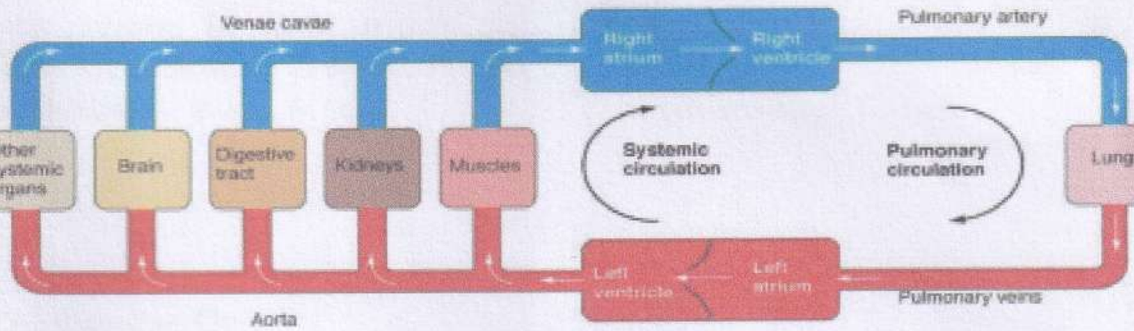
Return of oxygenated blood to the left atrium:

Exchange of gases occur in the lungs and the oxygenated blood return to the left atrium through **pulmonary veins.** The left ventricular filling is similar to that of right side of the heart. Both left and right ventricle fills at a time.

The left ventricular walls have more powerful muscles that start to contracts from the bottom. Pressure in the left ventricle increases and sufficient to push open the aortic valve, the blood run into aorta and start to circulate throughout the body. The left ventricular walls have more powerful muscles because it has to pump the blood throughout systemic circulation while right ventricle pumps the blood to pulmonary circuit which is comparatively small and present in near vicinity. Therefore, left ventricle pump against more resistance, although both pump the same volume of blood.







Pacemakers:

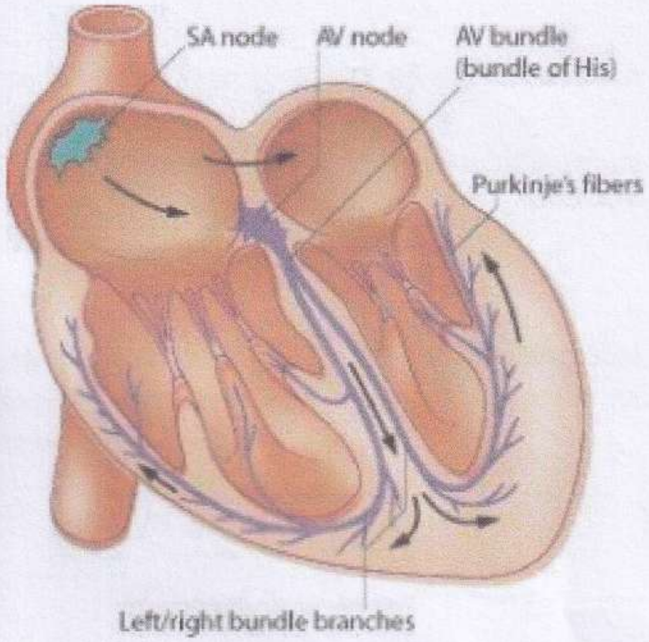
In myogenic heart in fact all cells have ability to set the rhythm. But certain cells are more specialized. The difference in them and other cells is they are highly unstable and have changing electrical potential. This is called as true **pacemaker cells**. The electrical potential of pacemaker cells is -55mv. This charge is unstable which causes depolarization (contraction of muscles). This depolarization is followed by repolarization, (relaxation of muscles) which causes diastole. In this way the charges on pacemaker cells keeps on changing constantly. This changes of charges in the heart muscles through conducting cells causes rhythmic contraction and relaxation of heart. According to Kollikar and Miller heart have 3 type of cells.

1) Pacemaker muscle cells
2) Conductive muscle cell
3) Contractive muscle cells

In the bird and mammal, pace making impulses arise in the sinoatrial node (S-A node) that is a true pacemaker which is a small mass of specialized cells measuring about 2 cm by 2mm in man located in the right atrium. AV node is also a true pacemaker which is located in the right atrium. This node spreads into ventricle through the branches of auricular-ventricular bundles which forms a network in ventricle called as Purkinge fibres. AV node also forms a bundle called as Bundle of 'His' So this true pacemakers AV and SA node helps in mammals to generate rhythm of heart properly.

We can se two types of hearts: Myogenic hearts and Neurogenic hearts.
In myogenic hearts the cardiac rhythm originates within the active region of the heart- the pacemaker, rather than in extrinsic nerves.

In neurogenic hearts the heart beat originates in the ganglion cells. The hearts of most invertebrates in general and that of arthropods in particular have a profuse nerve supply. In these animals the pacemaker is made up of nerve cells and they initiate the rhythm of heart.

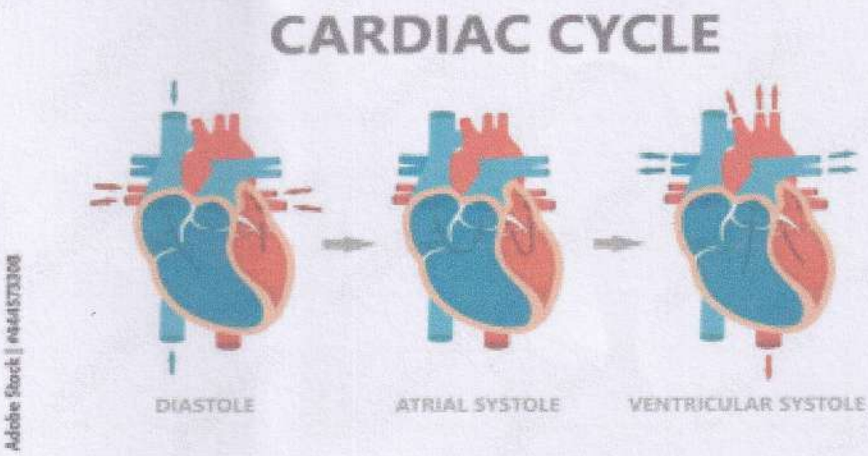


The Cardiac Cycle:

During the heartbeat, two phases: (i) **systole** or the contraction phase (ii) **diastole** or the relaxation phase, have been recognized. In mammals, the heart beat originates in the sinu-atrial node which functions as a pacemaker. The two atria contract simultaneously and force the blood into the ventricles, which is called as **auricular systole**. This systole lasts for about 0.15 sec.

After this slight pause, the ventricles also contract simultaneously. This is called as **ventricular systole**. They force the blood into the aorta. This phase lasts for about 0.3 sec. Following the phase of contraction, the auricles and the ventricles undergo relaxation and this phase is called as **diastolic phase**. The entire sequence of the contraction and relaxation of the auricles and the ventricles constitutes the cardiac cycle.

In case of human heart, which beats about 70 to 80 times/minute, each cardiac cycle lasts for about 0.8 sec. The diastolic phase (relaxation of both auricles and ventricles) is completed in 0.4 sec.



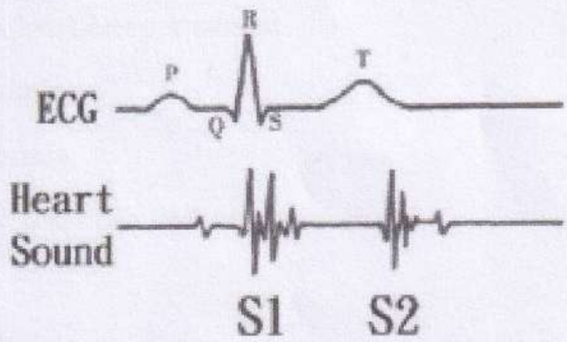
Heart sounds:

Each heart beat is accompanied by two heart sounds: First heart sound as *lubb* and second heart sound as *dup*.

Closing of the atrioventricular valves produces the *lubb* sound. Closing of the semilunar valves produces the sound *dup*.

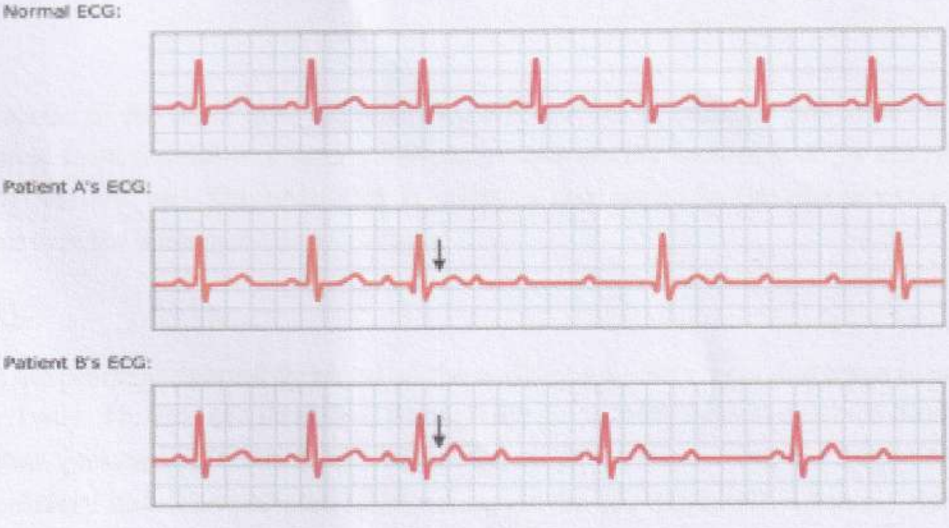
Electrocardiogram:

The electrical impulses in the heart produce electrical currents that flow through the body and can be measured on the skin using electrodes. This information can be observed as an electrocardiogram (ECG). ECG is read as waves called as **PQRST**.



To obtain a standard ECG a patient is connected to the machine with three electrical leads- one to each wrist and to the left ankle- that continuously monitor the heart activity. For a detailed evaluation of the heart function, multiple leads are attached to the chest region. Each peak in the ECG is identified with a letter from P to T that corresponds to a specific electrical activity of the heart. The P-wave represents the electrical **depolarization of the atria**, which leads to the contraction of both the atria. The QRS complex represents the **depolarization of the ventricles**, which initiates the ventricular contraction. The contraction starts shortly after Q and marks the **beginning of the systole**. The T-wave represents the return of the ventricles from excited to normal state (**repolarization**). The end of the T-wave marks the **end of systole**.

By counting the number of QRS complexes that occur in a given time period, one can determine the heart beat rate of an individual. Any deviation in this complex would indicate any possible abnormality. Bradycardia is a condition where heart beats less while Tachycardia is a condition where heart beats comparatively more than normal beats. Digitalis is a drug which inhibit sodium-potassium ion which regulates heart beats.



Cardiac Output:

The amount of blood ejected by each ventricle per beat is called *stroke volume* or *stroke output*. It is about 70 ml in a normal person. If the amount of blood in the ventricles is less, stroke output will automatically be low. But, if the amount of blood contained within the chambers is more due to overfilling, muscles will be stretched.

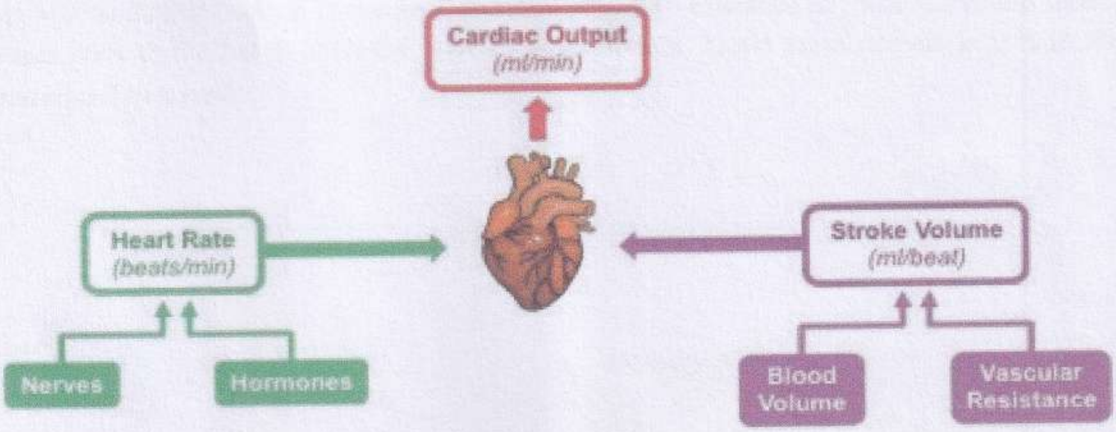
The amount of blood ejected by each ventricle in one minute is known *as cardiac output* and mainly depends on two factors: (1) Heart rate (2) Stroke volume. In other words, it is the volume of blood pumped by the heart in one minute. It is calculated by multiplying the number of heart contractions that occur per minute (heart rate) times the stroke volume (the volume of blood pumped into the aorta per contraction of the left ventricle).

Cardiac output per min.= Stroke volume per beat x heart rate per minute.

= 70 ml per beat x 70 beats/min

= 4900 ml per min = 5 liters/min

Therefore, cardiac output is directly proportional to heart rate and stroke volume.



Heart Rate:

Heart rate is the speed of the heart beat measured by the number of contractions of the heart per minute. It varies from animal to animal. It depends upon many factors such as age, sex, temperature, daily activity, etc. The heart rate is faster in new born. As the age advances it slows down. Heart rate for a normal man is 68/min.

Blood pressure:

Blood pressure is the pressure exerted by blood on the walls of a blood vessel that helps to push blood through the body. The rate of blood flow through the circulatory system depends directly on the atrio-venous pressure difference and inversely on the resistance to the blood flow presented by circulatory bed. The pressure of blood inside the blood vessels is mainly due to the force with which blood is ejected in them by the heart. The blood pressure in mammalian systematic aorta varies during the cardiac cycle.

As blood is ejected during the systole the pressure of blood inside the vessel is highest during this phase and is called **systolic pressure**. During diastole, as no blood is ejected in the arteries it will tend to come to zero, but it is prevented to fall to such a low level due to elastic recoil of vessels. The pressure of blood inside the vessels during diastole is known as **diastolic pressure**. The difference between systolic and diastolic pressure, that is, the change in pressure that occurs each time the heart beats is called the **pulse pressure**. The highest blood pressure is attained during systolic pressure while the lowest is attained during diastolic pressure.

Blood pressure is measured using various machines. It is done using manometer or sphygmanometer. It is expressed in manometric units, **mm Hg.**

In man, the arterial blood pressure in large and medium sized arteries is 120 mm Hg during systolic and 70/75 mm Hg during diastole. The blood pressure in pulmonary circuit is much lower; systolic is 27-30 mm Hg, while diastolic is 10-15 mm Hg. The blood pressure decreases along the circulatory system from the aorta to the veins. The blood is higher in the aorta and lower in the veins near the heart.

The high blood pressure in the arteries is essential to force blood through the capillaries, where resistance due to friction is greatest. Further, it is also essential to force the blood through the veins back to the heart. Both the systolic and diastolic blood pressures are higher in males as compared to females.

Control of heart beat:

The mammalian heart possesses automatic rhythmicity and is governed by a self-regulating mechanism. The better is the elasticity, the greater is the force of contraction however the force of contraction depends upon the nervous regulation and no of other factors such as the temperature and the hormones of the adrenal medulla.

1. Nervous regulation:

In mammalian heart, the vague nerve which innervate it has a dual control. The vagus nerve (10th cranial nerve) has both sensory and motor fiber. The heart receives outgoing branches of the vagus and sympathetic nerve fiber from upper thoracic region of the spinal cord coordinated through the medulla where actually the *control centers* are situated. These control centers include number of cell bodies which are of two types. 1) Cardioinhibator centre and 2) Cardioaccelerator centre.

The cardiac activity (heartbeat) is regulated by these centers through vagal and accelerator functions. Both these centre also send short neurons to each other.so that the activity of inhibitor centers can inhibit can depress the accelerator centre and vice versa. The cardiac activity also influenced by other parts of brain such as the thalamus and hypothalamus. Actually, these parts of brains contain centers which upon stimulation affect the emotional status of the individual and increase the heartbeat, during sleep and exercise.

The pacemakers are actually innervated by the parasympathetic neurons. When parasympathetic neurons are stimulated, the force of contraction is decreased and there is a decline in number of heartbeats per minute.

2. Chemical regulation:

The cardiac functions are greatly influenced by the chemical substances which may be secreted by the nerves innervating the heart muscles or administered into the body. The chemical substances may be classified into the following categories:

1.Neurotransmitters

2.Drugs.

1.Neurotransmitters:

The parasympatretic fibres innervating the heart muscle s secrete acetylcholine which is a neurotransmitter from the cholinergic nerves. Acetylcholine secretion from the nerves endings brings about ventricular arrest, while the auricular contraction are not affected by this substance.

The sympathetic nerve fibers upon stimulation secrete nor adrenalin (a neurotransmitter released by adrenergic nerves). This accelerates the rate of heart beat as well as the force of contraction. When injection of nor adrenaline or adrenaline are given, they lead to an increase in the blood pressure.

2. Drugs

1.Atropine: It causes the acceleration of heart beat.

2.Serotonin: It does influence the blood pressure.

3.Pilocarpine. It causes slowing of heart beat by acting on the heart muscles or vagal nerve termination.

4.Digitalis.It increases the tonicity of heart muscles. contractibility and irritability. It serves as powerful tonic to increase the force of contraction or cardiac output.

3. Effect of temperature:

In poikilotherms, the rate of heart beat is profoundly influenced by the temperature since increase in ambient temperature causes increase in the heart beat. This is owing to large amounts of blood needed for circulation in the body following increase in the metabolism.

In homeotherms, the temperature fluctuations do not have any appreciable effect, except during sweating and panting when increased blood flow may be noticed in the region of skin.

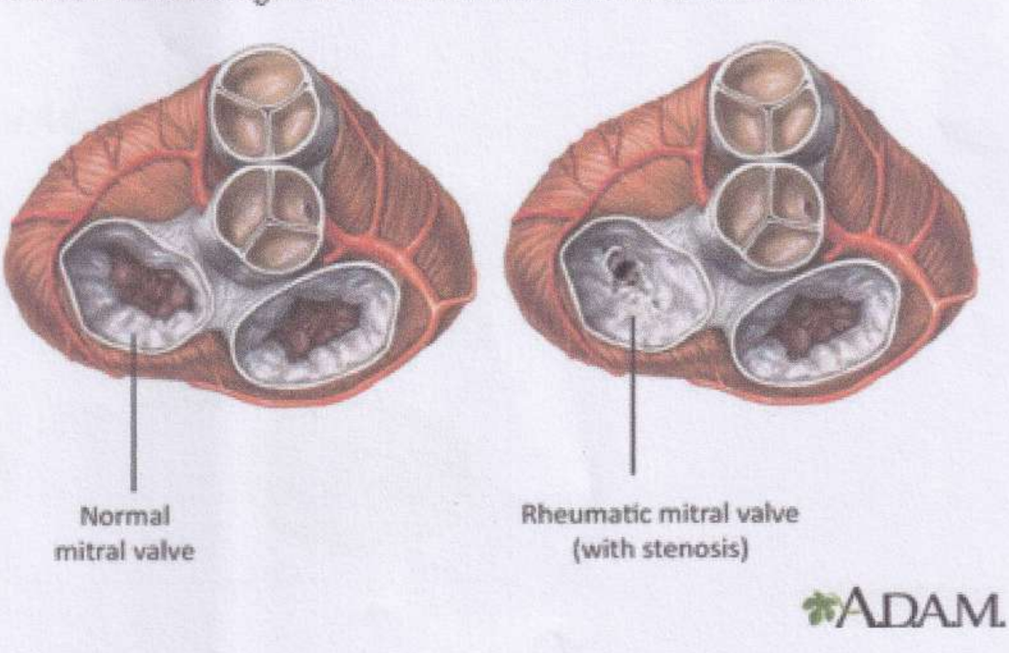
Various Heart Disease

Rheumatic Heart Disease:

Rheumatic heart disease is a chronic heart condition caused by rheumatic fever. This is a very common heart disease in children. This disease is more prevalent in developing countries, especially in areas of poverty.

Acute rheumatic fever is an inflammatory disease that primarily affects joints, the heart, and central nervous system. Heart valve damage is the most common result of rheumatic fever. Pericardium (outer sac) and endocardium (the inner lining) may be damaged due to the inflammation caused by the rheumatic disease.

Rheumatic fever generally starts with strep throat and develops into a fever. This development can be prevented by taking antibiotics or penicillin.



Symptoms:

Heart valve problems are the result of rheumatic fever and it's symptoms include

- Chest pain
- Excess fatigue
- Heart missing a beat
- Thumping sensation in the chest
- Swollen ankles
- Fainting etc.

Treatment:

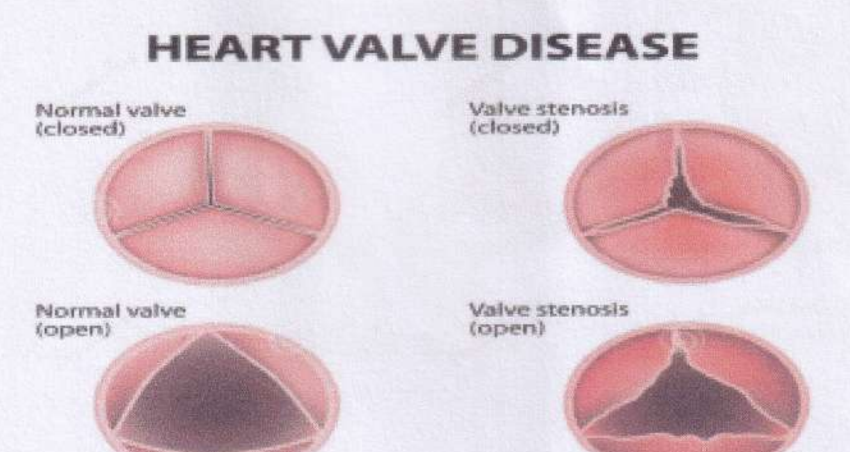
Treatment depends on the severity of the disease. Treatment for rheumatic heart disease generally includes:

- Antibiotics for strep throat and prevent rheumatic fever.
- Medicines that are helpful for blood thinning to prevent heart stroke.
- Surgery for repairing heart valves.

Valvular Heart Disease:

If any of the valves of the heart (aortic, mitral, pulmonary and tricuspid valves) are damaged, it results in valvular heart disease. The basic reason for this disease is the damage to heart valves due to age.

The functions of these valves are to ensure that blood is flowing at the right speed in the right direction. In valvular heart disease conditions, the valves of the heart become very thin and hard that changes the rate and speed of blood flow in the system. Sometimes they may be completely closed.



Symptoms:

Symptoms of this disease are very sudden. This disease advances slowly and heart adjusts to it and it becomes very difficult to find the symptoms. General symptoms are almost similar to rheumatic heart disease. Symptoms are:

- Giddiness
- Excess fatigue
- Palpitations
- Chest pain

Treatment:

Following are the treatment options:

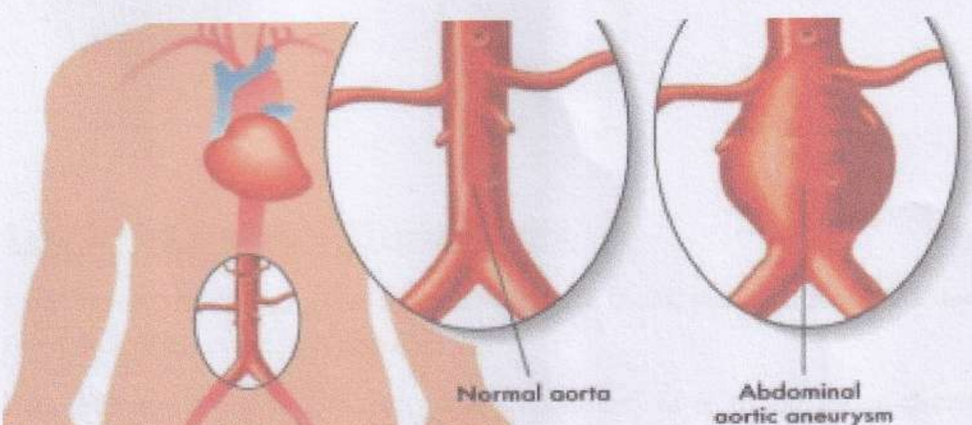
- Long term antibiotic therapy
- Medications which prevent clotting
- Balloon dilatation

Hypertensive Heart Diseases:

High blood pressure is the cause of this disease. It overburdens the heart and blood vessels causing damage to them. Following are some of the hypertensive heart diseases.

Aneurysm:

An aneurysm is a bulge or swelling of the artery. An aneurysm may be silent but causes serious problems, sometimes even causes death. An aneurysm can happen in any part of the body i.e., brain, nervous system, etc.



Atherosclerosis:

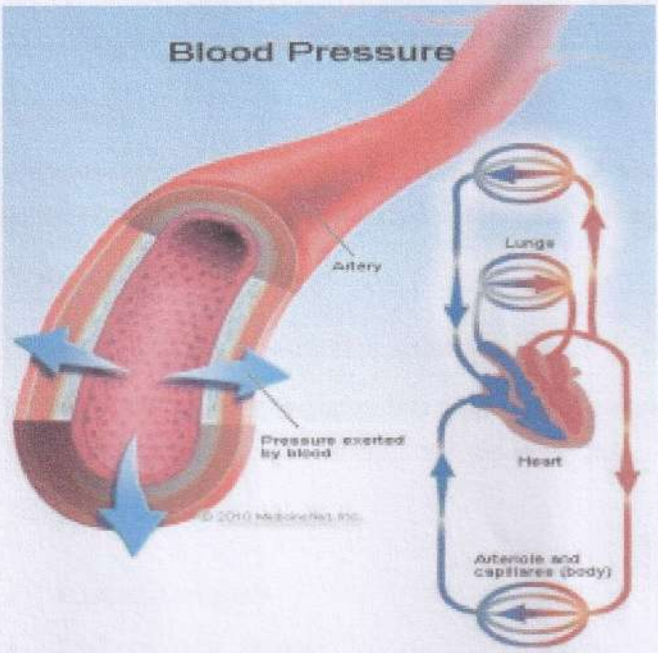
This is a condition in which walls of arteries become stiff and thick due to the accumulation of fat deposits called plaques. This, in turn, restricts the blood flow in the system. Atherosclerosis can occur in any part of the body. If atherosclerosis occurs in the heart, then it is coronary artery disease. If this occurs in the legs then it is peripheral artery disease.

High blood pressure (Hypertension):

As the name suggests, the pressure of blood flow increases in the blood vessels leading to many cardiovascular diseases like heart failure, renal failure, etc. It is a common condition in which the long-term force of the blood against the artery walls is high enough that it may eventually cause health problems.

Symptoms:

A few people with high BP may have headaches, shortness of breath or nosebleeds, but these signs aren't specific and usually don't occur until high blood pressure has reached a severe or life-threatening stage.



Low Blood Pressure (Hypotension):

Low blood pressure is generally considered a blood pressure reading lower than 90 mm Hg (systolic) or 60 mm Hg (diastolic).

Low BP might cause no noticeable symptoms, or it might cause dizziness and fainting. Sometimes, low blood pressure can be life-threatening.

LOW BLOOD PRESSURE	
90/60mmHg	**HYPOTENSION**
80/60mmHg	Nausea | Dizziness
80/50mmHg	Fainting | Tired
70/50mmHg	Weak | Blurry Vision
60/45mmHg	Sleepiness | Confusion
50/35mmHg	Coma & Death

Cerebrovascular Heart Disease:

Cerebrovascular heart disease is a condition in which blood circulation to the brain is affected. This is caused mainly due to atherosclerosis. As discussed earlier, atherosclerosis is a condition in which walls of arteries become stiff and thick due to the accumulation of fat deposits.

Blood pressure affects blood flow leading to ischemic stroke and a rise in blood pressure leads to tearing of blood vessels which may lead to intracranial haemorrhage.

Causes:

Atherosclerosis, embolism, low-fat states, and aneurysms are the basic or primary causes of cardiovascular heart disease. Risk factors include hypertension, smoking, diabetes, and obesity.

Treatment:

Treatment for cardiovascular disease involves surgery, lifestyle changes, and medications.

Medications include antiplatelets (like aspirin, clopidogrel), blood-thinning medications (like heparin, warfarin) and anti-diabetic medications.

Surgeries include:

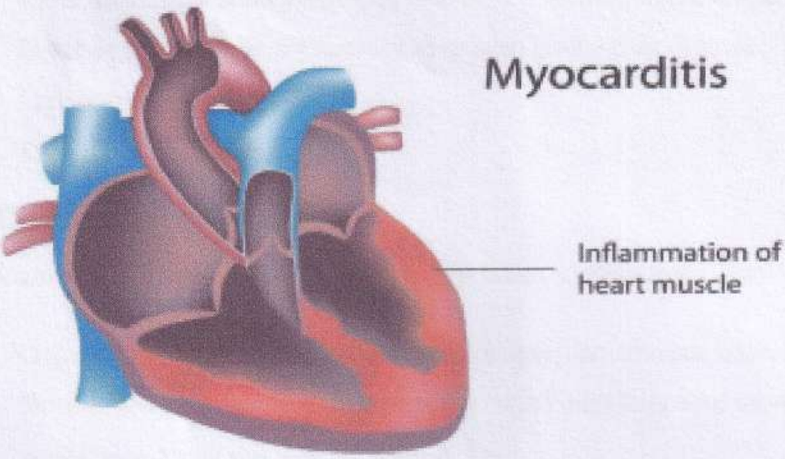
- Vascular surgery
- Endovascular surgery

Inflammatory Heart Disease:

Inflammatory heart disease is caused due to inflammation of the pericardium. Causes of this disease include

- Bacterial or fungal infection
- Heart attack and myocarditis
- Due to radiation therapy to the chest
- Use of medications that suppress the immune system

- Due to diseases such as cancer, leukaemia, tuberculosis, kidney failure etc.



Symptoms:

- Severe chest pain
- Difficulty in breathing when lying down
- Dry cough
- Anxiety
- Excess fatigue

Treatment:

The main goal of the treatment is to

- Suppress acute inflammatory process
- Eradication of streptococcal infection
- Prevent the further occurrence of disease
- Protect heart against damaging effects of carditis

Ischemic Heart Disease:

Ischemic heart disease is a wide range of heart diseases caused by the decreased supply of oxygen to the myocardium i.e., the muscle of the heart. It is also known as coronary artery disease

Angina:

Angina is caused due to a reduced supply of blood to the heart. Blood carries oxygen throughout the body and depriving the heart of oxygen will have fatal consequences.

Angina starts with chest pain and it spreads to the left arm, shoulder and jaw. It occurred due to shortness of breath and sweating.

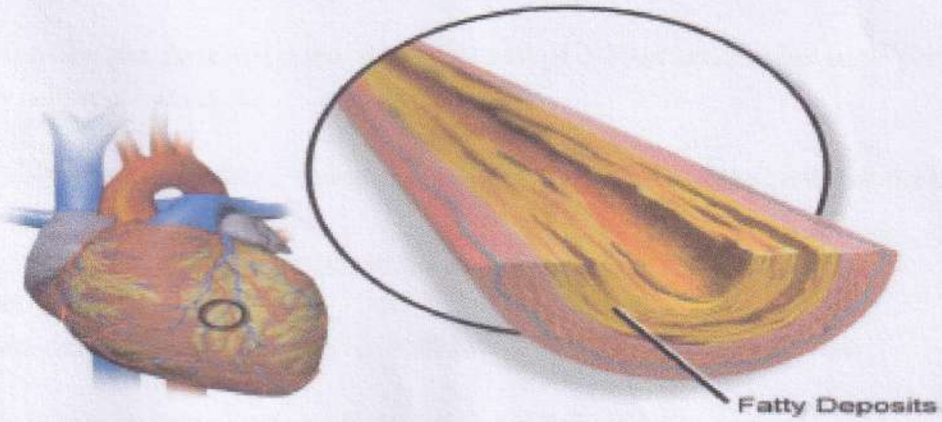
Causes of Ischemic Heart Disease:

- Risk factors include smoking, diabetes mellitus, and cholesterol levels.
- Genetic and hereditary factors may also cause this disease.
- Hypertension
- Stress is also a risk factor

Treatment:

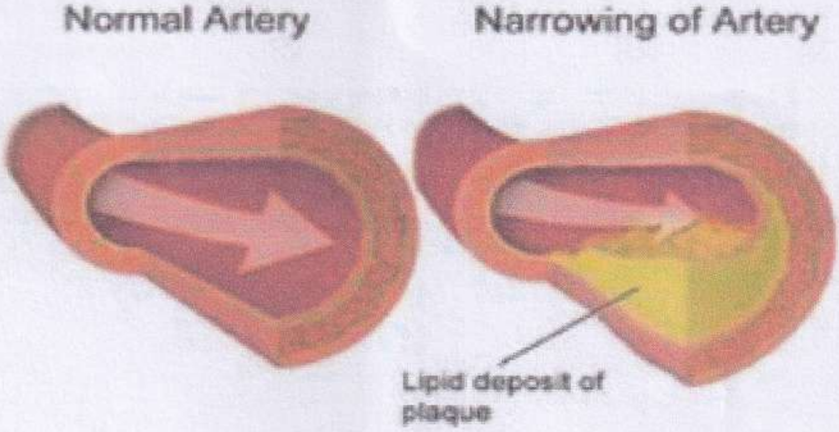
Treatment of Ischemic heart disease includes medications like

- Organic nitrates help to relax the non-specific smooth muscles.
- Beta-blockers help to reduce cardiac work and increase oxygen consumption.
- Aspirin reduces the risk of angina.
- Calcium channel blockers reduce the total coronary flow by blocking beta receptors.



Coronary artery disease:

It is the condition in which the coronary artery struggles to send blood to the heart muscles. This occurs due to high cholesterol levels and inflammation in the arteries.



Coronary Artery Disease

Myocardial Infraction:

Myocardial infarction happens when one or more areas of the heart muscle don't get enough oxygen. This happens when blood flow to the heart muscle is blocked. It is also called as heart attack.

Causes of a Heart Attack:

The blockage is caused by a build-up of plaque in the arteries (atherosclerosis). Plaque is made up of deposits, cholesterol, and other substances. When a plaque breaks (ruptures), a blood clot quickly forms. The blood clot is the actual cause of the heart attack. If the blood and oxygen supply is cut off, muscle cells of the heart begin to suffer damage and start to die. Irreversible damage begins within 30 minutes of blockage. The result is heart muscle affected by the lack of oxygen no longer works as it should.

Symptoms of a Heart Attack:

The following are the most common symptoms of a heart attack. But each person may have slightly different symptoms.

- Severe pressure, fullness, squeezing, pain, or discomfort in the centre of the chest that lasts for more than a few minutes
- Pain or discomfort that spreads to the shoulders, neck, arms, or jaw
- Chest pain that gets worse
- Chest pain that doesn't get better with rest or by taking nitro-glycerine

Chest pain that happens along with any of these symptoms:

- Sweating, cool, clammy skin, or paleness
- Shortness of breath
- Nausea or vomiting
- Dizziness or fainting
- Unexplained weakness or fatigue
- Rapid or irregular pulse

Although chest pain is the key warning sign of a heart attack, it may be confused with other conditions. These include indigestion, pleurisy, pneumonia, tenderness of the cartilage that attaches the front of the ribs to the breastbone, and heartburn. Always see your healthcare provider for a diagnosis.

Responding to heart attack warning signs:

If you or someone you know has any of the above warning signs, act right away. Call 911, or your local emergency number.

Treatment for a heart attack:

The goal of treatment for a heart attack is to relieve pain, preserve the heart muscle function, and prevent death. Treatment in the emergency department may include:

- Intravenous therapy, such as nitro-glycerine and morphine
- Continuous monitoring of the heart and vital signs
- Oxygen therapy to improve oxygenation to the damaged heart muscle
- Pain medicine to decrease pain. This, in turn, decreases the workload of the heart. The oxygen demand of the heart decreases.
- Cardiac medicine such as beta-blockers to promote blood flow to the heart, improve the blood supply, prevent arrhythmias, and decrease heart rate and blood pressure
- Fibrinolytic therapy. This is the intravenous infusion of a medicine that dissolves the blood clot, restoring blood flow.
- Antithrombin or antiplatelet therapy with aspirin or clopidogrel. This is used to prevent further blood clotting.
- Antihyperlipidemics: These medicines lower lipids (fats) in the blood, particularly low-density lipid (LDL) cholesterol. Statins are a group of antihyperlipidemic medicines.They include simvastatin, atorvastatin, and pravastatin. Bile acid sequestrants—colesevelam, cholestyramine, and colestipol—and nicotinic acid (niacin) are two other types of medicines that may be used to lower cholesterol levels.

You may need other procedures to restore blood flow to the heart. Those procedures are described below.

Coronary angioplasty:

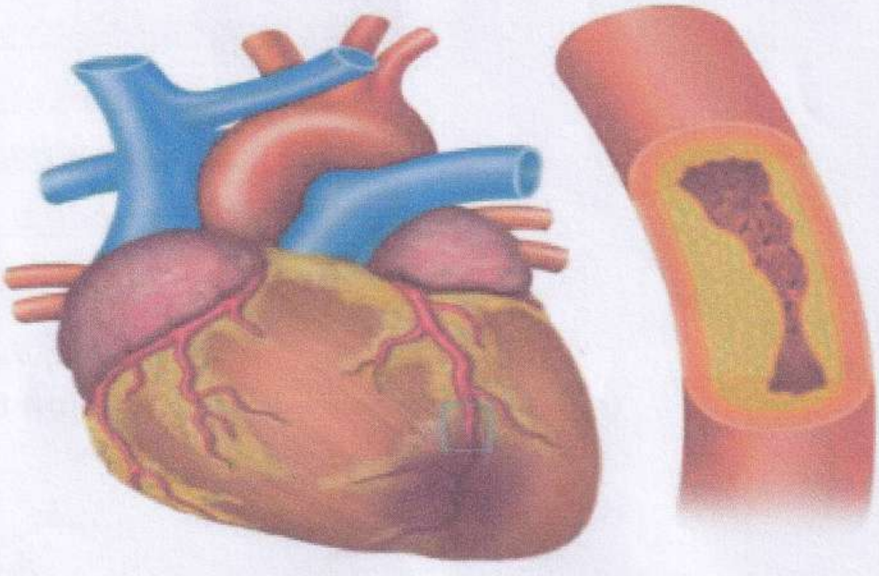
With this procedure, a balloon is used to create a bigger opening in the vessel to increase blood flow. This is often followed by inserting a stent into the coronary artery to help keep the vessel open. Although angioplasty is done in other blood vessels elsewhere in the body, percutaneous coronary intervention (PCI) refers to angioplasty in the coronary arteries. This lets more blood flow into the heart. PCI is also called percutaneous transluminal coronary angioplasty (PTCA). There are several types of PTCA procedures:

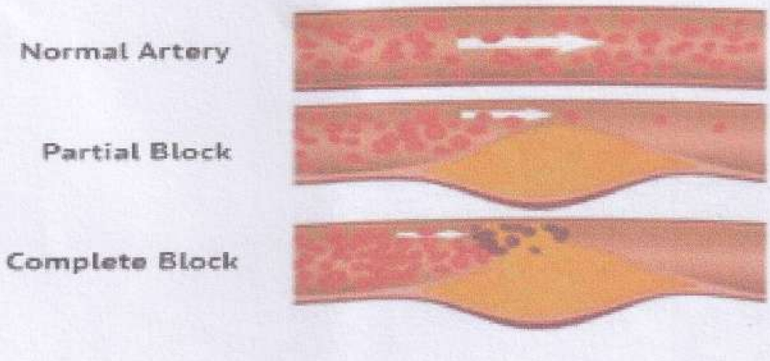
- **Balloon angioplasty:** A small balloon is inflated inside the blocked artery to open the blocked area.
- **Coronary artery stent:** A tiny coil is expanded inside the blocked artery to open the blocked area. The stent is left in place to keep the artery open.

- **Atherectomy:** The blocked area inside the artery is cut away by a tiny device on the end of a catheter.
- **Laser angioplasty:** A laser used to "vaporize" the blockage in the artery.

Coronary artery bypass:

This surgery is most commonly referred to as simply bypass surgery or CABG (pronounced "cabbage"). It is often done in people who have chest pain (angina) and coronary artery disease. Coronary artery disease is when plaque has built up in the arteries. During the surgery, the surgeon makes a bypass by grafting a piece of a vein above and below the blocked area of a coronary artery. This lets blood flow around the blockage. The surgeon usually takes veins from a leg, but he or she may also use arteries from the chest or an arm. Sometimes, you may need more than one bypass surgery to restore blood flow to all areas of the heart.





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