Notes on Circulatory System

BODY FLUIDS

All the functions in our body that needs transport(like, transportation of digested food) are performed by two circulating fluids – **blood and lymph**. Besides them, there is another fluid present in our body which is known as **tissue fluid** (occupies spaces between cells and organs).

In our body bloods always flows through the blood vessels,i.e., blood flows in our body in a closed manner and such a type of circulation is called **closed vascular system**. In some animals, such as insects, blood flows through open spaces,i.e., blood flows from their heart to their tissues directly without vessels which forms the **open blood circulatory system.**

There are few fluids in our body which do not circulate like **synovial fluid** which is present in between skeletal joints.

The Blood

It is the **principal circulatory fluid** in our body. Blood always remains in motion from the heart to the arteries and back through the veins.

It is bright red in colour when **taken from an artery** and dark red in colour when **taken from a vein**. It **tastes saltish** and it is also **slightly alkaline** with a pH of 7.3-7.45. An average adult human contains 5 to 6 litres of blood by volume in his body.

Blood performs various **functions** like –

1. **Transportation of digested food** from the alimentary canal to the tissues. These substances are simple sugars like glucose, amino acids, vitamins, minerals
2. **Transport of oxygen** from lungs to the tissues at different parts of the body.
3. **Transport of carbon dioxide** from the tissues to the lungs.
4. **Distribution of hormones** secreted by special glands (endocrine glands) directly into blood.
5. **Blood forms a clot** wherever there is a cut in a blood vessel in order to ***prevent*** – **further loss of blood** and **entry of disease causing germs.**

Composition of Blood

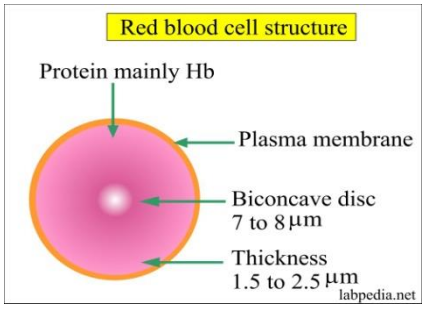
The blood consists of –

i. ***Plasma*** : it is the **fluid part of blood which is light yellow in colour and alkaline in nature**. Plasma mainly consists of –
   1. ***Water*** – 90-92%
   2. ***Proteins*** – 7-8%
   3. ***Inorganic salts*** like **sodium chloride** and **sodium bicarbonate** – 1%
   4. ***Other substances*** like **glucose, amino acids, fibrinogen, urea** are found in traces.

   Plasma constitutes 55-60% of blood. The plasma from which fibrinogen (a protein) has been removed is called ***serum***.

ii. ***Cellular elements*** : the formed or cellular elements of blood are of three types – **Red blood cells (erythrocytes), White blood cells (leukocytes)** , **Blood platelets (thrombocytes).** They constitute 40-45 % of blood.

   Red Blood Cells – these are **minute disc-like biconcave structures**, flat in the centre and thick and rounded at the periphery. They have a size of about 7 microns. The **small size and concavities on either side provide a large surface area which makes them very efficient in absorbing oxygen** , it also **enables them to travel in fine capillaries where they have to travel in a single file.** An *adult human has about 4.5-5 million RBCs per mm^3 of blood.*



   RBCs have a colourless spongy body or stroma which contains a respiratory pigment called *haemoglobin (Hb)*. It is formed of an iron-containing part (haemin) and a protein (globin). Haemoglobin being red in colour gives a reddish colour to blood too.

   Haemoglobin can readily combine with oxygen to form *oxyhaemoglobin*, an unstable compound which readily gives oxygen to needy tissues. It can

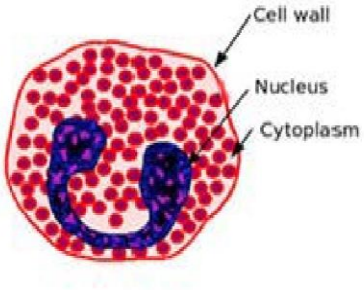
also **carry a very small amount of carbon dioxide in the form of *carbaminohaemoglobin*.**

In ***adults***, RBCs are produced in the bone marrow of long bones, especially in the ribs, breast bone and ilium of hip girdle. Whereas, in an ***embryo*** it is produced in the liver and spleen.

When new red blood cells are produced they do have nuclei but as they mature the nuclei is lost. **Loss of nuclei increases space in the cell**. Despite not having nuclei, it performs all the functions of a cell. Mammalian red blood cells also ***lack*** **mitochondria(so that all the oxygen is transported**) and **endoplasmic reticulum (so that flexibility of cell increases**)

The ***average life on an RBC is about 120 days*** and the **old and weak cells are destroyed in spleen, liver and bone marrow**; their iron part is retained in the liver and the rest is excreted as bile pigment

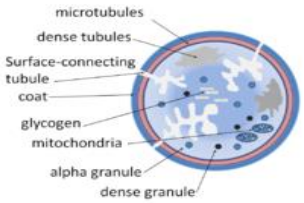
White Blood Cells- White blood cells or leukocytes ***differ*** from red blood cells in having a nucleus and not containing haemoglobin. Their ***number is much less, usually about 4000-8000 per mm^3 of blood***. WBCs are amoeboid and can produce pseudopodia with which they can squeeze through the walls of capillaries into the tissues, a process named ***diapedesis***. A typical WBC looks like this.



Leukocytes have the ability to engulf particle-like solids, especially bacteria, this process is known as ***phagocytosis***. Leukocytes also produce antibodies which kill or neutralize the germs, or the poison from them. Thus, **we can say the main function of WBCs in our body is to provide immunity and to keep our body free from pathogens.**

WBC are **produced in the bone marrow, lymph nodes and sometimes even in liver and the spleen**. Their average life is about 2 weeks. It is destroyed the same way as RBCs.

Blood Platelets **–** blood platelets are **minute oval or round structures**, **non-nucleated**, floating in the blood. These are about 200,000 – 400,000 per mm^3 of blood in an adult. A typical platelet looks like



Platelets are derived from some giant cells called **megkaryocytes** in the red bone marrow. These are ***budded off from megakaryocytes in a manner that each one is completely surrounded with membrane.***

Their life span is about 3-5 days and are **destroyed mainly in the spleen** (a lymphatic organ located in abdomen).

They are very important in clotting of blood because at the site of injury , **the platelets disintegrate to release a chemical substance thrombokinase which initiates the process of clotting of blood.** In a **disease** like ***dengue fever***, number of platelets get reduced to as low as 25-30 thousands per mm^3 of blood.

Tissue Fluid

The blood flowing through capillaries of the tissue **leaks out as some plasma and leukocytes** through their walls. This fluid bathes the cells and is called the **tissue fluid** or the **intercellular fluid**. It is **from this fluid that the cells absorb oxygen and other required substances, and in turn, give out carbon dioxdie and other wastes back to it.**

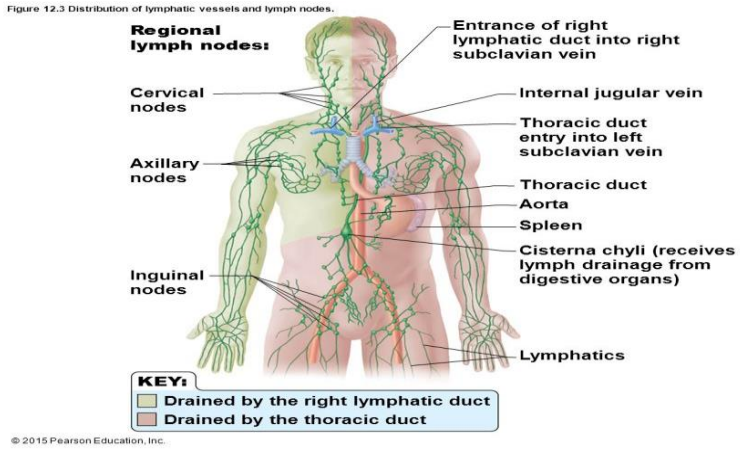
Lymph and Lymphatic system

Some of the **tissue fluid** may be reabsorbed into the blood vessels, but most of it enters another set of minute channels named lymph vessels where it is called ***lymph***.

The lymph flows in the lymph vessels due to contraction of the surrounding muscles. This again is a benefit of physical exercise. The lymph vessels on the way drain lymph into **Lymph Nodes** from where fresh lymph channels arise and **ultimately pour the lymph into the major anterior veins close to their entry into a heart chamber called**

right auricle, and is again in circulation. **Lymphatic system acts as an alternate/parallel circulatory system**

The major lymph vessels are shown below



Composition of Lymph

- ***Cellular part*** – **only leukocytes (WBC)** , no blood platelet or RBCs are present
- ***Non – cellular part*** – **water (94%)** , **solids like carbohydrate, enzymes, antibodies (6%)**

Functions of lymph

- **Nutritive** : supplies nutrition and oxygen to those parts where blood cannot reach
- **Drainage** : it drains away excess tissue fluid and metabolites and return protein to the blood from tissue spaces
- **Absorption** : fats from the intestine are absorbed through lymphatics (***lacteals located in the intestinal villi***)
- **Defence** : leukocytes present in the lymph function to defend the body. the **lymphatics also remove bacteria in the tissues**. The lymph nodes tend to localize the infection and prevents it from spreading to the body as a whole.

  The **tonsils** on the side of neck are also lymph glands. **Spleen is another lymph organ**

BLOOD TRANFUSION AND BLOOD GROUPS

Sometimes it becomes necessary to inject blood into the body of patients undergoing surgical operation from a different individual. This is called ***Blood Transfusion***. Blood taken from a healthy person (**donor**) is introduced through one of the patient's vein. But, for doing so, it is necessary that the kind or the type of blood

to be transfused should match (or be compatible) with the type of blood of the receiving person (**recipient**)

There are several systems of blood grouping in order to know what kind of blood we carry. Two of the most important grouping systems are – **ABO system** and **Rh system**

Care should also be taken that the donor does not have an infection and the instruments through which the blood would be collected are sterilised

ABO system

Acoording to the ABO system, the human blood can be classified into **four** types – A, B , AB and O. All these **types have some antigen and antibody specific to them** like, blood group A has A antigen and anti-B antibody. **To prevent the antigen antibody interaction or sticking of the RBCs(might lead to death of the recipient), the blood group is very cautiously chosen.**

transfusion of one's own type of blood can be like : A → A , AB → AB , B→B

besides this, other possible transfusions are there too, like : **blood group O** can donate blood to blood groups A, B, AB and hence it is called **universal donor**.

Blood group AB can receive blood from blood groups A, B, O and hence it is called **universal recipient.**

Summary of compatibility is given below

Blood group of donor	**Blood group of recipient**			
	A	B	AB (universal recipient)	O
A	Possible	Not possible	Possible	Not possible
B	Not possible	Possible	Possible	Not possible
AB	Not possible	Not Possible	Possible	Not possible
O (universal donor)	Possible	Possible	Possible	Possible

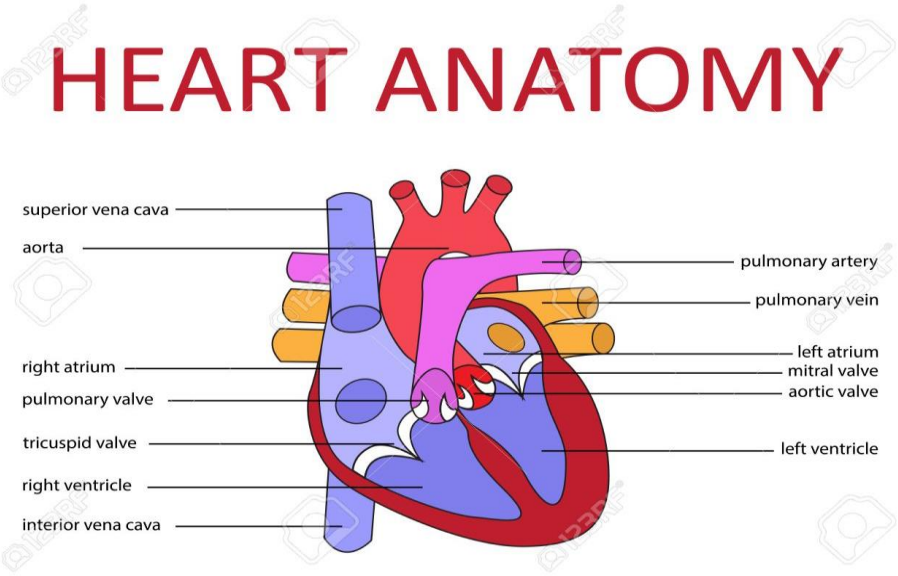
Rh system – Rh system deals with grouping blood of people on the basis of presence or absence of Rh factor(Rh stands for rhesus monkey). E.g.- ***blood group B having Rh factor will be tagged as B + and if the blood does not have the factor it will be tagged as B –***

THE CIRCULATORY SYSTEM

The human circulatory system (**of blood and not lymph**) consists of heart, arteries, veins and capillaries.

The Heart

The heart is located right in the centre between the two lungs and above the diaphragm. The narrow end of the roughly triangular heart is pointed to the left side. The heart in adult humans is about the size of our closed fist – 12 cm in length and 9 cm in width. It is protected by a double walled membranous covering called ***pericardium*** and it also contains a lubricating fluid which reduces the friction during heart beat and protect it from mechanical injuries, this fluid is known as ***pericardial fluid.***



Chambers of the heart – the heart consists of **four chambers** – two upper atria (singular – atrium) and two lower ventricles.

The **atria (**also called **auricles)** have thinner walls because their major function is to receive blood from the body and pump it into the very next ventricle.

The **ventricles** have thick muscular walls because they have to pump blood to long distances. The **right ventricle pumps blood only up to the lungs for oxygenation**. But the **left ventricle pumps it up to farthest points in the body, such as, up to the toes in the feet or up to the brain against gravity, and so its walls are thicker.**

Blood vessels entering the heart - the **right Atrium** receives two large vessels :

i. **anterior vena cava** (also called **superior vena cava**) brings deoxygenated blood from the upper part of the body including head, chest and arms.

ii. **Posterior** (or inferior) **vena cava** brings blood from the posterior or the lower region of the body including abdomen and legs.

The **left atrium** receives 4 pulmonary veins (two from each lung) which ***brings oxygenated blood.***

Bloods vessels leaving the heart – arising from the ventricles are two large blood vessels :

1. The ***pulmonary artery*** arises from the right ventricle and carries deoxygenated blood to the lungs **for oxygenation.**
2. The ***aorta*** arises from the left ventricle and **carries oxygenated blood** to supply to all parts of the body.

Two **coronary arteries** arising from the base of aorta brings blood to the heart muscles. The **cardiac veins** carry blood **from heart walls** and pours it into the right auricle. **Blockage in any of the coronary artery or in any one or more branches leads to "deandening" of the corresponding area** of the heart muscles leading to "**myocardial infarction**" or a heart attack in popular language.

Valves present in different parts – valves regulate the flow of blood in one direction, there are four valves in the heart as follows :

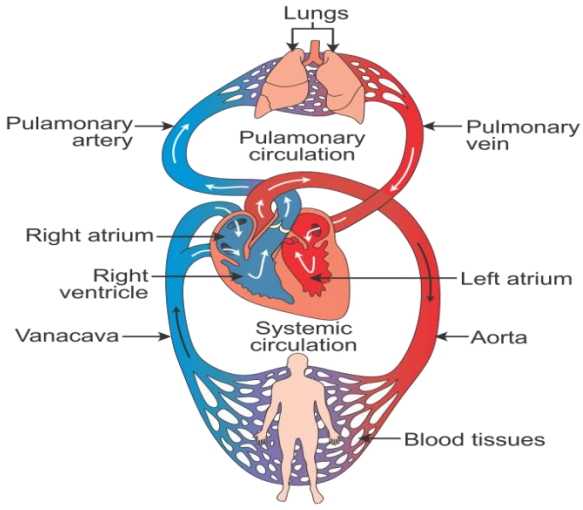
a. **Right atrio-ventricular valve** is located at the aperture between right atrium and right ventricles. It has three thin triangular leaf-like flaps (cusps) and is therefore also called **tricuspid valve**. The apices of the flaps are held in position by **tendinous cords** (***chordae tendinae***) arising from the muscular projections of the ventricle wall known as **papillary muscles**.
b. **Left atrio-ventricular valve** is located in the similar way(between left atrium and left auricle) on the left side of the heart. It has two cusps, and is, therefore, called **bicuspid (or mitral) valve.**
c. **Pulmonary semilunar valves** are located at the opening of the right ventricles into the pulmonary artery. These are **pocket-shaped and three in number**
d. **Aortic semilunar valves** are located at the point of origin of aorta from the left ventricle. These are also **three in number and pocket shaped**.

Circulation of the blood in heart

- It begins with the contraction of two atria(also called **atrial systole**). The ventricles at this time are relaxing (or dilating) and are empty. Therefore, **the blood from atria passes into the ventricles and fills them.**

- Next, the ventricles contract (also called **ventricular systole**) and the atria relax (**atrial diastole**). The blood from the ventricles under pressure tend to return to the atria, but the **flaps of the two cuspid valves get tightened and puff up, thus closing the passage and preventing the return of blood.**
- The **chordae tendinae** hold the flaps of valve in position and prevent their overturning into the atria.
- The only course left for the ventricular blood is to **enter the pulmonary artery from the right ventricle** and the **aorta from the left ventricle**.
- The mouths of the pocket-like valves at the bases of the two blood vessels face away from the ventricles. Therefore, **the blood leaving the ventricles presses the valves flat and get a clear passage in between**
- When the ventricle dilate(**ventricular diastole**), the blood from the pulmonary artery and the aorta tends to return, the **blood fills the pockets of the valves and closes the passage.**

- Next, the **pulmonary artery** arising from the right ventricle soon divides into two branches that enter the respective lungs. **Pulmonary veins** collect the oxygenated blood from the lungs and carry it back to the left auricle of the heart. This is known as **pulmonary circulation**.
- The **aorta** that arises from the left ventricle arches back and continues behind. The **aorta divides into numerous arteries** so that they can carry oxygenated blood to various body parts and their tissue. From there the blood is collected by veins and brought back to heart. This is called **systemic circulation**
- It is evident that the blood flows twice in the heart before it completes one full round. This type of blood circulation is called **double circulation**.



Heart Beat – the whole sequence of heart beat is called **cardiac cycle**. Each heart beat consists of **two** main steps :

contraction of atria (**systole**) and its relaxation (**diastole**) followed by contraction of ventricles. At the end of ventricular systole, they start relaxing (**ventricular diastole**). Meanwhile the atria have also been relaxing and **for a short period, both the atria and the ventricles are in a relaxed state** (***joint diastole***).

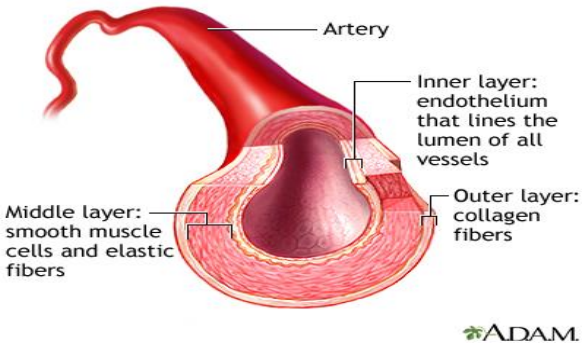
We perceive the heart beat as the heart sounds – **LUBB** and **DUP**. each ***full beat of human heart lasts for about 0.85 seconds.***

The Blood Vessels

The **blood vessels are branched tubes extending from the heart to all parts of the body**. they are of **three** kinds – ***arteries, veins and capillaries.***

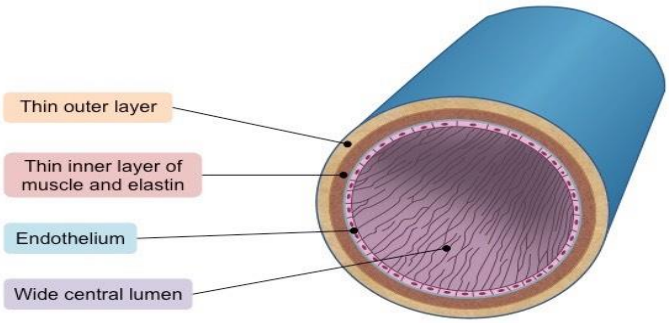
Artery – it is a **vessel which carries blood away from the heart towards any organ**. It carries oxygenated blood. It has

- Thick **muscular and elastic walls** in order to bear the pressure of the blood coming from the ventricles.
- A **narrow lumen** (the central bore)
- Have **no valves** in their inner lining
- The ***blood flows in spurts*** which correspond to the ventricular contractions of the heart and they **do not collapse when empty**.
- It can **constrict or dilate** to control blood flow.
- The smallest or the final branch of artery is called **arteriole**
- They are placed generally deeper in the body.



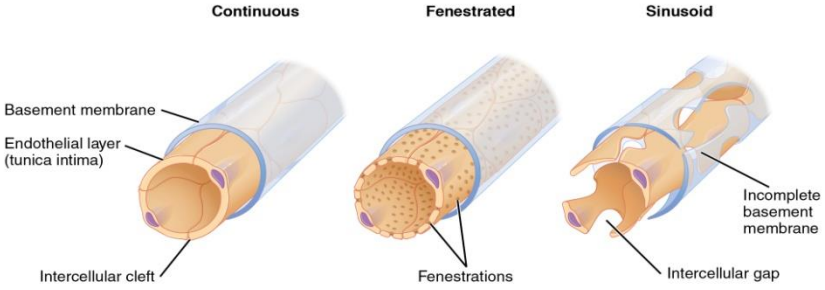
Veins – it is a **vessel which conveys the blood away from an organ towards the heart**. It carries deoxygenated and carbon dioxide laden blood. Its characteristic are :

- **Thin muscular and non-elastic walls** because blood doesn't enter into them under pressure
- A **wider lumen**
- The blood **flows in it uniformly** and they might collapse when empty
- It contains **thin pocket-shaped valves** whose openings face in the direction of heart; these ***valves prevent the backflow of blood***.
- Smallest veins arise from **venules**.
- They are **more superficially placed** (nearer to the skin).
- It **cannot constrict** like arteries.



Capillaries – the arterioles from the artery breaks up into capillaries. Capillaries are very narrow tube (about 8 micrometres in diameter)

- Its **walls** consists of only one layer of cells (cells of endothelium)
- It has **no muscles**. There are huge amount of capillaries in our body
- **Capillaries can constrict and dilate which controls the blood flow**.
- Capillaries **gradually reunite and increase in size like arteries and veins**.



Functions of capillaries :

i. To allow **outward diffusion of oxygen** into the intercellular fluid and from there into the tissue cells.
ii. To allow **inward diffusion of carbon dioxide** from the tissue fluid
iii. To allow **inward and outward diffusion** of substances like glucose, amnio acids, hormones.
iv. To allow **leukocytes to squeeze out through the capillary walls**.

A unique thing is showed by the veins starting from stomach and intestines. **They do not directly convey the blood to the posterior vena cava**. Instead they first enter the liver as a combined **hepatic portal vein**. The ***liver monitors the substances before passing the blood into the body***.

- Excess of glucose is retained by the liver as glycogen and the **excess amino acids are broken down by the liver.**
- Harmful chemicals are detoxified and **bacteria are destroyed.**
- **Excess minerals, water and vitamins are stored in liver**.
- A **hepatic vein** is then formed which joins the posterior vena cava.

Blood Pressure

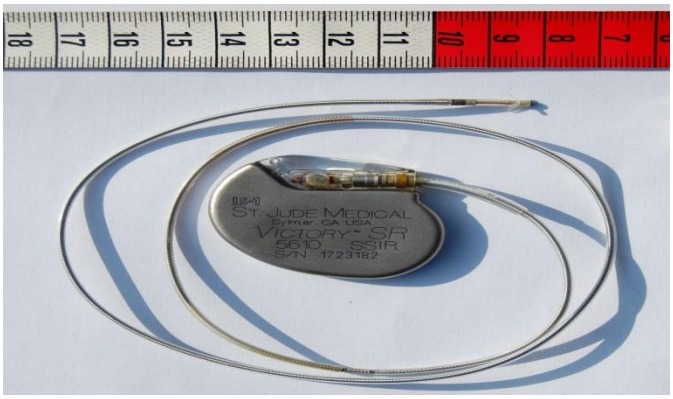
Blood pressure is the pressure which the blood flowing through the arteries exerts on their walls. There are two limits of this pressure –

- ✓ The **upper limit** (***systolic pressure***) which is at the time when fresh blood is pushing through the artery as a result of the ventricular contraction of heart
- ✓ The **lower limit** (***diastolic pressure***) is the one recorded when the wave has passed over , or when ventricular relaxation begins

The normal blood pressure for the adult is **100-140 mm (systolic)** and **60-80 mm (diastolic).**

Pacemaker

A **pacemaker is a small device that is placed in the chest or abdomen to help control abnormal heart rhythms**. The device uses electrical pulses/signals to prompt the heart to beat at a normal rate.



Pacemakers are **used to treat arrhythmias**, which are problems with the rate or rhythm of the heartbeat. ***During an arrhythmia, the heart can beat too fast , too slow, or with an irregular rhythm***. Due to this, the heart may not be able to pump

blood to the body. This **can cause symptoms such as tiredness, shortness of breath, or fainting**. A pacemaker can relieve some arrhythmia symptoms , such as fatigue and fainting and it can also fix the abnormal heart rhythms.

Conditions relating to heart

1. **Cardiac arrest** – cardiac arrest indicates complete stoppage of the heart beat , i.e., heart stops beating. Which also indicates that blood is not supplied to other parts of body and neither to heart itself.
2. **Palpitations** – it is the beating of heart too hard or too fast or even skipping of a beat. This **often happens due to stress or anxiety**. It can be frightening, but not serious or harmful and often this condition goes away on its own
3. **Hypertension** – this is the condition that occurs in a person when blood flows through the blood vessels with a force higher than normal. This **condition is also called high blood pressure**. It might strain the heart, damage blood vessels and increase the risk of heart attack or stroke.