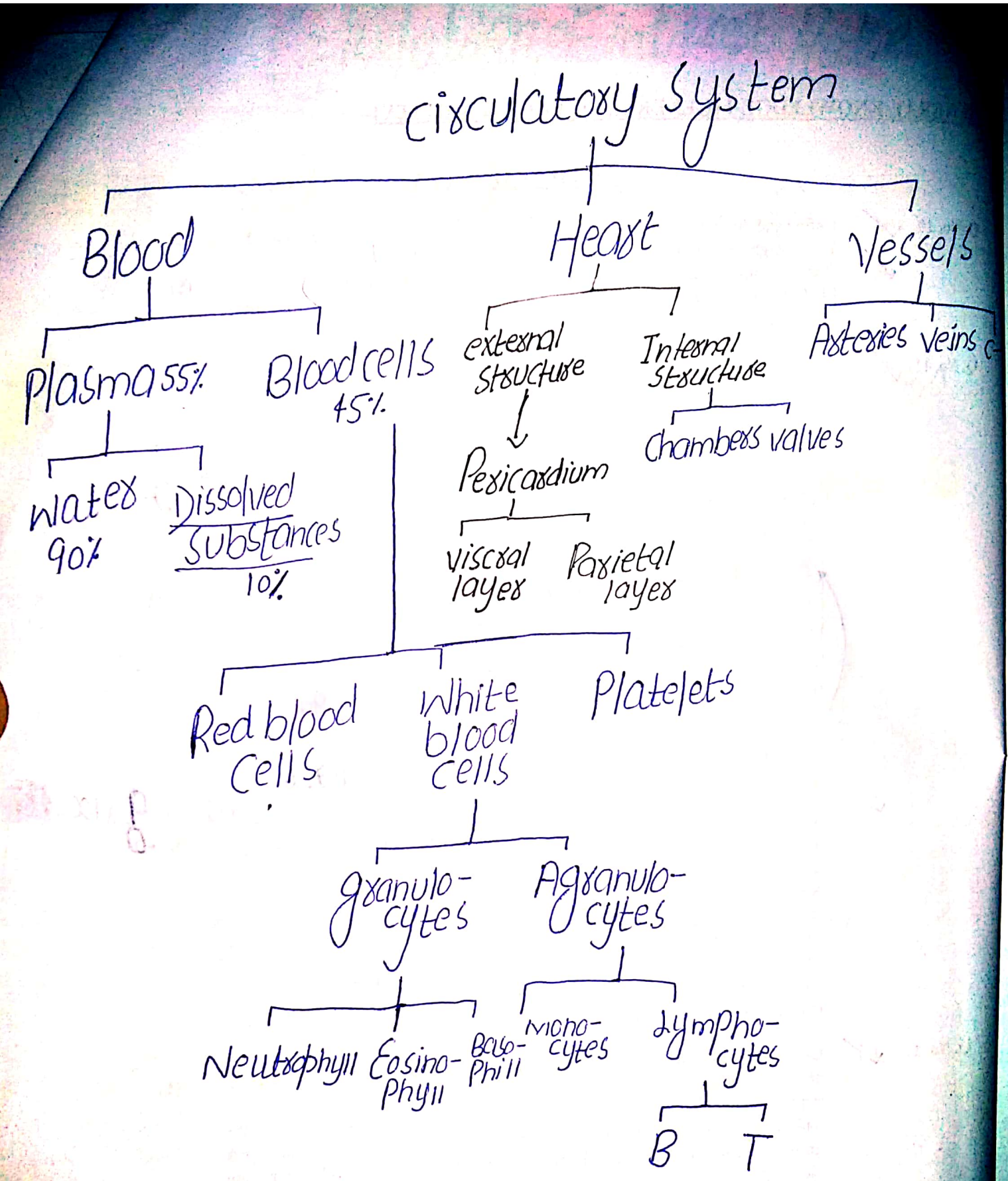


CIRCULATORY SYSTEM

The circulatory system consists of three independent systems that work together: the heart (cardiovascular), lungs (pulmonary), and arteries, veins, coronary and portal vessels (systemic).

The system is responsible for the flow of blood, nutrients, oxygen and other gases, and as well as hormones to and from cells

Components of circulatory system

The circulatory system of humans have the ~~same~~ 3 basic components

(A) Circulating fluid - the blood.

(B) The pumping organ - the heart.

(C) The blood vessels, arteries, capillaries and veins

(A) The circulatory fluid-the blood

The blood is the medium in which dissolved nutrients, gases, hormones, and wastes are transported through the body. It is made up of two main components, (i) plasma and (ii) cells or cell - like bodies (white blood cells, red blood cells, platelets). The weight of the blood in our body is about 1/12th of our body.

(i) PLASMA : It has been estimated that in a normal person plasma constitutes about 55% by volume of the blood, and cells or cell-like bodies about 45% by volume of the blood.

Plasma is primarily water in which proteins, salts, nutrients and wastes are dissolved. Water constitutes about 90% of plasma, 10% are dissolved substances. Most of the dissolved substances are maintained at a constant or nearly constant level, but others occur in varying concentrations.

The substances dissolved or present in plasma vary in their concentrations, with the condition of the organism and with the portion of the system under examination. The solutes can be divided into six categories:

Inorganic salts (ions) - Plasma proteins - Organic nutrients - Nitrogenous waste products - Special products being transported and gases which are dissolved.

1. **Inorganic ions or mineral ions.** Together the inorganic ions and salts make up 0.9 per cent of the plasma, of humans, by weight; more than two thirds of this amount is sodium

chloride the ordinary table salt. Even if the total concentration of dissolved substances remains the same, shifts

in the concentration of particular ion can create serious disturbances. The normal pH of human blood is 7.4; and it is maintained between narrow limits, because the change in pH would afect the chemical reactions of the body.

7-9%

2. **The plasma proteins** constitute 7-9 percent by weight of the plasma. Most of these proteins are synthesized in the liver. Some of the globulins, called immunoglobulins or antibodies, are produced in response to antigens, by lymphocytes; and then are passed to plasma, and lymph.

a b

The proteins like prothrombin acts as a catalyst in blood clotting process. Fibrinogen takes part in the blood clotting process. Immunoglobulins play important role in body's defenses against disease.

c

3. **Organic nutrients** in the blood include, glucose, fats, phospholipids, amino acids and lactic acids. Some of them enter the blood from the intestine (absorption). Lactic acid is produced in muscles as a result of glycolysis, and is transported by blood to liver. Cholesterol is an important constituent, it is metabolized to some extent, but also serves as precursor of steroid hormones.

Urea, Uric acid

4. Plasma also contains **nitrogenous waste products** formed as a result of cellular metabolism. These products are carried from the liver where they are produced, to the organs from where they are removed i.e. kidneys. Urea and small amounts of uric acid are present in plasma.

5. All the **hormones** in the body are carried by blood - so they are present in the plasma.

6. The **gases** such as CO2, O2 are present in the plasma of the blood.

(ii) BLOOD CELLS AND CELL LIKE BODIES : — Erythrocytes, leucocytes, platelets

These include red blood cells, (Erythrocytes), white blood cells (leucocytes) and platelets.

(a) Red blood cells (Erythrocytes) : 95% Haemoglobin, 5%

These are most numerous of the cells in the blood. A cubic millimeter contains 5-1/2 million of them in males, and 4-1/2 million in females. These cells, when formed, have nucleus, but it is lost before they enter the circulatory fluid or blood. 95% of the cytoplasm of red blood cells is the red pigment, called haemoglobin the remaining 5% consists of enzymes, salts and other proteins. The red cells once mature, do not divide.

formation

Red blood cells are formed principally in the red bone marrow of short bones, such as the sternum, ribs and vertebrae .In the embryonic life, they are formed in the liver and spleen. The average life span of red blood cell is about four months after which it breaks down and disintegrates in the liver and spleen - partly by phagocytes ~~by phagocytosis~~.

4 month
120 days

Monocyles ⇒ Phagocytic functions

(b) White blood cells (Leucocytes): granulocytes (red bone marrow) (NEB) 3
agranulocytes (lymphoid tissues) (M, L

These blood cells are colourless, as they do not contain pigments. One cubic millimetre of blood contains 7000 to 8000 of them. They are much larger than the red blood cells. There are at least five diferent types which can be distinguished on the basis of the shape of the nucleus and density of granules in the cytoplasm They can be grouped into two main types, granulocytes and agranulocytes. Granulocytes, include neutrophils, eosinophils and basophils. They are formed in the red bone marrow

Agranulocytes are formed in lymphoid tissue, such as those of the lymph nodes, spleen, tonsils, adenoids and the thymus. Agranulocytes include monocytes and lymphocytes (B and T). Monocytes stay from 10- 20 hours in the blood, then enter tissues and become tissue macrophages, performing phagocytic function, Lymphocytes have life spans of months or even years; but this depends on the body's need for these cells

Functions

Leucocytes protect the body against foreign invaders, and use circulatory system to travel to the site of invasion. Monocytes and neutrophils travel through capillaries and reach the site of wound where bacteria have gained entry. Macrophages and neutrophils feed on bacterial invaders or other foreign cells, including cancer cells (Fig. 14.21). They typically die in the process, and their dead bodies accumulate and contribute to the white substance called pus, seen at infection sites.

axine
hine

Basophils produce heparin - a substance that inhibits blood clotting. These also produce chemicals, such as histamine, that participate in allergic reactions and in responses to tissue damage and microbial invasion. Lymphocytes help to provide immunity against the disease.

(c) Platelets : Fibrinogen (soluble) ⇒ Fibrin (insoluble)

These are not cells, but are fragments of large cells called megakaryoctyes ~~(Fig. 14.22).~~ There is no nucleus in them. There is no pigment in them. Platelets help in conversion of fibrinogen, a soluble plasma protein, into insoluble form, fibrin. The fibrin threads enmash red blood cells and other platelets in the area of damaged tissue, ultimately forming a blood clot. The clot serves as a temporary seal to prevent bleeding until the damaged tissue can be repaired

HUMAN HEART

The heart is a hollow muscular organ which beats over 100,000 (Lakh) times a day to pump blood around the body's 60,000 miles of blood vessels. The heart pumps around 5.7 litres of blood in a day throughout the body.

- **The heart is situated at the centre of the chest and points slightly towards the left.**

- On average, the heart beats about 100,000 times a day, i.e., around 3 billion beats in a lifetime.
- The average male heart weights around 280 to 340 grams (10 to 12 ounces). In females, it weights around 230 to 280 grams (8 to 10 ounces).
- An adult heart beats about 60 to 80 times per minute, and newborn babies heart beats faster than an adult which is about 70 to 190 beats per minute

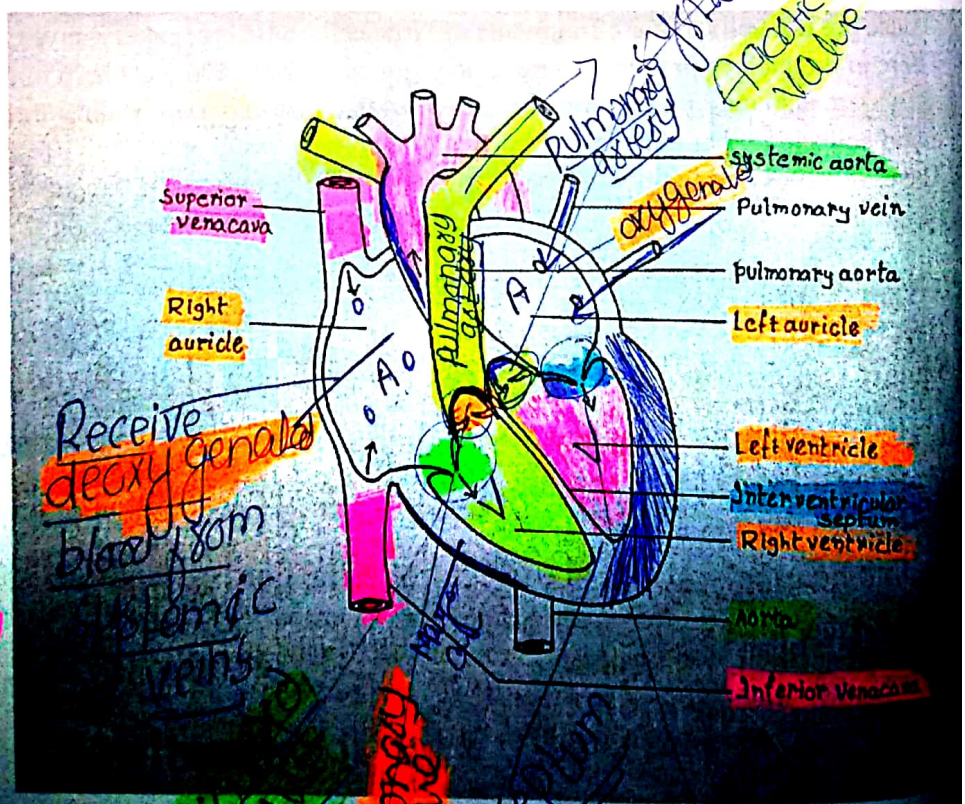
External Structure of Heart

One of the very first structures which can be observed when the external structure of the heart is viewed is the pericardium.

Pericardium

The human heart is situated to the left of the chest and is enclosed within a fluid-filled cavity described as the pericardial cavity. The walls and lining of the pericardial cavity are made up of a membrane known as the pericardium.

The pericardium is a fibre membrane found as an external covering around the heart. It protects the heart by producing a serous fluid, which serves to lubricate the heart and prevent friction between the surrounding organs. Apart from the lubrication, the pericardium also helps by holding the heart in its position and by maintaining a hollow space for



the heart to expand itself when it is full. The pericardium has two exclusive layers—

- **Visceral Layer:** It directly covers the outside of the heart.
- **Parietal Layer:** It forms a sac around the outer region of the heart that contains the fluid in the pericardial cavity.

Structure of the Heart Wall

The heart wall is made up of 3 layers, namely:

- **Epicardium** – Epicardium is the outermost layer of the heart. It is composed of a thin-layered membrane that serves to lubricate and protect the outer section.
- **Myocardium** – This is a layer of muscle tissue, and it constitutes the middle layer wall of the heart. It contributes to the thickness and responsible for the pumping action.
- **Endocardium** – It is the innermost layer that lines the inner heart chambers and covers the heart valves. Furthermore, it prevents the blood from sticking to the inner walls, thereby preventing potentially fatal blood clots

INTERNAL STRUCTURE OF HEART

Chambers of the Heart

The internal cavity of the heart is divided into four chambers:

- Right atrium
- Right ventricle
- Left atrium
- Left ventricle

The two atria are thin-walled chambers that receive blood from the veins. The two ventricles are thick-walled chambers that forcefully pump blood out of the heart. Differences in thickness of the heart chamber walls are due to variations in the amount of myocardium present, which reflects the amount of force each chamber is required to generate.

The right atrium receives deoxygenated blood from systemic veins; the left atrium receives oxygenated blood from the pulmonary veins

Valves of the Heart

Valves are actually flaps (leaflets) that act as one-way inlets for blood coming into a ventricle and one-way outlets for blood leaving a

Semilunar valves / aortic valve
Pulmonary Valve

ventricle. Normal valves have 3 flaps (leaflets), except the mitral valve. It only has 2 flaps. The 4 heart valves are:

Inlet

- **Tricuspid valve.** This valve is located between the right atrium and th right ventricle.
- **Pulmonary valve.** The pulmonary valve is located between the right ventricle and the pulmonary artery.
- **Mitral valve.** This valve is located between the left atrium and the left ventricle. It has only 2 leaflets.

Bicuspid valve

- **Aortic valve.** The aortic valve is located between the left ventricle and the aorta.

How do the heart valves work?

As the heart muscle contracts and relaxes, the valves open and shut. This lets blood flow into the ventricles and atria at alternate times. Here is a step-by-step description of how the valves work normally in the left ventricle:

- When the left ventricle relaxes (empty), the aortic valve closes and the mitral valve opens. This lets blood flow from the left atrium into the left ventricle.
- The left atrium contracts. This lets even more blood to flow into the left ventricle.

Atrioventricular Valves / Bicuspid valves
Tricuspid valves

Semilunar Valves / Aortic Valves
Pulmonary Valves

Contraction
Relaxation → fill with blood
Filled

- When the left ventricle contracts, the mitral valve closes and the aortic valve opens. This is so blood flows into the aorta and out to the rest of the body.
- While the left ventricle is relaxing, the right ventricle also relaxes. This causes the pulmonary valve to close and the tricuspid valve to open. This lets blood flow into the right ventricle that was returned to the right atrium from the body.
- When the left ventricle contracts, the right ventricle also contracts. This causes the pulmonary valve to open and the tricuspid valve to close. Blood flows out from the right ventricle to the lungs before it is returned to the left atrium as fresh, oxygenated blood.

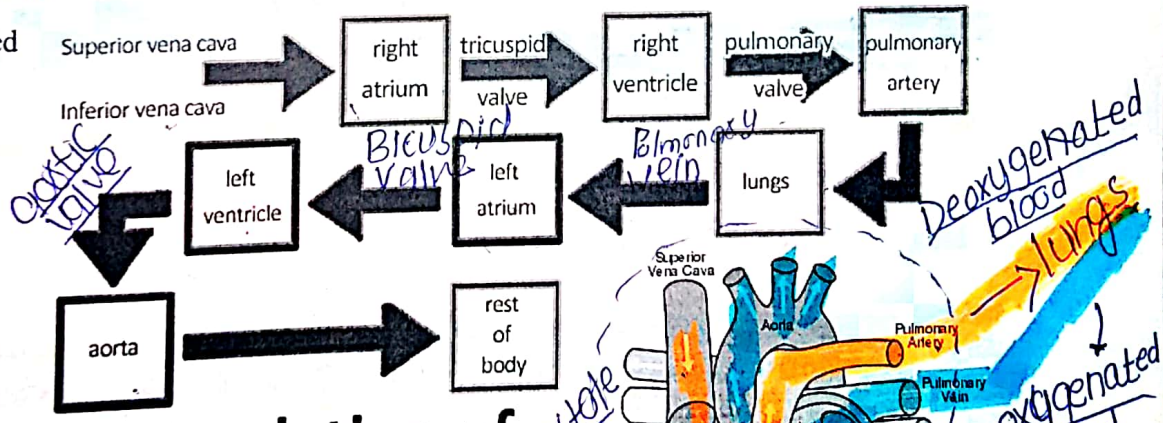
Types of Circulation

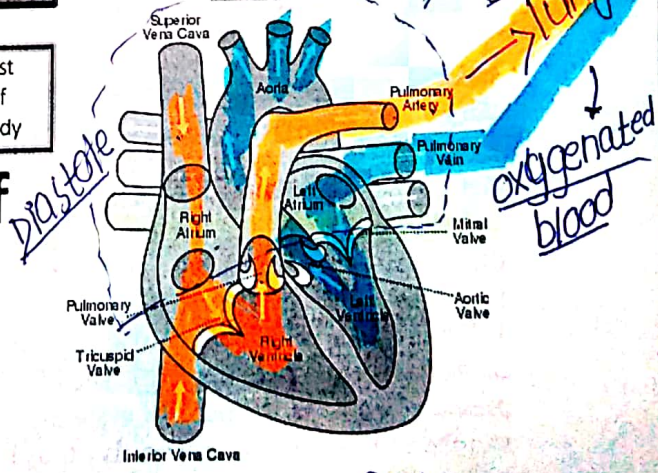
Pulmonary Circulation step1
systemic Circulation step2

- **Pulmonary circulation** is a portion of circulation responsible for **carrying deoxygenated blood away from the heart**, to the lungs and then brings oxygenated blood back to the heart.
- **Systemic circulation** is another portion of circulation where the **oxygenated blood is pumped from the heart to every organ** and tissue in the body, and then back again to the heart.

Now, the heart itself is a muscle and therefore, it needs a constant supply of oxygenated blood. This is where another type of circulation comes into play, the coronary circulation.

- **Coronary circulation** is an essential portion of the circulation, where oxygenated blood is supplied to the heart. This is

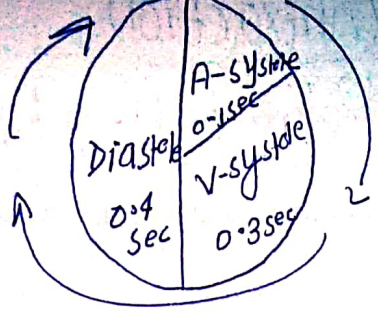




Circulation of Blood Through the Heart:

1 → Relaxation – LV
2 → Contraction → LA
3 → Contraction → LV

A → Relaxation → RV
→ Contraction → R



important as the heart is responsible for supplying blood throughout the body. Moreove organs like the brain need a steady flow of fresh, oxygenated blood to ensure functionality.

CARDIAC CYCLE, blood pressure and heart beat

0.4sec

Relaxation phase - diastole.

The deoxygenated blood enters right atrium through vena cava, and oxygenated blood enters l atrium through pulmonary veins. The walls of the atria and that of ventricles are relaxed. As th atria are filled with blood, they become distended and have more pressure than the ventricles. This relaxed period of heart chambers is called diastole.

0.1

Atria Contract - atrial systole

The muscles of atria simultaneously contract, when the atria are filled and distended with blood, this is called atrial systole. The blood passes through tricuspid and bicuspid valves, into the two ventricles which are relaxed.

0.3sec

Ventricles contract - ventricular systole

When the ventricles receive blood from atria, both ventricles contract simultaneously and the blood is pumped to pulmonary arteries and aorta. The tricuspid and bicuspid valves close, and 'lubb' sound is made. Ventricular systole ends, and ventricles relax at the same time semilunar valves at the base of pulmonary artery and aorta close simultaneously, and 'dubb' sound is mad (Lubb, dubb can be heard with the help of a stethoscope).

One complete heart beat consists of one systole and one diastole, and lasts for about 0.8 second In one's life, heart contracts about 2.5 billion times, without stopping.

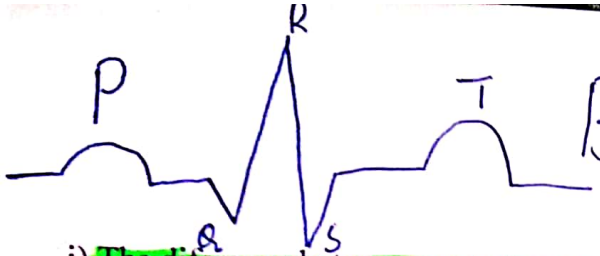
Blood Pressure and Rate of low of Blood

It is the measure of force with which blood pushes up against the walls of blood vessels. It is th force that keeps blood flowing from the heart to all the capillary networks in the body. This pressure is generated by the contraction of ventricles (ventricle systole) and is the highest in aorta, then gradually reduces in arteries. The walls of arteries are elastic and the low of blood stretches them, and it is felt as pulse. During diastole, the relaxation phase of the cardiac cycle, the heart is not exerting pressure on the blood in the arteries and pressure in them falls. The pressure reaches its high point during systole (systolic pressure which in normal individuals is 120 mm Hg) and its low point during diastole (diastolic pressure which in normal individuals ranges between 75-85 mm Hg). The blood pressure gradually declines .The decline of the blood pressure in successive parts of systemic circuit, is the result of friction between the flowing blood and the walls of the blood vessels - thus blood moves from a region of higher pressure towards region of lower pressure.

Several other changes occur along the route of blood low.

Aorta → Arteries → Capillaries → Veins → Vena Cava

Max P → Min P



BP = V. contract 120 mm HG systolic Pressure / V. Relax 80 mmHg diastolic Pressure

i) The difference between systolic and diastolic pressure continues to diminish until it disappears in the capillaries and veins.

ii) The rate of blood flow tends to fall as the blood moves through the branching arteries and arterioles, the rate is lowest in the capillaries, and increases again in the venules and veins. These changes in rate of blood flow result from changes in the total cross sectional area of the vessel system. The flow of blood in veins is maintained by the contraction of surrounding muscles and the action of semilunar valves which prevent back flow of blood. Muscular activity including breathing movements help normal low of blood in the body.

A. BLOOD VESSELS

Arteries

- Have thick walls of muscles.
- These help in carrying blood away from the heart. All arteries except pulmonary artery carry blood from the heart to ~~other parts~~ lungs.
- Pulmonary artery brings blood from the heart to the lungs and hence termed as Pulmonary artery as term pulmonary indicates its relation to lungs.
- These have internal lumens that are small passages for blood.
- These have relatively high pressure as the heart pushes the blood with the pumping.

Veins

- Its function is to carry blood from organs to the heart.
- It always carries deoxygenated blood except for the pulmonary vein which carries blood from the lungs to the heart.
- The walls are thin.
- The internal lumen is large.
- These have low blood pressure.

Capillaries

- Found in the lungs and muscles.
- These are very fine and thin
- These have low blood pressure
- Capillaries function in exchange of gases. Through capillaries, the oxygen [illegible] tissues while tissue also gives out the carbon dioxide into the