10. Circulatory system

Circulatory system refers to the heart, blood vessels (Arteries, veins and capillaries) and the blood. The heart is a pumping while blood vessels are for carrying the blood. Arteries carry blood away from heart and veins carry blood towards to heart and capillaries are microscopic blood vessels that connect the smallest arteries to the smallest veins.

Another term usually in use is the cardiovascular system which refers the passage through which the blood flow the heart and the blood vessels. The human circulatory system is called a **closed system**, because the blood is contained within either the heart or blood vessels at all time.

11.1 The main function of the circulatory system

a. Transport of nutrients, gases, hormones, blood cells, nitrogen wastes products to and from the cells in the body
b. Help to fight disease
c. They help stabilize body temperature and PH to maintain homeostasis

A. The blood

Blood is a liquid connective tissue that constitutes the transport media of the circulatory system our body contains 4 or 5 litters of blood. Function of the blood are:-

- Transporting nutrients and oxygen to the cell
- Transporting carbon dioxide and wastes away from the cells
- Transfers heat to the body surface and involve in temperature regulation
- Plays role in regulation of PH and electrolytes
- Prevents accidental loss of blood from the body by forming blood clot
- Plays a role in body defense against disease

i. Blood composition

Blood is composed of a liquid part (called blood plasma) and cellular part (called blood cells)

a) **Blood plasma**:- is approximately 55% of blood and made up of a straw colored fluid. Plasma is 90% water and 10% dissolved fats, sugar and proteins called plasma proteins. There are 3 types of proteins

- **Albumus**: is the most abundant plasma protein and help to regulate osmotic pressure
- **Globulms** (antibody): includes antibody that gives immunity
- **Fibrinogens**: responsible for blood clotting and prevent loss of blood from the body

b) **Blood cell:-** the cellular portion of the blood constitute 45% of the blood. It includes three types of the cells.

- **Erythrocytes or red blood cell**: RBC found in large numbers. One microliters of blood contains about 5 million RBCs. They are produced in the bone marrow and contain iron (Fe) containing protein called haemoglobin. Haemoglobin gives RBC the ability to carry oxygen and responsible for the red color of RBCs. Matured RBCs do not have nucleus and organelles and stay in circulation for about 120 days.
- **Leukocytes or white blood cells** (WBC): WBCs are produced by the red marrow, lymph nodes and spleen. They are larger than RBCS almost colorless, do not have haemoglobin they are numerous than RBCs. WBCs have nucleus and can live for many months or years. The main function of WBCs is to protect the body against invasion by foreign cells or disease causing organisms. There are five groups of WBCs. Neutrophils, Eosinophils, Basophils, lymphocytes and Monocytes.
- **Blood platelets:** are not cells but are tiny fragments of other cells that are formed in the bone marrow. Platelets plays important role in the blood clotting to prevent blood loss. They help clotting process releasing protein called clotting factors.

ii. Blood cell production

The process of blood cells production is called hematopoiesis or hemopoies (hemo, hemato= blood; poiesis = to make). This process occurs in the red bone marrow. The tissues that produce blood are called hemopoietic tissues.

Erythrocyte production: the process is called erythropoiesis. It generates about 2.5 million RBCs per second (20 ml/day). The sequence of cell transformations leading to an erythrocytes is

hemocytoblast = proerythroblast= erythroblast= normoblast= reticulocyte= erythrocyte. The overall process from hemocytoblast to reticulocytes takes 3 to 5 days.

iii. Blood types

Blood type is determined by the types of antigen presents on the surface of RBC. An antigen is a protein or carbohydrate that acts as a signal enabling the body to recognize foreign substances in the body. Three of the most important human blood antigens are A, B, and Rh. An individual's RBC many carry an A antigen, B antigen, both A and B antigens or no antigen at all. Based on this there are 4 blood types (groups) in the A, B, AB and O.

Table 1. types of blood and their antigen and antibody.

Blood type	**Antigen type**	**Antibody type**
A	A	Anti B antibody
B	B	Anti A antibody
AB	AB	No antibody
O	No antigen	Anti A antibody and Anti B antibody

Transfusion of blood is possible with compatible blood types. If incompatible an antigen will react with antibodies and agglutination (clumping of RBCs) will occur. Types AB can receive any types of blood and is known as **universal receiver**. Type O can donate blood to any one and known as **universal donor**.

Table 2. Blood donor receiver chart

Blood type	**Can donate to**	**Can receive from**
A	A, AB	A,O
B	B, AB	B,O
AB	AB	A, B, O
O	A,B, AB, O	O

B. The Heart

The heart is a four chambered, double pump, located in the throracic cavity between the lungs. It is a hollow, cone shaped muscular organ about the size of a fist. It has a mass of between 250 and 350 grams. The heart is composed of cardiac muscle. The term cardiac (as in cardiology) means related to the heart and comes from the Greek word kardia for heart.

a. Structure and function of the heart

The primary function of the heart is to pump blood through the blood vessels by repeated, rhythmic contractions. The heart has two separate pumps, a right heart the pumps blood through the lungs and a left heart tha pumps to peripheral organs. The heart keeps blood circulating properly.

i) Covering of the heart

The heart is surrounding by a double membrane called the pericardium a sac with two layers. The outer fibrous pericardium, which anchors the heart to the surrounding structures. The inner serous pericardium, which consists of an outer parietal layer and an inner visceral layer. Between the parietal and visceral layers is pericardial cavity containing a pericardial fluid. The fluid lubricates the heart wall and reduces friction when the heart glides.

ii) Layers of the heart wall

The heart wall richly supplied with blood vessels is composed of three layers.

- ***Epicardium*** is the superficial visceral layer of the serous pericardium
- ***Myocardium*** (muscle heart) it is the middle layer composed mainly of cardiac muscle
- ***Endocardium*** inside layer is a thin smooth endothelial inner linning of the heart.

iii) Heart chambers

The heart has 4 chambers, two superior atria and two inferior ventricles. Atria have thinner walls than ventricles. The atria are divided into right and left atria, which receive blood coming into the heart. The ventricles are divided into right and left ventricle, pump blood out of the heart.

The left ventricle is the thickest chamber of the heart because it pumps blood to all parts of the body. Vertically diving the right and left sides is a common wall called septum, which prevents mixing of oxygenated and non-oxygenated blood.

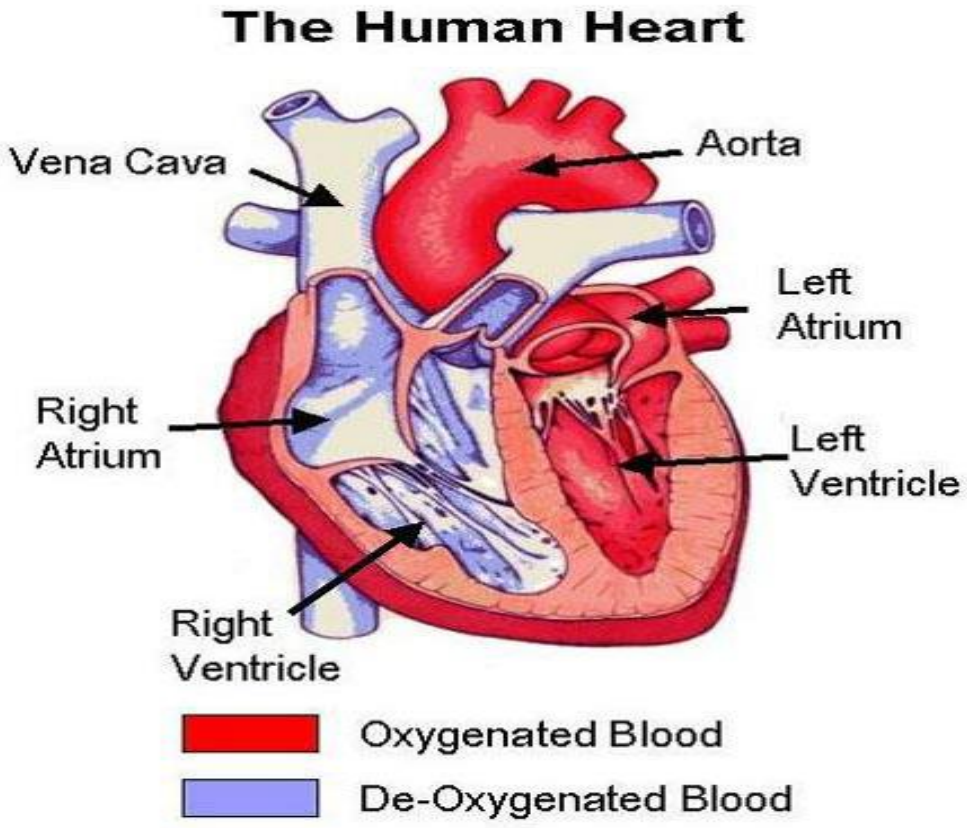

Figure: Human heart chambers

Valves: valves are present in the heart and blood vessels. Valves prevent the backflow of blood to ensure the blood flow only in one direction. These valves are grouped into two main categories

a) **Semilunar valves**: are present in the arteries leaving the heart. Two of the valves are:-

- *The pulmonary semilunar valve*: lies between the right ventricle and the pulmonary trunk and
- *The aortic semilunar valve*: located between the ventricle and the aorta blood from flowing back into the ventricles.

b) **Atrioventricular (AV**): are located between atria and ventricles. They prevent the back flow of blood from atria into the ventricles. These valves include`:-

- *The right AV valve*: it is also called the tricuspid valve, located between the right atrium and the right ventricles. The tricuspid valve allows blood to flow the right atrium into the right ventricle when the heart is relaxed during diastole.
- *The left AV valve:* is also called the bicuspid valve. This valve prevent flow of blood in the left ventricle from flowing into the atrium.

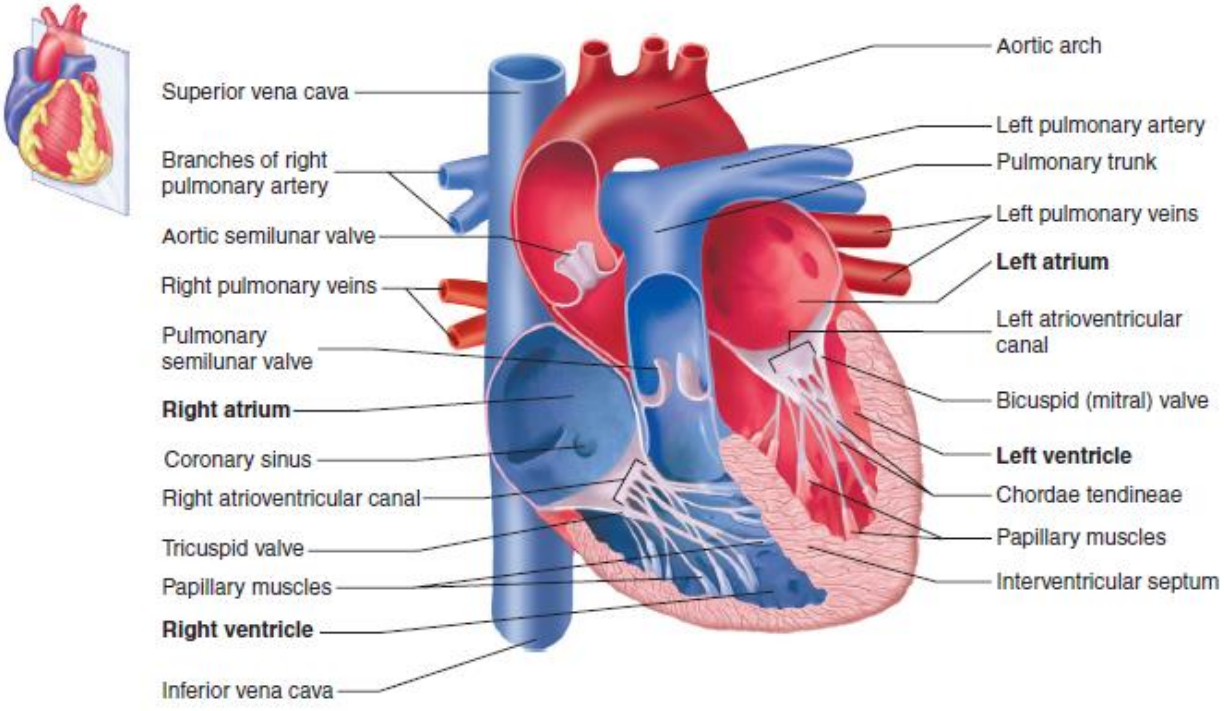

Figure: Types of valves in human heart

C. Circulatory pathways

Blood returning from the lungs enters the left atrium and passes through flaps of tissue called atrioventricular (AV) valve. The valve that separates the left atrium and left ventricle is called the bicuspid (mitral) valve. From the left ventricle blood is pumped through a semilunar valve called the aortic valve into the aorta artery that carries it to every part of the body except the lungs. Aortic valve prevents blood from flowing back into the left ventricle.

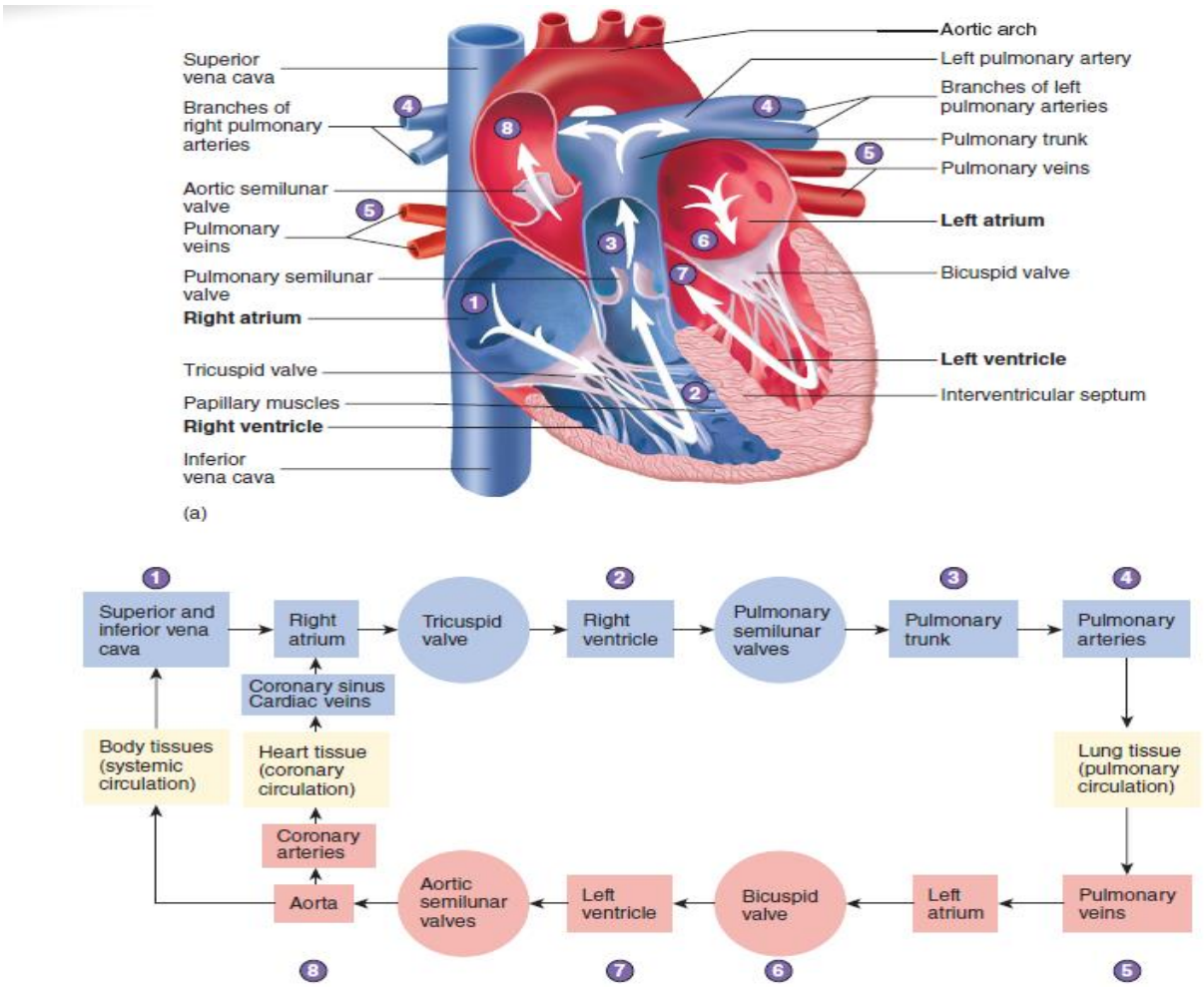

Figure: Ways of Circulatory pathways

a. Types of circulation

Blood moves through body in a continuous of which there 2 major paths:-

1) **Pulmonary circulation** is carries blood between the heart and lung. It begins at the right ventricle and ends at the left atrium. Deoxygenated blood is pumped out of right ventricle into the lungs through the pulmonary arteries, which are the only arteries that carry deoxygenated blood. Blood return to the heart through the pulmonary veins which are the only veins to carry oxygenated blood.
2) **Systematic circulation**: at the left ventricle and ends at atrium carries blood to the rest of the body. Oxygenated blood leaving the heart passes through aorta, a number of arteries and capillaries that lead to veins through which blood returns to the right artrium. The

systematic circulation can be divided into 3 subdivision: i) **coronary** circulation: supplies blood to the heart; ii) **renal** circulation: supplies blood to the kidney; iii) **hepatic** portal circulation: nutrients are picked up by capillaries in the small intestine and are transported to the liver.

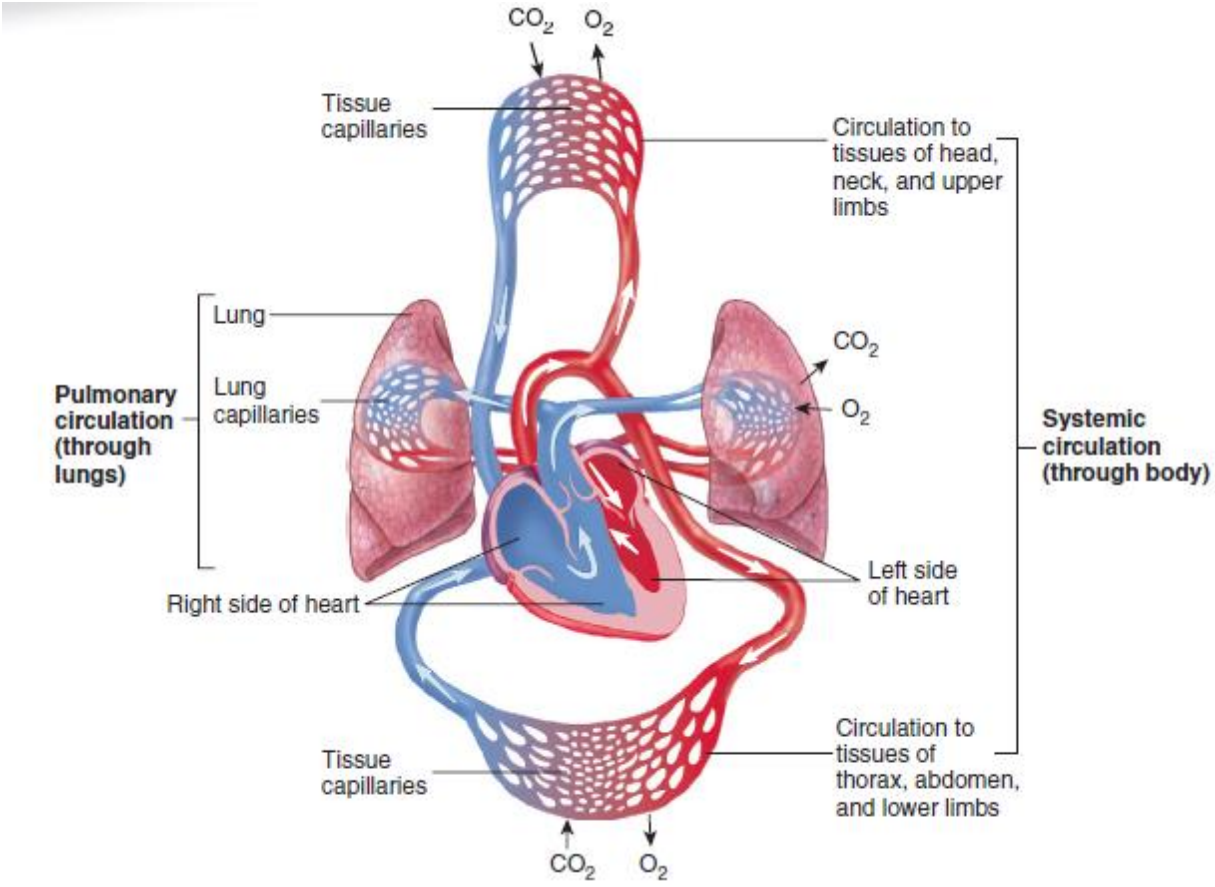

Figure: Types of Circulatory pathways

A. The heartbeat (Cardiac cycle) and cardiac output

The cardiac cycle is the sequence of events in one heartbeat, the simultaneous contraction of the 2 atria followed by the simultaneous contraction of the 2 ventricles

The heartbeat has 2 phases

A). **systole**: the contraction of the cardiac muscle tissue in the ventricles is called systole. When the ventricles contract they force the blood from their chambers into the arteries leaving the heart. The left ventricle empties into the aorta and the right ventricle into the

pulmonary artery. The increased pressure due to the contraction of the ventricles is called systolic pressure.

B). **diastole**: the relaxation of the cardiac muscle tissue in the ventricle is called diastole. When the ventricles relax, they make room to accept the blood from the atria. The decreased pressure due to the relaxation of the ventricles is called diastole pressure.

Each heartbeat produce 2 sounds often called **lub-dup** that can be heard with a stethoscope. The first sound the loudest and longest is caused by ventricular systole closing the AV valves. The second sound is caused by the closure of the aortic and pulmonary valves (SL).

Heartbeat capacity of heart;-

a). **stroke volume (SV)** is the volume of blood ejected by each ventricle during a single contraction. The stroke volume of the left and right ventricles are normally equal

b). **cardiac output (CO)** is the volume of blood pumped out of the right or left ventricle per minute. CO = SV x HR.

Cardiac output varies widely with the health of the individual and the state of activity at the time of measurement. The **Sino atrial (SA)** node is a natural pacemaker of the heart. Pacemaker initiates each heartbeat and sets the pace for the heart rate. The ANS influences the heart rate, in which the sympathetic nervous system increase the rate and the parasympathetic system decrease the rate. At rest our heartbeats between 60-80 beats per minute. Ventricles do not expel all of their blood some amount of blood is reaming in the ventricle which is about 70ml. in average resting heart each ventricle contain an EDV which is about 130ml.

EVD = ESV +SV

E.g if ESV IS 60ml and SA is 70ml EVD

EVD = 60 + 70 = 130ml

The volume of blood pumped by each ventricle in 1minute is termed the cardiac output. It is determined by the volume of blood ejected from the ventricle with each beat the stroke volume and the number of beats of the heart per minute the heart rate. The cardiac output average 5 liters/minute for an adult at rest.

B. Blood pressure

Blood pressure is a measure of force that blood exerts against a blood vessel wall. Blood pressure is erpressed as the systolic number over the diastolic number. The normal blood pressure of an adult male is 120/80mmHg and that females is 110/70mm mercury.

C. Blood vessel

There are 3 types of blood vessels (arteries, capillaries and veins). With exception of capillaries and tiny veins, the walls of blood vessels are made up of 3 layers of tissue that provide strength and elasticity. The inner most layer is epithelial tissue the middle layer is smooth muscle tissue and the outer layer is connective.

I). **Arteries**: is carry blood from the heart to capillaries and the rest of the body. Except pulmonary arteries, all arteries carry oxygenated blood. The walls of arteries are generally thicker and made up of smooth muscle cell and elastic fibbers that enables them to withstand high pressure of blood as it is pumped from the heart. The largest artery is called **aorta** and it carry oxygenated blood from left ventricle to all parts the body except the lungs. The aorta branches into smaller arteries that supply all parts of the body and smallest arteries are called arterioles.

II). **Capillaries**: arteries into network of very small blood vessels called capillaries. Its wallis made up of only one layer of cells (thin-Walled) through which materials (nutrients, oxygen, waste) can diffuse easily.

III). **Veins**: blood flows from capillaries into veins. Veins collect blood from every part of the body and carries back to the heart. The largest veins are called **vena cava** and the smallest ones are called venules. There are 2 types of vena cava brings blood from the upper part of the body to the heart and heart and the inferior vena cava brings from the lower part of the body to the heart. Large veins contain valves that help to keep one directional flow of the blood. Although blood pressure drops as the blood reaches the veins blood flow in veins is helped by contraction of skeletal muscles and valves.

D. Electrical conduction system

The heart is composed primarily of muscle tissue. A network of nerve fibers coordinates the contraction and relaxation of the cardiac muscle tissue to obtain an efficient, wave lie pumping action of the heart. It consist of the following component

- Sinoatrial node (SA node)
- Atrioventricular node (AV node)
- Common AV Bundle (AV bundle)
- Right and left bundle branches (purkinje fibers)

The sinoatrial node (often called the SA node or sinus node) serves as the natural pacemarker for the heart. Nestled in the upper area of the right atrium it sends the electrical impulse that triggers each heartbeat. The impulse spreads through the atria promoting the cardiac muscle tissue to contract in a coordinated wave like manner.

The impulse that originates from the sinoatrial node strikes the Atrioventricular node (AV node) which is situated in the lower portion of the right atrium. The atrioventricular node in turn sends an impulse through the nerve network to the ventricles initiating the same wave like contraction of the ventricles. The electrical network serving the ventricles leaves the atrioventricular node through the right and left bundle branches. These nerve fibers send impulse that cause the cardiac muscle tissue to contract.

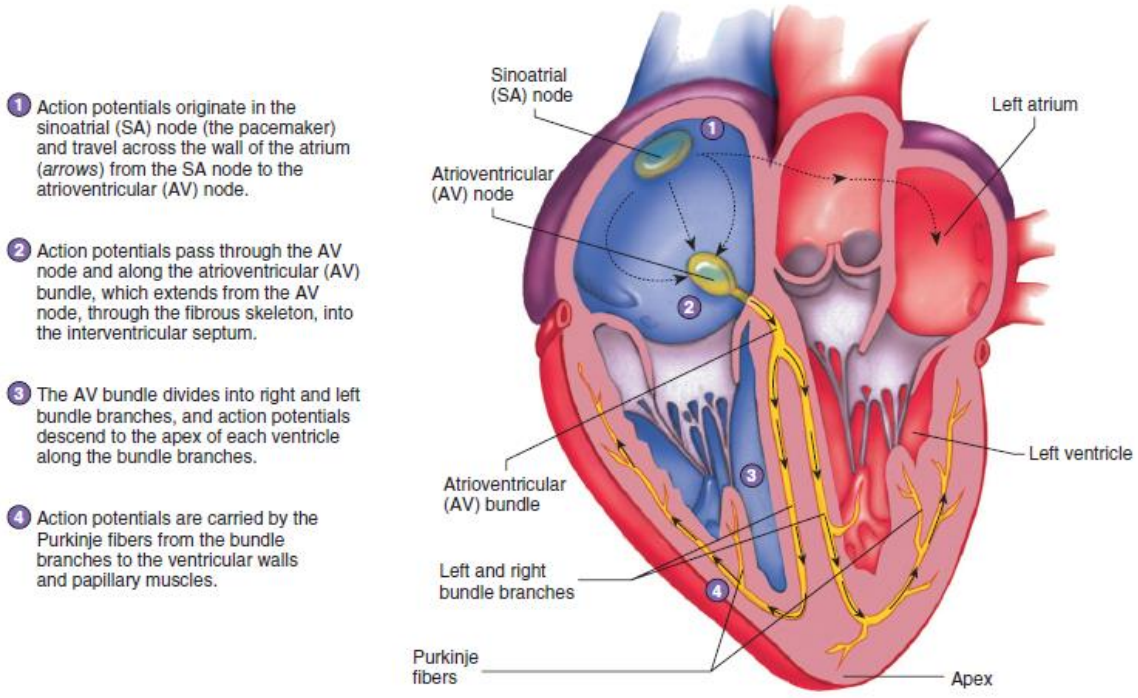

Figure: Electrical conduction system

E. Heart sound

The nrmal heart sound are usually described by the syllables **lub** and **dup**. the **lub** is a longer lower pitched sound that occurs at the start of ventricular systole. It is probably caused by a combination of things including closer of the atrioventricular valves. The **dup** sound is shorter and sharper. It occurs at the beginning of ventricular relaxation and is due in large part to sudden closure of the semilunar valves.

ECG is a record of the electrical activity of the conducting system body is a good conductor of electricity (lots of salts) potential changes at body's surface are picked up by 12 leads ECG is NOT a record of heart contractions.

P wave = passage of current through atria from SA Node conduction through atria is very rapid atrial depolarization

QRS wave = passage of current through ventricles from AV Node – AV Bundle – Purkinje Fibers impulse slows as it passes to ventricles ventricular depolarization.

T wave = repolarization of ventricles (atrial repolarization is masked by QRS) by comparing voltage amplitudes and time intervals between these waves from several leads can get idea of how rapidly the impulses are being conducted and how the heart is functioning