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HUMAN ANATOMY AND PHYSIOLOGY – I

UNIT 5

TOPIC :

- **Cardiovascular system**

  Heart– anatomy of heart, blood circulation, blood vessels, structure and functions of artery, vein and capillaries, elements of conduction system of heart and heart beat, its regulation by autonomic nervous system, cardiac output, cardiac cycle. Regulation of blood pressure, pulse, electrocardiogram and disorders of heart

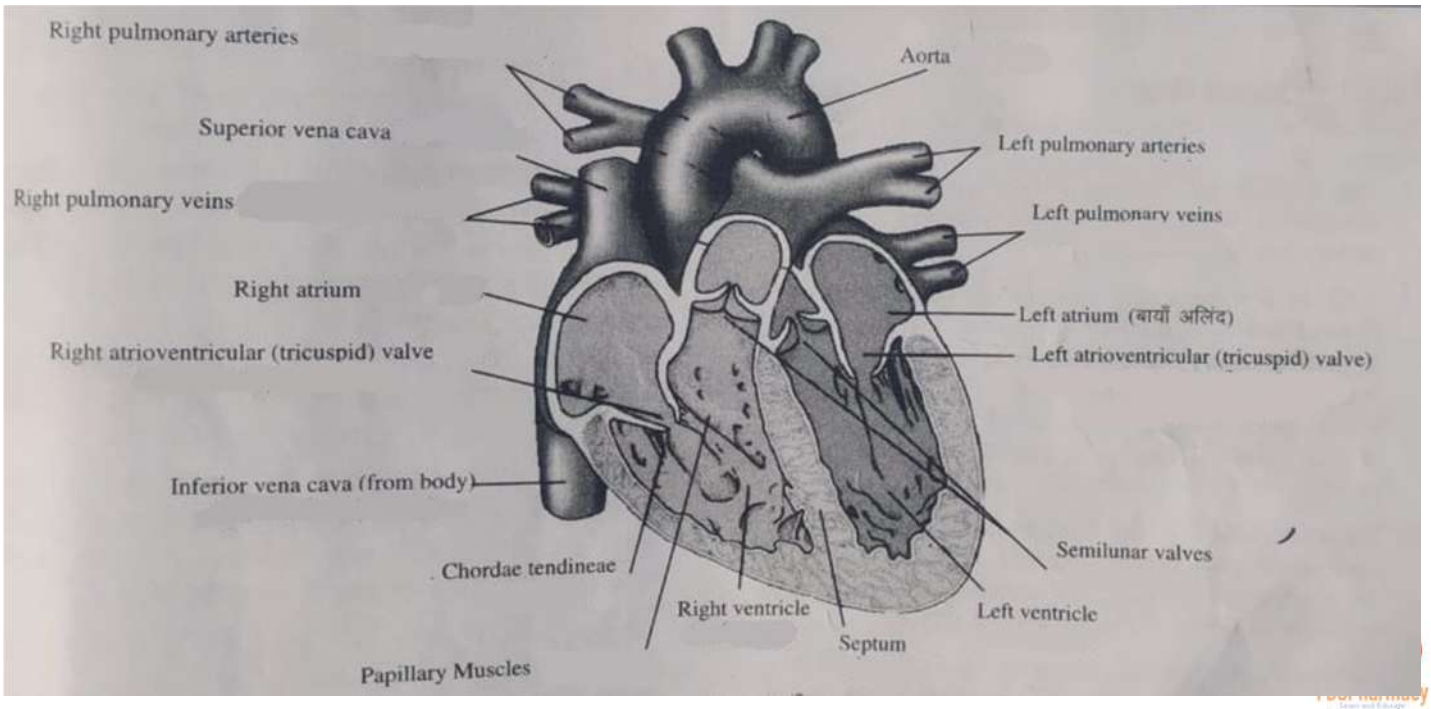
Cardiovascular System

→ The system that fulfils the transportation needs of the body is cardiovascular system.
→ This system is composed of the heart, blood vessels, and blood.

Main functions of the cardiovascular system are:

i. Distribution of 02 and nutrients to all Jhe body cells and tissues.
ii. Transportation of CO_2 and metabolic waste products from tissues to lungs and other excretory organs.
iii. Distribution of water, electrolytes, and hormones throughout the body.
iv. Thermoregulation.

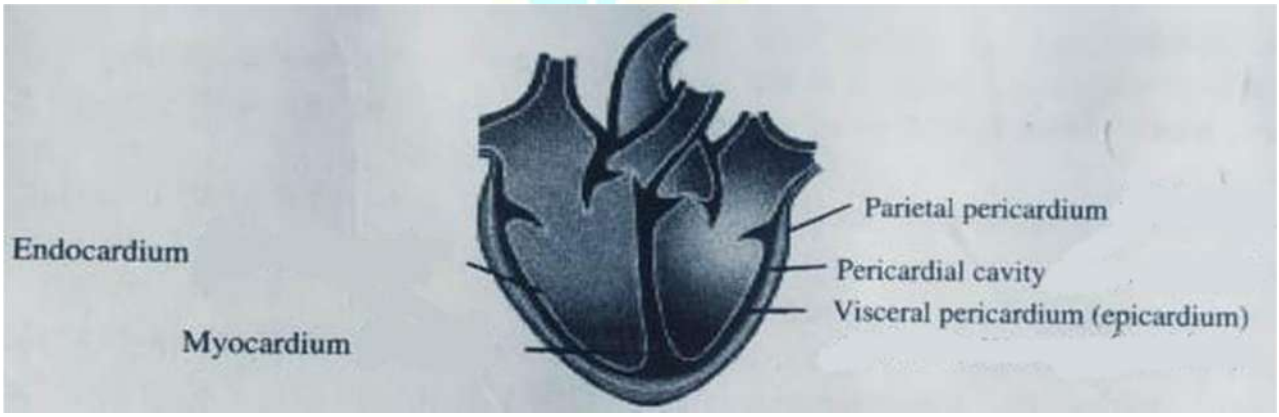
→ Blood is pumped by the heart (a muscular organ of the circulatory system).
→ Heart consists of very strong cardiac muscle tissue and shows rhythmic contraction and relaxation
→ As a result of this contraction and relaxation, a force Is generated that pumps the blood to the entire body along With nutrients and oxygen.



→ Heart is a muscular organ, present in all vertebrates that pump blood to the whole body continuously.
→ In humans, its size is equal to the size of a clenched fist, and average weight for females is 250-300gm, and 300-350gm for males.
→ Average human heart beats around 70-72 times per minute.

Anatomy of Heart

- Heart is situated in the thoracic cavity, obliquely between the lungs in the mediastinum space, just above the diaphragm.
- Heart is present in the midline of the body, is slightly tilted towards the left.
- It is a rounded cone shaped structure
- Heart is enclosed by a serous membrane known as pericardial sac or partial pericardium.



The pericardial sac consists of two membranes:

- **Fibrous Pericardium :** This pericardium covers the heart joining it to great vessels (vena cava, aorta, pulmonary vein, and artery).

- **Serous Pericardium :** This pericardium is a thin, delicate membrant. The outermost layer of the heart wall (known as epicardium) and large blood vessels are continuous with this membrane.

Heart Wall

The wall of the heart is composed of three layers :

- **Epicardium or Visceral Pericardium :** This is the visceral layer of partial pericardium and forms the outer most layer of heart.This is a transparent, thin layer and consists of specialised epithelial tissues known as mesothelium.Pericardial cavity is a space between the epicardial membrane of heart and the serous pericardium of pericardial sac.Fluid present in this cavity is known as pericardial fluid and it protects the heart from friction and erosion

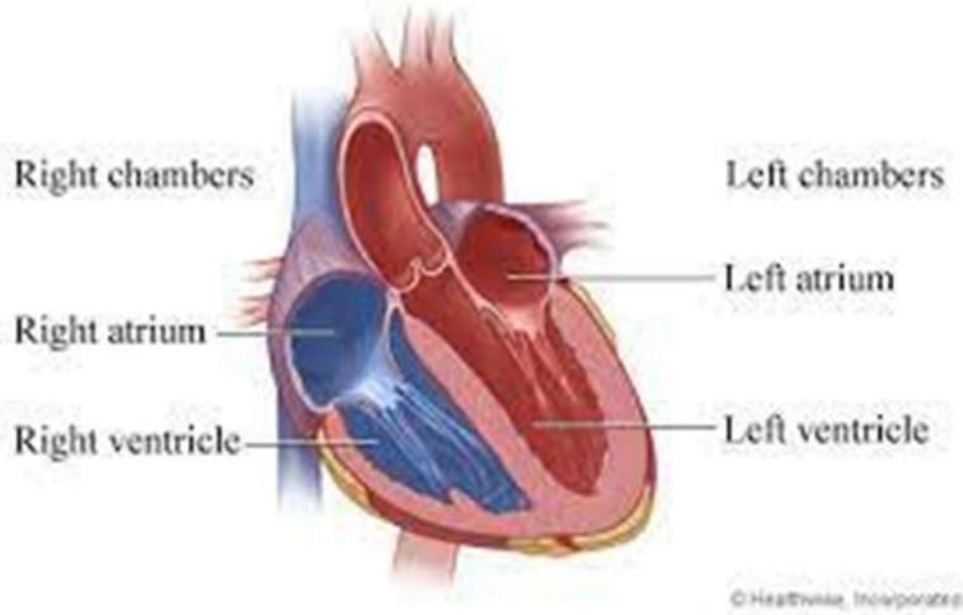
- **Myocardium :** It is the thickest layer and consists of cardiac muscle tissue. Fibres of cardiac muscle tissue are striated, involuntary, and branched. Heart contracts by the contraction of the myocardial membrane

- **Endocardium :** It is the innermost and third layer of the heart wall. It consists of a thin layer of specialised epithelial tissues (known as endothelium) which overlies a thin layer of connective tissue. This Layer provide Smooth blood flow to heart and vessles. Endothelium also lines inner cavities of the heart , covers valves, and forms the inner lining of blood vessels

Chambers of Heart

→ The heart is composed of muscular walls and has four distinct chamber of different thickness.

→ The left Atrium (LA) and Right Atrium (RA) situated above the Left Ventricle (LV) and Right Ventricle (RV), Respectively, Ventricles are thick-walled, large chamber performing many function



Valve of Heart

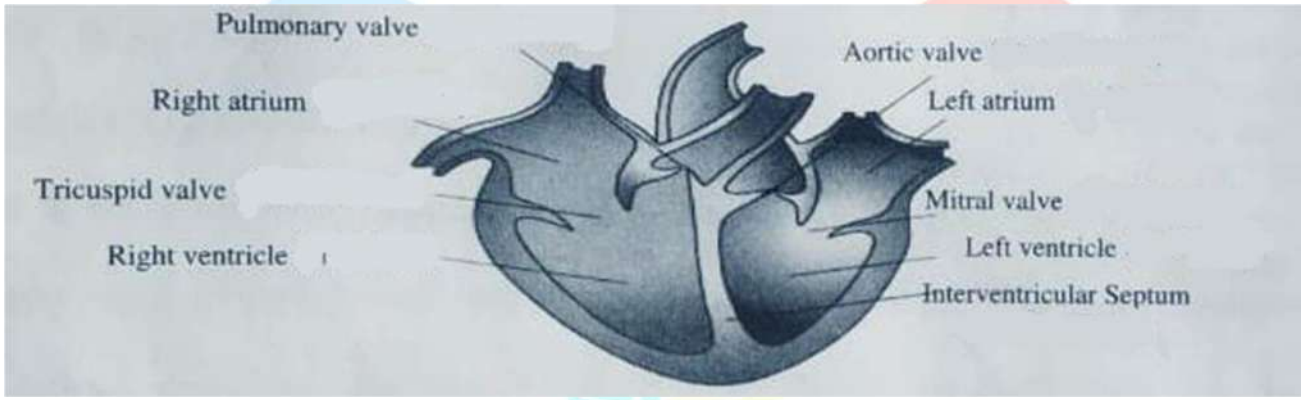
→ Heart pump blood to the lungs and other body system A system of on way Valves is present in the heart that prevent the backflow of blood into the heart valves can be categorized into two types

Atrioventricular (AV) Valves:

- These valves are present in the middle of the heart between the atria and ventricles, and only allow blood to flow from the atria into the ventricles
- The AV valve located on the right side of the heart is known as the tricuspid valve.
- The AV valve on the left side of the heart is known as mitral valve or the bicuspid valve

Semilunar Valves:

- These are crescent moon-shaped valves, located between the ventricle and the arteries, and carrying blood away from the heart towards the other body parts
- The semilunar valve present in the right chamber of heart is known as pulmonary valve
- The semilunar valve present in the left chamber of the heart is known as aortic valve



Circulation of Blood through the Heart

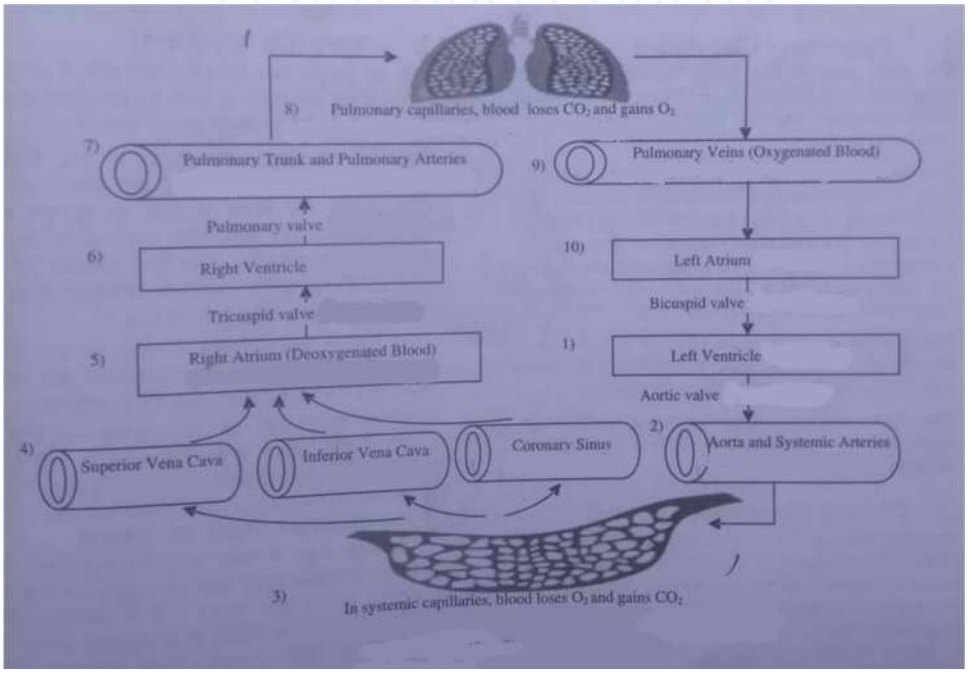
- With every heart beat the blood is pumped into two closed circuits, i.e., the pulmonary and the systemic circulation.

The following four routes of blood circulation through heart have been discussed below:

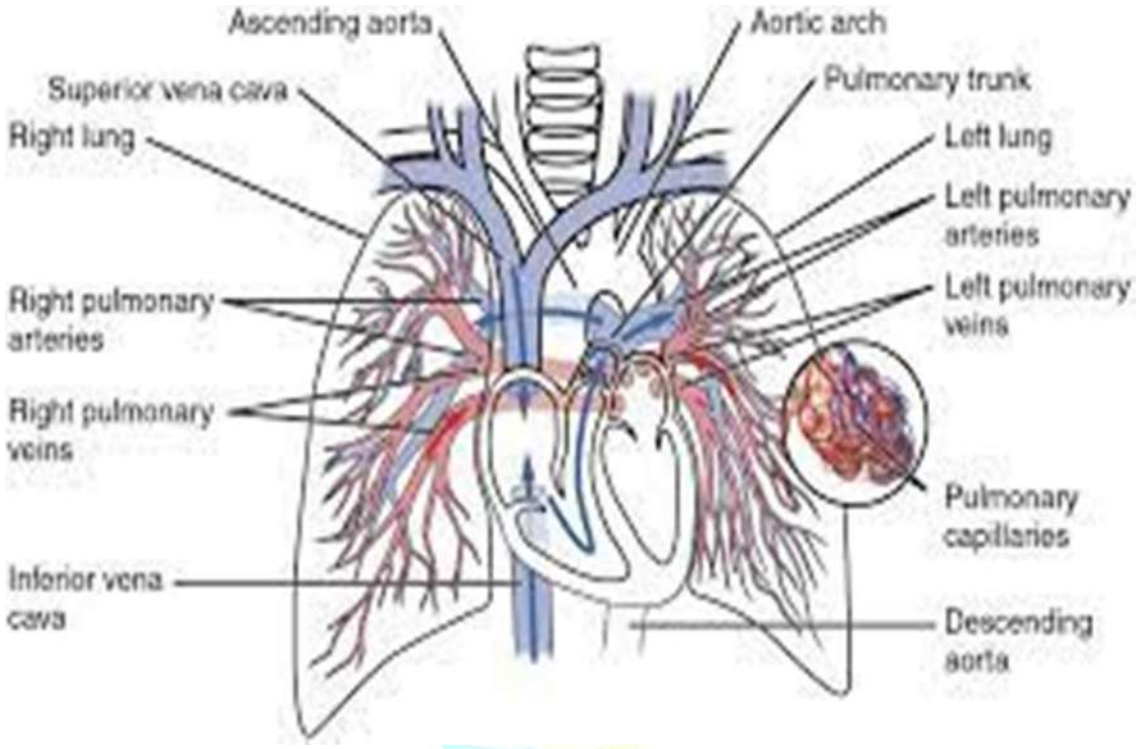
1) Systemic circulation
2) Pulmonary circulation
3) Portal circulation
4) Coronary Circulation

1. Systematic Circulation

- Left side of the heart participates in systemic circulation and receives oxygenated blood from the lungs.
- From the left ventricle blood is pumped into the aorta and the backflow is guarded by the aortic valve,
- The arteries then divide into small diameter arterioles which further divide into systemic capillaries. Nutrient and gaseous exchange are seen across the thin walls of the capillaries. Oxygen is delivered and carbon dioxide is picked up via capillaries.
- The deoxygenated blood then enters the systemic venules (smallest diameter blood vessels carrying deoxygenated blood). The venules further unite to form large systemic veins.
- They carry away the deoxygenated blood (blood rich in carbon dioxide) from the tissues. Next, via the systemic veins, blood enters the superior and inferior vena cava (the largest veins carrying deoxygenated blood from the upper and lower parts of the body, respectively to the heart) and the coronary sinus (receives deoxygenated blood of the heart) and brings back the deoxygenated blood to right atrium.

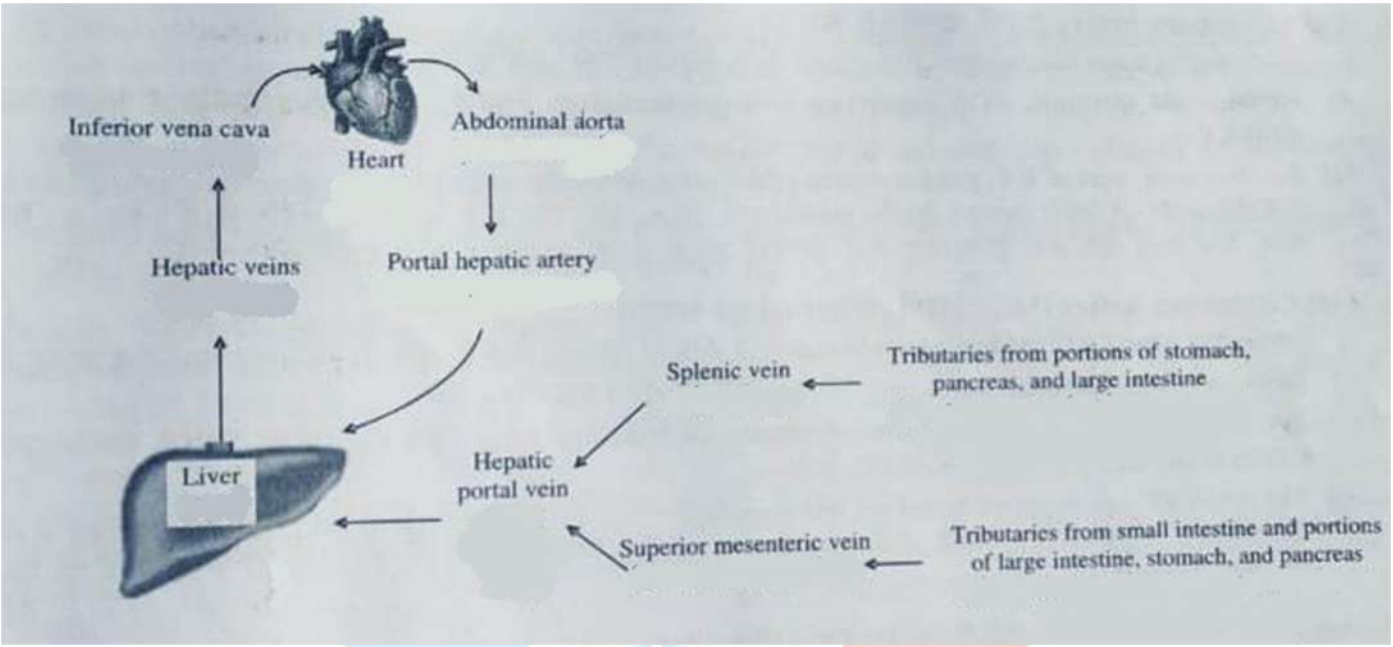


2. Pulmonary circulation



- The right side of the heart is involved in the pulmonary circulations. It receives deoxygenated blood returning from the systemic circulation and pumped to the lungs.
- The deoxygenated blood enters the right ventricle from the right atrium and the backflow is checked by the tricuspid valve. From the right ventricle blood is pumped into the pulmonary trunk and then, into the pulmonary arteries and the backflow is checked by the pulmonary valve. The pulmonary circulation carries deoxygenated blood to the lungs.
- The gaseous exchange takes place at the surface of alveoli and the blood gets oxygenated (i.e., loses carbon dioxide) in the pulmonary capillaries.
- The oxygen-rich blood is then carried via pulmonary veins, to the left atrium from where it is distributed to the rest of the body systems.

3. Portal Circulation



→ Blood enters the liver from two sources.

→ The hepatic artery supplies oxygenated blood from the abdominal aorta and the hepatic portal vein carries deoxygenated blood from the digestive organs.

→ The flow of deoxygenated blood from the digestive organs to the liver before returning to the heart is called hepatic portal circulation.

→ A vein which does not carry blood directly to the heart but forms networks of capillaries in another or intermediate organ before reaching the heart is called a portal vein.

→ A portal vein together with small veins through which it receives blood is called the portal system.

Blood Vessels

- The cardiovascular system is responsible for pumping of blood throughout the body and thus transport oxygen, nutrients and hormones to different body organs and tissues and carrymg away wastes Therefore the cardiovascular system maintains homeostasis of all other systems in the body blood vessels (the main part cardiovascular system) form a closed circuit of tubules for carrying blood away from the heart to different tissues and then bringing it back to the heart
- Blood vessels from the left ventricle supplying different tissues in the body are Ix IO^5 km long.
- The blood vessels comprise the major Path of the circulatory system and maintain blood circulation in the body

Types

Various kinds of blood vessels are discussed below in series:

1) **Arteries:** These are elastic vessels, carrying blood from the heart (under high pressure) to different tissues and organs. For example,
    - Aorta the largest artery, carries blood out of the heart, and
    - Branches of the aorta, the carotid artery, the subclavian artery, the celiac trunk, the mesenteric arteries, the renal artery, and the iliac artery.

2) **Arterioles:** They are the sub-divisions of arteries. They are thinner than the arteries.

3) **Capillaries:** These blood vessels have smallest diameter. They connect the arterioles (smallest diameter arteries) to the venules (smallest diameter veins).

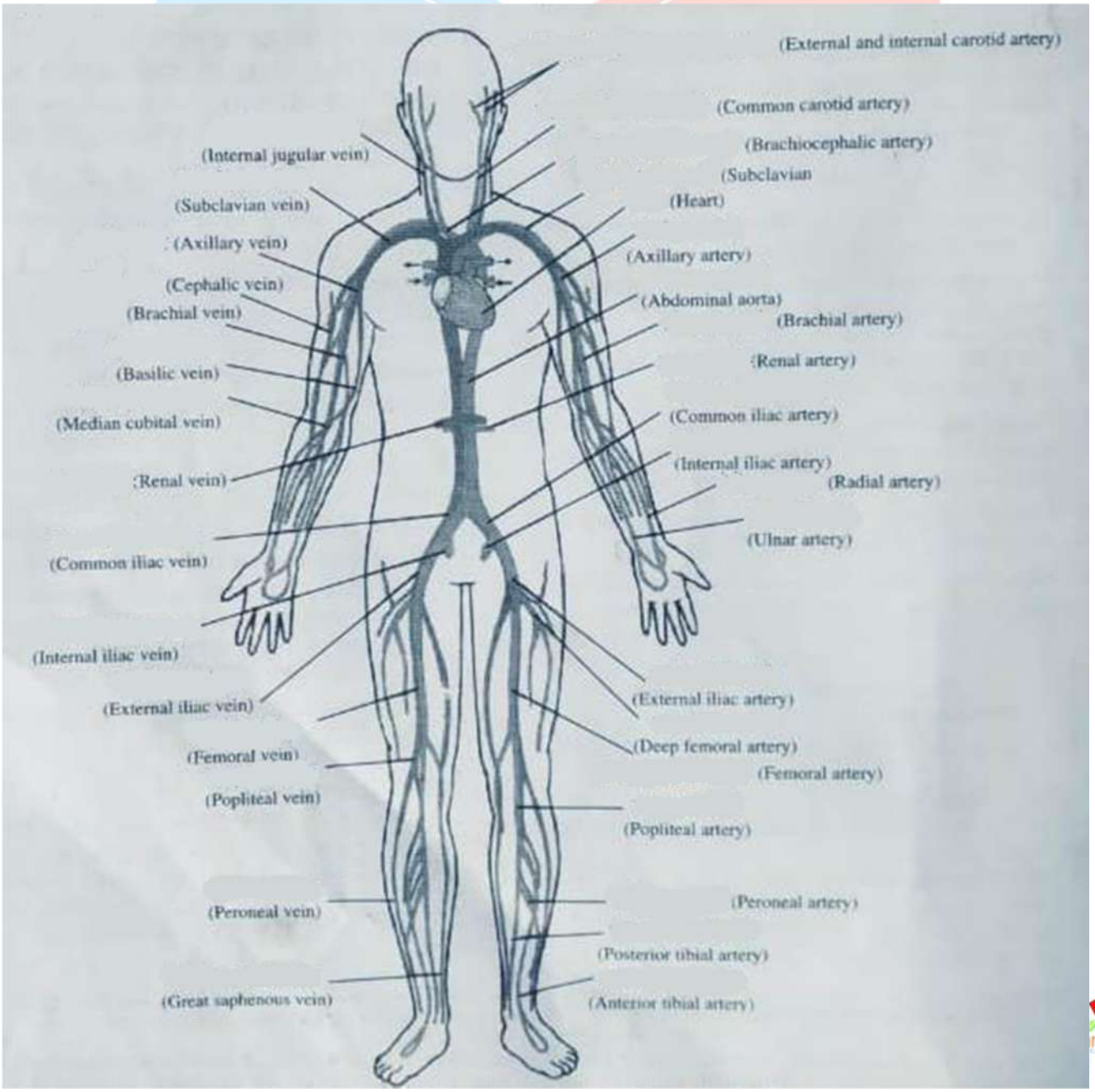
4) **Venules:** These are veins having the smallest diameter. They connect the capillaries to the larger veins.

5) **Veins:** These blood vessels carry blood from different organs and tissues, back to the heart (atria)

For example :

i. Large collecting vessels, such as the subclavian vein, the jugular vein, the renal vein and the iliac vein, and

ii. Vena cava (2 large veins, carry blood into the heart)

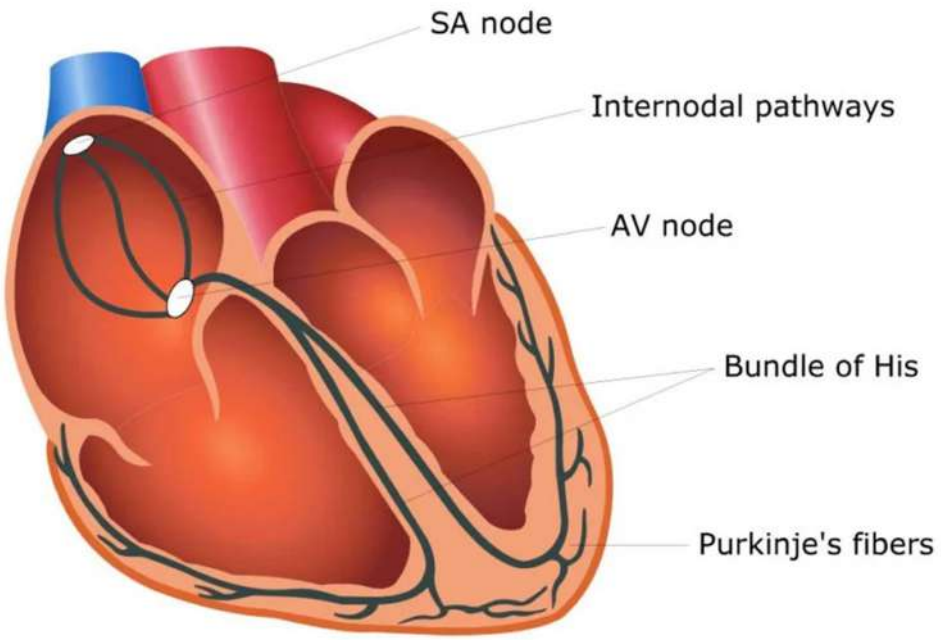


Conducting system of the heart

→A special system is available in the heart which is responsible for the rhythmic contraction and conduction of impulses in the heart. The rate at which the heart conducts electrical impulses is called as the cardiac conduction

→This system can be divided into five parts.

- ✓ SA node or Sino atrial node
- ✓ AV node or Atrioventricular node
- ✓ AV bundle or bundle of His
- ✓ Right and left bundle branches
- ✓ Conduction myofibrils (Purkinje fibres)



SA Node:

- Cardiac excitation begins in the SA node, located in the right atrial wall just below the opening of superior vena cava. The action potential from the SA node propagates throughout both the atrium. On receiving the action potential, the atrium undergoes contraction. Each SA node action potential travels throughout the heart via the conduction system.

AV Node:

- The atrioventricular (AV) node lies on the right side of the partition that divides the atria, at the bottom of the right atrium. There is a brief delay when the impulses from the SA node reaches the AV node. During this period, the atria contract and empty their contents. Once the atria are empty of blood, the valves between the atria and ventricles close. The atria begin to refill and the electrical stimulus passes through the AV node and Bundle of his into the Bundle branches and Purkinje fibres.

AV Bundle (Bundle of His):

- The Bundle of His connects with the distal part of the compact AV node and penetrates the membranous septum. From the AV node, the action potential enters the bundle of His, the only electrical connection between atria and ventricle. This bundle of fibres branches off into two bundles and the impulses are carried down the center of the heart to the left and right ventricles.

Right and Left Bundle Branches:

- The bundle branches originate at the superior margin of the muscular interventricular septum, immediately below the membranous septum.After travelling along the AV bundle, the

action potential then enters both the right and left bundle branches that runs through the interventricular septum towards the apex of the heart

Purkinje Fibres:

- These fibres are less concentrated at the base of the ventricle and the papillary muscle tips. The Purkinje fibres connect with the ends of the bundle branches to form interweaving networks on the endocardial surface of both ventricles. They penetrate only the inner third of the endocardium. They transmit the cardiac impulses almost simultaneously to the entire right and left ventricular endocardium.

Heartbeat

→ Rhythmic contraction and relaxation of the heart is known as heartbeat.

Heartbeat can be regulated by the following two mechanisms :

- **Nervous Regulation :** Sympathetic nervous system increases the heartbeat by secreting adrenaline hormone. Parasympathetic nervous system supplying vagus nerves decreases the heartbeat by secreting Acetylcholine (Ach).
- **Hormonal Regulation :** Thyroxine, epinephrine, and nor-epinephrine affect the heartbeat. Thyroxine is secreted by the thyroid gland and increases the heartbeat indirectly by increasing Basal Metabolic Rate (BMR). Epinephrine and nor-epinephrine are secreted by the adrenal medulla. In cases of emergency, epinephrine increases the heartbeat; while under normal conditions, nor-epinephrine increases the heartbeat.

Cardiac Output

→ Cardiac output is defined as the amount of blood flowing from the heart (i.e., from the left ventricle into aorta) over a given period of time (or in one heartbeat).

→ Cardiac Output = Stroke Volume x Heart Rate
= 70ml x 72/min = 5040ml/min
= about 5 litre/min

→ Where, Stroke volume = Volume of blood pumped by heart/heartbeat).

→ Heart rate = Ventricular systole/min.)

Cardiac Cycle and Heart Sound

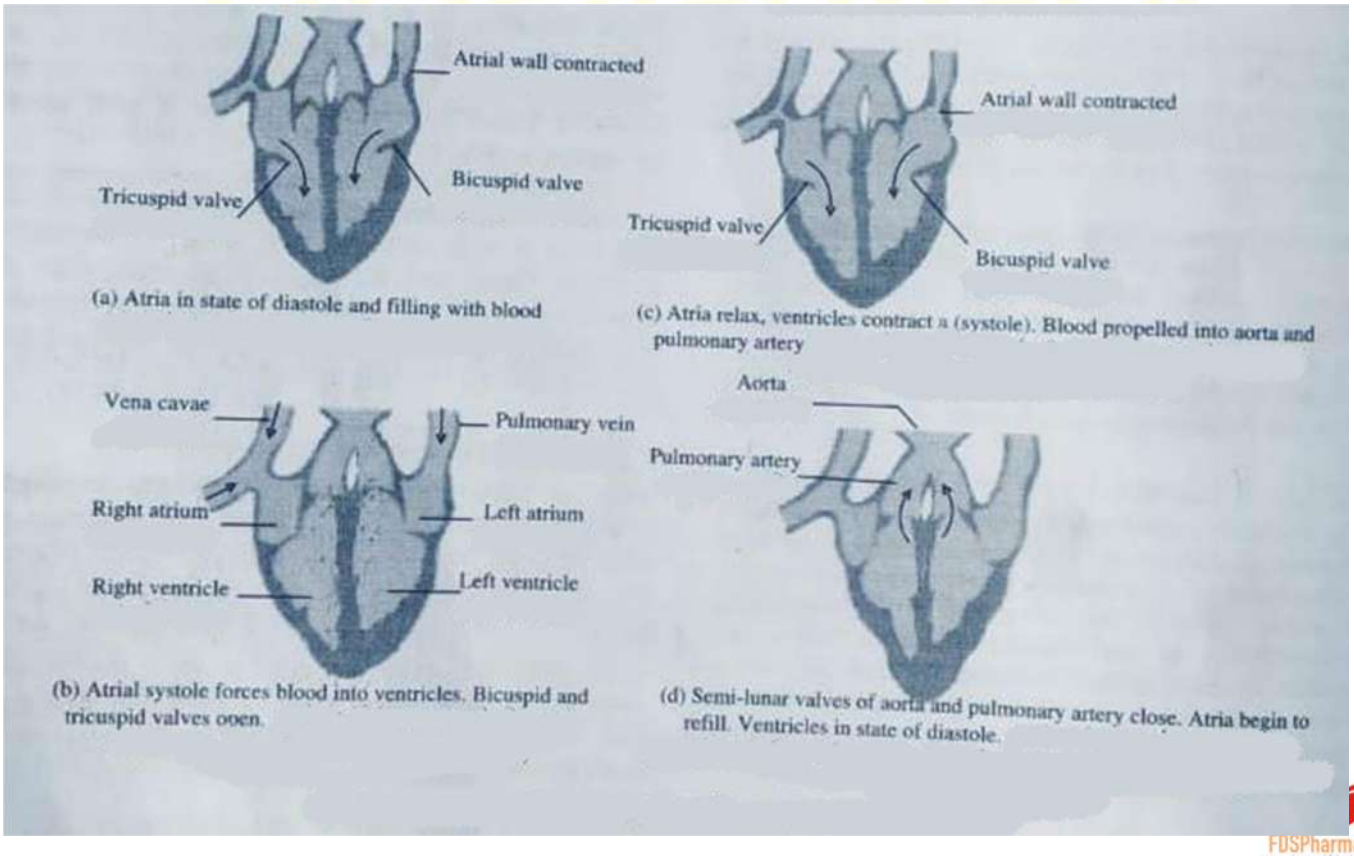
→ The alternate contraction (systole) and relaxation (diastole) of auricles and ventricles, resulting in one heart beat is known as a cardiac cycle.

→ As the auricles contract (auricular systole), the ventricles relax (ventricular diastole); and as the ventricles contract (ventricular systole), the auricles (auricular diastole) relax; and thus it is a continuous cycle.

→ A systole signifies pumping out of blood from the cardiac chamber, whereas a diastole signifies the entry of blood into a cardiac chamber.

Blood Flow in the Heart During a Cardiac Cycle

- **Atrial Systole :** This is marked by stimulation of the SA node. A wave of contraction spreads through the atria, and the bicuspid and tricuspid valves open up; thus pumping blood from the atria into the ventricles.
- **Ventricular Systole :** Next, contraction of ventricles occurs as a wave of contraction spreads through both the ventricles. This is stimulated by AV node stimulation. The bicuspid and tricuspid valves close and produce the first heart sound, i.e., lub (lasting for 0.16-0.90sec.
- **Ventricular Diastol :** As ventricles relax both semilunar valves close with a sound of dub. At this time, pressure within the ventricles decreases continually.
- **Joint Diastole :** Before the cycle starts again (i.e. before the atrial systole), both the atria and ventricles are relaxed and this state is known as the joint diastole.



Blood Pressure and its Regulation

→ Blood pressure is the hydraulic pressure exerted by the blood on the blood vessels

→ Normal blood pressure has high systolic value and low diastole value 120mmHg/ 80mm Hg in arteries.

→ Arterial blood are be of four types:

- **Systolic Pressure :** It is the maximum L pressure or peak pressure (120mmHg in a healthy adult) exerted in the arteries during the systole of the heart.It occurs at the beginning of the cardiac cycle when the left ventricle contracts and pumps blood to the aorta.
- **Diastolic Pressure :** It is the minimum pressure (80mmHg in a healthy adult) on the arteries It occurs at the end of the cardiac cycle when the ventricles are in resting phase after pumping the blood.
- **Pulse Pressure :** It is the differential pressure of systolic and diastolic pressur It is about 4QmmHg in a healthy adult.)
- **Mean Arterial Pressure :** It is the average pressure on the arteries.

Pulse and its Regulation

→ The **pulse** is the rhythmic throbbing of arteries caused by the contraction of the heart, particularly the **left ventricle**, as blood is pumped through the arteries. It can be felt at various pulse points like the **wrist (radial artery)**, neck (carotid artery), and foot (dorsalis pedis artery).

Regulation of Pulse:

- Pulse rate is regulated mainly by the **autonomic nervous system** and influenced by various factors:

1. Nervous Control:

- **Sympathetic Nervous System (SNS):** Increases heart rate and pulse (fight or flight).
- **Parasympathetic Nervous System (PNS):** Decreases heart rate (rest and digest).

2. Medulla Oblongata:

The **cardiac center** in the medulla controls:

- **Cardioacceleratory center** – activates SNS.
- **Cardioinhibitory center** – activates PNS.

Basics of ECG (Electrocardiogram)

→ Electrical currents generated in the heart by the propagation of action potential can be detected on the surface of the body as electrical signals.

→ These changing signals are recorded by an instrument known as an electrocardiograph.

→ The recordings obtained are known as electrocardiogram (ECG).

→ Hence, ECG is a composite record of action potentials produced by all the muscle fibres of the heart with each heartbeat.

→ Comparison of these records with each other and with the normal one helps in determining the complications like:

- Any abnormality in the conducting pathway,
- Any enlargement in the heart,
- Damage to any region of the heart, or
- Any type of pain occurring in the chest

Components of a Normal ECG Waveform :

Wave/Segment	Description
P wave	Atrial depolarization (contraction of atria)
QRS complex	Ventricular depolarization (contraction of ventricles)
T wave	Ventricular repolarization (relaxation of ventricles)
PR interval	Time between atrial and ventricular depolarization
ST segment	Time between ventricular depolarization and repolarization

Regulation of Electrical Activity in the Heart (Cardiac Conduction System):

→ The regulation of ECG is based on how the heart generates and conducts electrical impulses. This is controlled by the cardiac conduction system:

1. Sinoatrial (SA) Node (Pacemaker):

- Located in the right atrium.
- Initiates electrical impulses.
- Sets the basic heart rhythm (normal sinus rhythm ~70–100 bpm).

2. Atrioventricular (AV) Node:

- Receives impulse from SA node.
- Delays the impulse slightly to allow atria to empty into ventricles.

3. Bundle of His (AV Bundle):

- Carries impulses from AV node to ventricles.

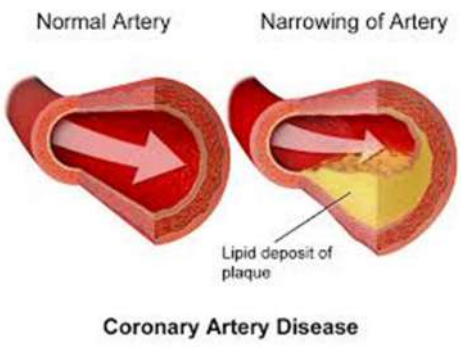
4. Right and Left Bundle Branches:

- Conduct impulses through the interventricular septum.

5. Purkinje Fibers:

- Spread the impulse throughout the ventricular walls, causing ventricular contraction.

Disorders of the Heart



Coronary Artery Disease

1. Coronary Artery Disease (CAD):

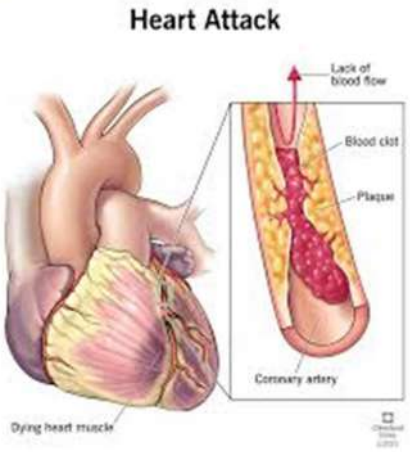
→ CAD is a condition in which the coronary arteries (that supply blood to the heart muscle) become narrowed or blocked due to atherosclerosis (plaque buildup).

Symptoms:

- Chest pain (angina)
- Shortness of breath
- Fatigue

Complication: Can lead to heart attack (myocardial infarction).

2. Myocardial Infarction (Heart Attack):



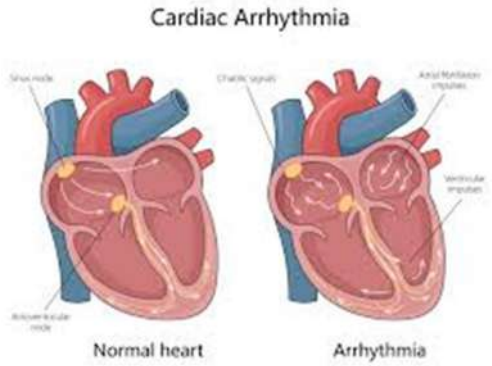
→ A condition where a part of the heart muscle dies due to a lack of blood supply, usually caused by a blocked coronary artery.

Symptoms:

- Severe chest pain
- Sweating
- Nausea
- Pain radiating to the left arm or jaw

Emergency condition – requires immediate treatment.

3. Arrhythmias:



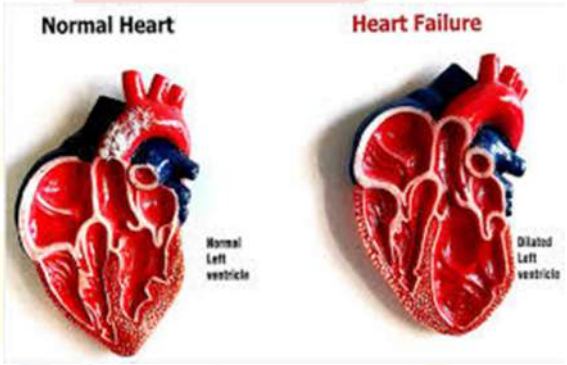
→ Arrhythmias are abnormal heart rhythms caused by improper electrical activity in the heart.

Types:

- **Tachycardia:** Fast heart rate (>100 bpm)
- **Bradycardia:** Slow heart rate (<60 bpm)
- **Fibrillation:** Irregular and rapid heartbeat (e.g., atrial fibrillation)

Symptoms: Palpitations, dizziness, fainting.

4. Heart Failure:



→ Heart failure occurs when the heart cannot pump enough blood to meet the body's needs.

Types:

- **Left-sided heart failure:** Affects lungs (causing breathlessness)
- **Right-sided heart failure:** Affects body (causing swelling in legs)

Symptoms:

- Shortness of breath
- Swelling in ankles or abdomen
- Fatigue