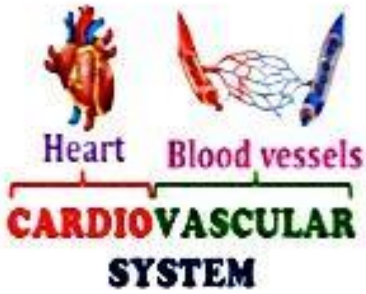
CARDIOVASCULAR SYSTEM

7.1 INTRODUCTION



- The cardiovascular system is the transport system of the body by which food, oxygen, water and all other essentials are carried to the tissue cells and their waste products are carried away.
- It also plays an important role in stabilizing body temperature and pH levels, as well as in maintaining homeostasis.

7.2. THE HEART

- The branch of science which deals with the study of the normal heart and the diseases associated with it is known as **cardiology**. [Cardio = heart; logy = study of].

7.2.1 Anatomy of Heart

- The heart is a hollow, muscular organ. It lies in the centre of thorax and between the two lungs; but is more to the left of the middle.
- It is cone-shaped and presents a base above and an apex below. It is of the size of a closed fist of the individual.
- The dimension of heart is 12 cm long, 9 cm wide and 6 cm thickness.
- The apex is about 09 cm to the left of the midline at the level of the fifth intercostal space; the base extends to the level of second rib.
- The average weight is 250 g in adult females and 300 g in adult males.
- It rests on the diaphragm, near the midline of the thoracic cavity.

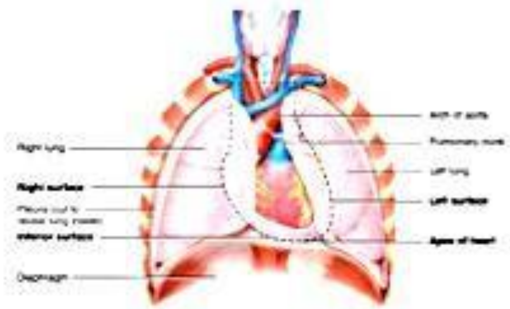


Fig.7.1: Position of the Heart in the Thorax

- It lies in the mediastinum that extends from the sternum to the vertebral column the first rib to the diaphragm and between the lungs.
- About two-thirds of the heart lies to the left of the midline.

✓ **Organs associated with the heart:**

1. **Inferiorly:** The apex rests on the central tendon of the diaphragm
2. **Superiorly:** The great blood vessels i.e., aorta, superior vena cava, pulmonary artery, and vein.
3. **Posteriorly:** Oesophagus, Trachea, Bronchus, Descending aorta, inferior vena cava, and thoracic duct.
4. **Laterally:** The lungs- the left lung overlaps the left side of the heart
5. **Anteriorly:** The body of the sternum, ribs, and adjoining costal cartilages; left lung, and pleura (apex).

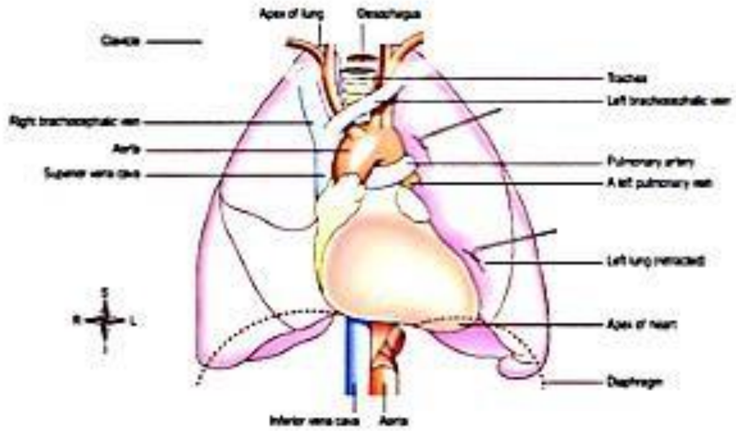


Fig.7.2: Organ associated with the Heart

7.2.2 Functions of the Heart

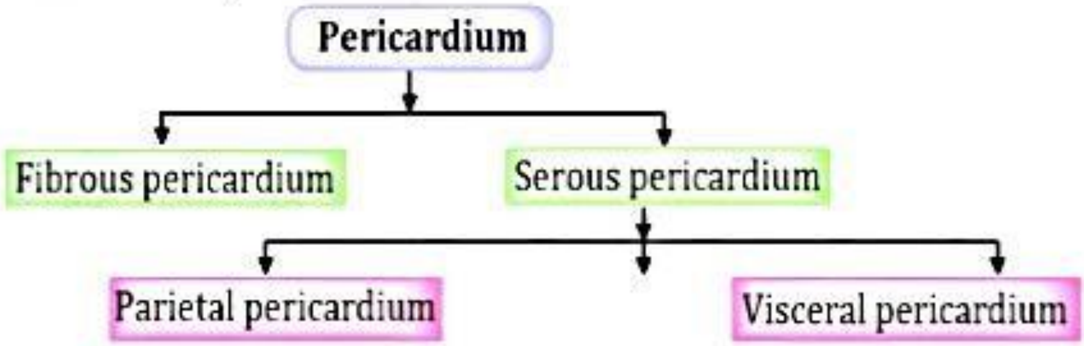
The heart acts as a pump. It maintains a constant circulation of blood throughout the body. It is achieved as follows:

1. The superior vena cava and inferior vena cava bring venous blood from various parts of the body to the heart. The venous blood fills the right atrium.
2. When it is full, the right atrium contracts sending blood to the right ventricle.
3. Now, the right ventricle contracts. This sends blood to the lungs through pulmonary trunk (which divides into right and left pulmonary arteries).
4. The blood gets oxygenated in the lungs. The oxygenated blood is carried by pulmonary veins to the left atrium.
5. Now, the left atrium contracts and sends blood to the left ventricle.
6. Now, the left ventricle contracts and sends blood into the aorta. This blood is circulated throughout the body.

7.3 STRUCTURE OF HEART WALL

The heart is composed of three layers of tissue **(a) Pericardium (b) Myocardium (c) Endocardium**

- The pericardium is a conical, flask-like, fibroserous sac that surrounds the heart.
- It protects and lubricates the heart and keeps it in place within the chest.
- The pericardium is made up of two main layers: Fibrous pericardium and the Serous pericardium.



✓ Fibrous Pericardium

- The fibrous pericardium is the outer layer of the pericardium, made up of dense and loose connective tissue.
- The fibrous pericardium is a conical-shaped sac.
- It is composed of tough, inelastic, dense irregular connective system
- The fibrous pericardium prevents overstretching of the heart, provides protection and holds the heart at a particular position.

✓ Serous Pericardium

- Is a thinner, more delicate membrane that forms a double layer around the heart.
- The outer parietal layer of serous pericardium is called as the epicardium (external layer of heart wall).
- The space in between parietal and visceral layer is filled with pericardial fluid which is secreted by serous membrane itself.
- The space that contains the pericardial fluid is called as the pericardial cavity.

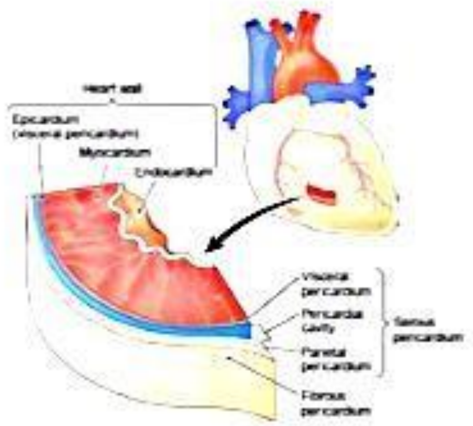


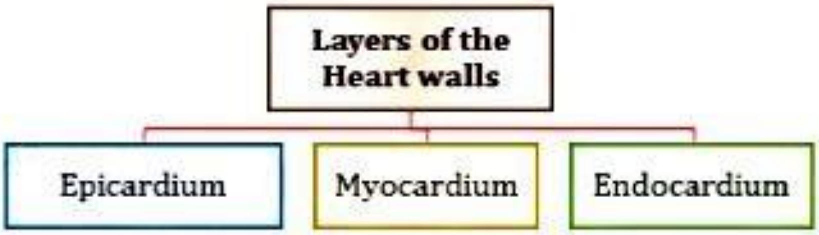
Fig.7.3: Structure of Heart wall

- **The serous pericardium is divided into two parts:**

(a) Parietal pericardium: Parietal pericardium which lines the interior side of the superficial portion of the pericardial sac, is fused to and inseparable from the fibrous pericardium.

(b) Visceral layer: It also known as the epicardium, covers the myocardium of the heart and can be considered its serosa. The two layers are continuous with each other at the base of the large vessels.

✓ Layers of the Heart Walls



1. Epicardium:

- The epicardium is the outermost layer of the heart wall and is just another name for the visceral layer of the pericardium.
- Thus, the epicardium is a thin layer of serous membrane that helps to lubricate and protect the outside of the heart.
- Below the epicardium is the second, thicker layer of the heart wall the myocardium.

2. Myocardium:

- The myocardium is the muscular middle layer of the heart wall that contains the cardiac muscle tissue.
- Myocardium makes up the majority of the thickness and mass of the heart wall and is the part of the heart responsible for pumping blood.
- Below the myocardium is the thin endocardium layer.

3. Endocardium:

- It is the inner surface of the myocardium.
- It is the simple squamous endothelium layer that lines the inside of the heart.
- It provides smooth lining for the chambers of the heart and covers the valves of the heart.

- The endocardium is continuous with the endothelial lining of the large blood vessels attached to the heart.

7.3.1 Chamber of Heart Wall

- The heart is divided into a right and left side by the septum
- On each side of the wall, there is a small collecting chamber called an 'atrium', which leads into a large pumping chamber called a 'ventricle'.
- The heart contains **four chambers.**

(i) Two superior chambers (Upper chambers)

(a) Right atrium

(b) Left atrium

(i) Two Inferior chambers (Lower chambers)

(a) Right ventricle

(b) Left ventricle

- On each side of the wall, there is a small collecting chamber called an 'atrium', which leads into a large pumping chamber called a **'ventricle'.** The atria are smaller than the ventricles and have thinner, less muscular walls than the ventricles.

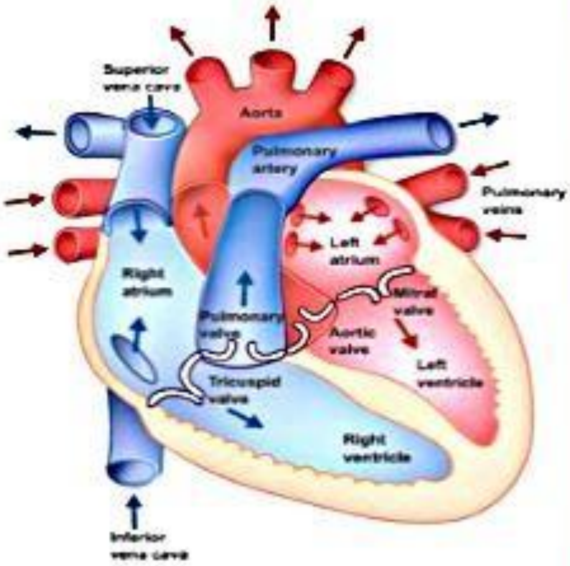


Fig.7.4: Chamber of Heart Wall

- The atria act as receiving chambers for blood, so they are connected to the veins that carry blood to the heart.
- The ventricles are the larger, stronger pumping chambers that send blood out of the heart.
- The ventricles are connected to the arteries that carry blood away from the heart.
- The chambers on the right side of the heart are smaller and have less myocardium in their heart wall when compared to the left side of the heart.
- The right side of the heart maintains pulmonary circulation to the nearby lungs while the left side of the heart pumps blood all the way to the extremities of the body in the systemic circulatory.

7.3.2 Valve of the Heart

- The valves of the heart are structures which ensure blood flows in only one direction. They are composed of connective tissue and endocardium (the inner layer of the heart).
- There are four valves of the heart, which are divided into two categories:

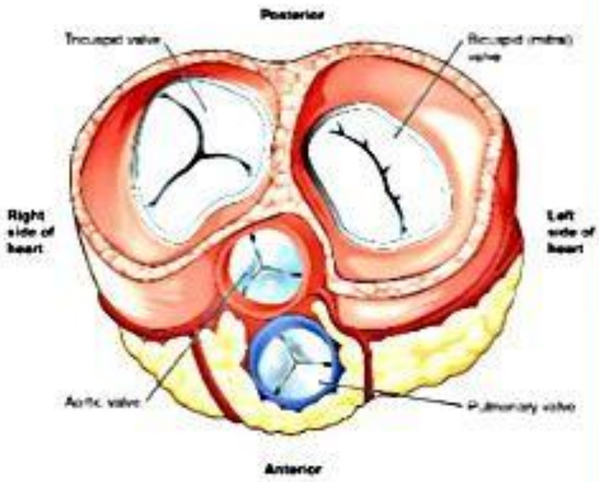


Fig.7.5: Valve of Heart Wall

1. Atrioventricular valves:

- The tricuspid valve and mitral (bicuspid) valve.
- The atrioventricular valves are located between the atria and the ventricles.
- They close during the start of ventricular contraction (systole), producing the first heart sound.
- There are two **AV valves:**

Tricuspid valve

- It located between the right atrium and the right ventricle (right atrioventricular orifice).
- It consists of three cusps
  - (i) Anterior
  - (ii) Septal
  - (iii) Posterior

Mitral valve or Bicuspid

- It is located between the left atrium and the left ventricle (left atrioventricular orifice).
- It is also known as the bicuspid valve because it has **two cusps**
  - **(i) Anterior cusps**
  - **(ii) Posterior cusps**
- Like the tricuspid valve, the base of each cusp is secured to fibrous ring that surrounds the orifice.

2. Semilunar valves

- The pulmonary valve and aortic valve.
- They are located between the ventricles and their corresponding artery, and regulate the flow of blood leaving the heart.
- The semilunar valves are located between the ventricles and outflow vessels.
- They close at the beginning of ventricular relaxation (diastole), producing the second heart sounds.
- There are two semilunar valves:

i. Pulmonary valve

(a) It is located between the right ventricle and the pulmonary trunk (pulmonary orifice).

(b) The valve consists of three cusps are left, right and anterior (named by their position in the foetus before the heart undergoes rotation).

ii. Aortic valve

(a) It is located between the left ventricle and the ascending aorta (aortic orifice).

(b) The aortic valve consists of three cusps are right cusps, left cusps and posterior cusps.

7.4 FLOW OF BLOOD THROUGH THE HEART

- The two largest veins of the body, the superior and inferior venae cava, empty their contents into the right atrium.
- This blood passes via the right atrioventricular valve into the right ventricle, and from there is pumped into the pulmonary artery or trunk (the only artery in the body which carries deoxygenated blood).
- The opening of the pulmonary artery is guarded by the pulmonary valve, formed by three semilunar cusps.
- This valve prevents the backflow of blood into the right ventricle when the ventricular muscle relaxes.
- The pulmonary artery divides into left and right pulmonary arteries, which carry the venous blood to the lungs where exchange of gases takes place: carbon dioxide is excreted and oxygen is absorbed.
- Two pulmonary veins from each lung carry oxygenated blood back to the left atrium.

- Blood then passes through the left atrioventricular valve into the left ventricle, and from there it is pumped into the aorta, the first artery of the general circulation.
- The opening of the aorta is guarded by the aortic valve, formed by three semilunar cusps.
- From this sequence of events, it can be seen that the blood passes from the right to the left side of the heart via the lungs, or pulmonary circulation.
- However, it should be noted that both atria contract at the same time and this is followed by the simultaneous contraction of both ventricles.

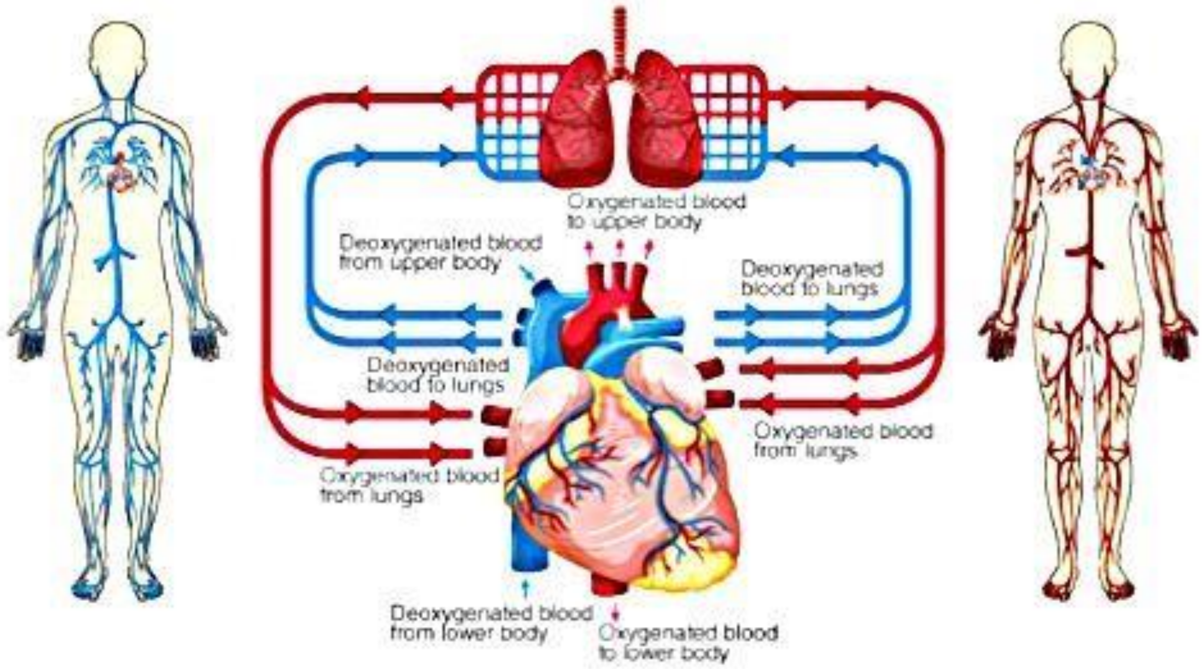


Fig.7.6: Blood flow through the Heart

7.5 BLOOD SUPPLIED TO THE HEART (THE CORONARY CIRCULATION)

✓ Arterial supply

- The arterial supply of the heart is provided by the right and left coronary arteries, which arise from the ascending aorta immediately above the aortic valve.
- The coronary arteries receive about 5% of the blood pumped from the heart, although the heart comprises a small proportion of body weight.
- This large blood supply, especially to the left ventricle.
- The coronary arteries traverse the heart, eventually forming a vast network of capillaries.

✓ Venous drainage

- Most of the venous blood is collected into a number of cardiac veins that join to form the coronary sinus, which opens into the right atrium.
- The remainder passes directly into the heart chambers through little venous channels.

7.6 CONDUCTING SYSTEM TO THE HEART

- Cardiac conduction system is a group of specialized cardiac muscle cells in the walls of the heart that send signals to the heart muscle causing it to contract.
- The main components of the cardiac conduction system are the SA node, AV node, a bundle of His, bundle branches, and Purkinje fibers.
- The SA node (anatomical pacemaker) starts the sequence by causing the atrial muscles to contract.
- From there, the signal travels to the AV node, through the bundle of His, down the bundle branches, and through the Purkinje fibers, causing the ventricles to contract.
- This signal creates an electrical current that can be seen on a graph called an Electrocardiogram (EKG or ECG).

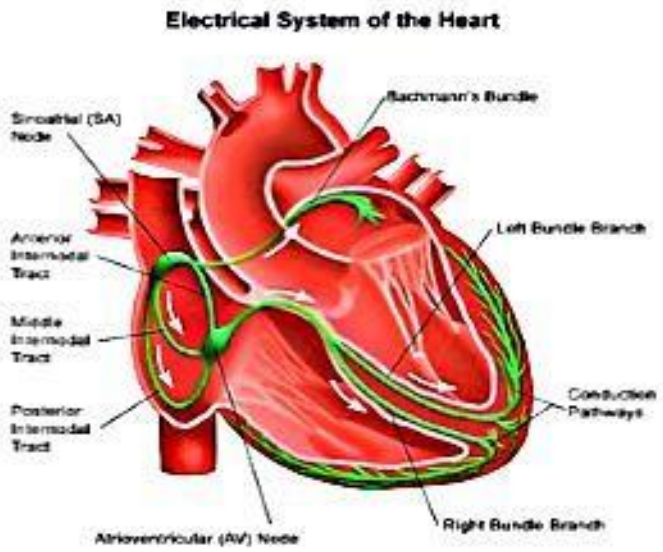


Fig.7.7: Blood flow through the Heart

✓ Sinoatrial node (SA node)

- This small mass of specialised cells lies in the wall of the right atrium near the opening of the superior vena cava.

- The sinoatrial cells generate these regular impulses because they are electrically unstable.
- This instability leads them to discharge (depolarise) regularly, usually between 60 and 80 times a minute.
- This depolarisation is followed by recovery (repolarisation), but almost immediately their instability leads them to discharge again, setting the heart rate.
- Because the SA node discharges faster than any other part of the heart, it normally sets the heart rate and is called the pacemaker of the heart.
- Firing of the SA node triggers atrial contraction.

✓ Atrioventricular node (AV node)

- This small mass of neuromuscular tissue is situated in the wall of the atrial septum near the atrioventricular valves.
- Normally, the AV node merely transmits the electrical signals from the atria into the ventricles.
- There is a delay here; the electrical signal takes 0.1 of a second to pass through into the ventricles.
- This allows the atria to finish contracting before the ventricles start.
- The AV node also has a secondary pacemaker function and takes over this role if there is a problem with the SA node itself, or with the transmission of impulses from the atria.
- Its intrinsic firing rate, however, is slower than that set by the SA node (40–60 bpm).

✓ AV Node Impulse Conduction

- This is a mass of specialised fibres that originate from the AV node.
- The AV bundle crosses the fibrous ring that separates atria and ventricles then, at the upper end of the ventricular septum, it divides into right and left bundle branches.
- Within the ventricular myocardium the branches break up into fine fibres, called the Purkinje fibres.

- The AV bundle, bundle branches and Purkinje fibres transmit electrical impulses from the AV node to the apex of the myocardium where the wave of ventricular contraction begins, then sweeps upwards and outwards, pumping blood into the pulmonary artery and the aorta.

✓ Nerve supply to the heart

- As mentioned earlier, the heart is influenced by autonomic (sympathetic and parasympathetic) nerves originating in the cardiovascular centre in the medulla oblongata.
- The vagus nerves (parasympathetic) supply mainly the SA and AV nodes and atrial muscle. Parasympathetic stimulation reduces the rate at which impulses are produced, decreasing the rate and force of the heartbeat.
- The sympathetic nerves supply the SA and AV nodes and the myocardium of atria and ventricles. Sympathetic stimulation increases the rate and force of the heartbeat.

7.7 FACTORS AFFECTING THE HEART

✓ Heart rate

- The heart rate determines cardiac output.
- If heart rate rises, cardiac output increases, and if it falls, cardiac output falls too.
- The main factors determining heart rate:
  - (i) Autonomic nervous system
  - (ii) Circulating chemicals [hormones adrenaline (epinephrine) and noradrenaline (norepinephrine)]
  - (iii) Position
  - (iv) Exercise
  - (v) Emotional states
  - (vi) Gender and Age
  - (vii) Temperature
  - (viii) Baroreceptor reflex

7.8 CARDIAC CYCLE

- The cardiac cycle is the performance of the human heart from the beginning of one heartbeat to the beginning of the next.
- It consists of two parts:

1. **Ventricular contraction called systole.**
2. **Ventricular relaxation called diastole.**

- A healthy heart beat at a rate of 60 to 80 beats per minute, each cardiac cycle, or heartbeat, takes about 0.8 second to complete the cycle.
- Duration of different stages of the cardiac cycle is given below:

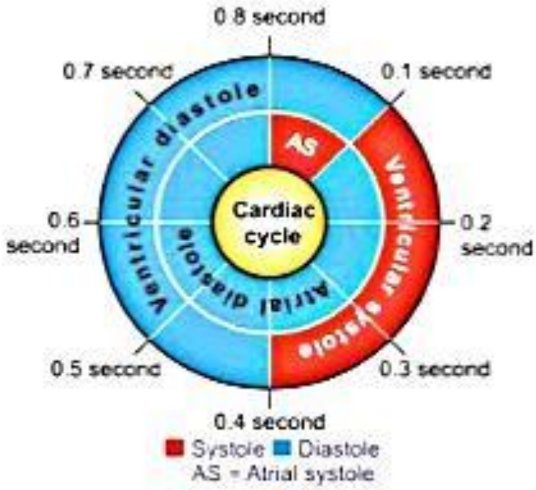


Fig. 7.8 : Cardiac Cycle

i. Ventricle: 0.8 sec

(a) Ventricular systole: 0.3 second
(b) Ventricular diastole: 0.5 second

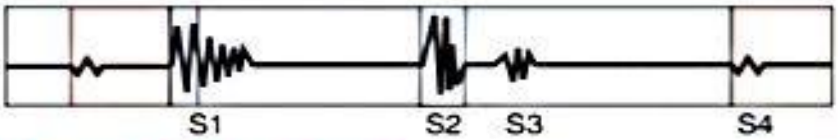
ii. Atrial: 0.8 sec

(a) Atrial systole: 0.1 second
(b) Atrial diastole: 0.7 second

✓ Heart sound

- Contraction and relaxation of heart produces sounds
- There are four heart sounds, each corresponding to a particular event in the cardiac cycle.
- The first two are most easily distinguished, and sound through the stethoscope like "lub dup".
- The first sound (S_1) "Lub" is fairly loud and is produced by the closure of the atrioventricular valves at the beginning of ventricular systole.
- The second sound (S_2) is "Dub" is softer and is produced by the closure of the semilunar valves (aortic valve and pulmonic valve) at the end of ventricular systole.

- The third heart sound (S_3) is a faint sound and it is due to blood turbulence during rapid ventricular filling.
- The fourth heart sound (S_4) is an abnormal late diastolic sound and it is due to blood turbulence during atrial systole.



✓ Electrical changes in the heart

- As the body fluids and tissues are good conductors of electricity, the electrical activity within the heart can be detected by attaching electrodes to the limbs and chest.
- The pattern of electrical activity may be displayed on an oscilloscope screen or traced on paper.
- The electrocardiogram (ECG) is a measure of the overall electrical activity of the heart.
- The apparatus used is an electrocardiograph and the tracing is an electrocardiogram (ECG).

- The normal ECG tracing shows five waves which, by convention, have been named P, Q, R, S and T.
- The P wave is caused by atrial depolarization, the QRS complex is caused by ventricular depolarization, and the T wave is caused by ventricular repolarization.
- The P wave is caused by atrial depolarization, the QRS complex is caused by ventricular depolarization, and the T wave is caused by ventricular repolarization

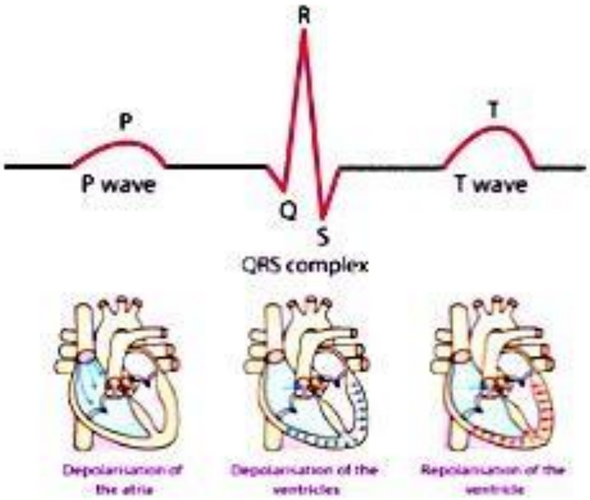


Fig.7.9 : A Normal Electrocardiogram(ECG)

- The P wave arises when the impulse from the SA node sweeps over the atria (atrial depolarisation).
- The QRS complex represents the very rapid spread of the impulse from the AV node through the AV bundle and the Purkinje fibres and the electrical

activity of the ventricular muscle (ventricular depolarisation).

- The T wave represents the relaxation of the ventricular muscle (ventricular repolarisation).

✓ Cardiac Output

- The cardiac output is the amount of blood ejected from each ventricle every minute.
- The amount expelled by each contraction of each ventricle is the **stroke volume.**
- Cardiac output is expressed in litres per minute (l/min) and is calculated by multiplying the stroke volume by the heart rate (measured in beats per minute):

Cardiac Output(CO) = Stroke Volume (SV) x Heart Rate (HR)
(mL/min) (mL/beat) (beats/min)

- In a healthy adult at rest, the stroke volume is approximately 70 ml and if the heart rate is 72 per minute, the cardiac output is 5 lit./minute.
- Following Factors affecting cardiac output: Heart rate and stoke volume
- Factors affecting stroke volume:
  1. VEDV (ventricular end-diastolic volume – preload)
  2. Venous return
     – Position of the body
     – Skeletal muscle pump
     – Respiratory pump
  1. Strength of myocardial contraction
  2. Blood volume

✓ Stroke Volume

- Stroke Volume (SV) is the volume of blood pumped from the left ventricle per beat.
- Stroke volume is calculated using measurements of ventricle volumes from an echocardiogram.
- The stroke volume is determined by the volume of blood in the ventricles immediately before they contract, i.e. the ventricular end-diastolic volume (VEDV), sometimes called preload.
- In turn, preload depends on the amount of blood returning to the heart

through the superior and inferior vena cava (the venous return).

- Increased preload leads to stronger myocardial contraction, and more blood is expelled.
- In turn the stroke volume and cardiac output rise.
- Stoke volume is calculated by

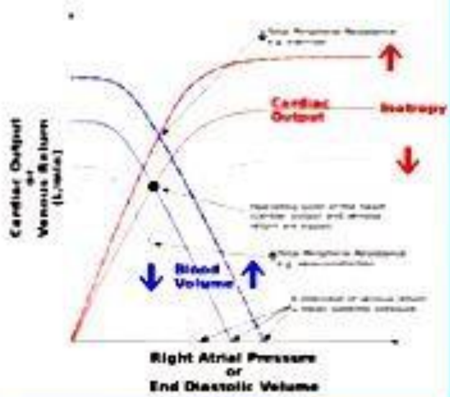
SV = End Diastolic Volume (EDV) - End Systolic Volume (ESV)

- Three factors regulate stroke volume and ensure that the left and right ventricles pump equal volumes of blood:
  (a) Preload, the degree of stretch on the heart before it contracts.
  (b) Contractility, the forcefulness of contraction of individual ventricular muscle fibres.
  (c) Afterload, the pressure that must be exceeded before ejection of blood from the ventricles can occur.
- Other factors that increase myocardial contraction include:
  (a) Increased sympathetic nerve activity to the heart
  (b) Hormones, e.g. adrenaline (epinephrine), noradrenaline (norepinephrine), Thyroxine.

➢ Arterial blood pressure

- This affects the stroke volume as it creates resistance to blood being pumped from the ventricles into the great arteries.
- This resistance is determined by the distensibility, or elasticity, of the large arteries and the peripheral resistance of arterioles.
- Increasing afterload increases the workload of the ventricles, because it increases the pressure against which they have to pump.
- This may actually reduce stroke volume if systemic blood pressure becomes significantly higher than normal.

➢ Venous return



- Venous return is the quantity of blood flowing from the veins into the right atrium each minute.
- The venous return and cardiac output must equal each other except for a few heart beats at a time when blood is temporarily stored in or removed from the heart and lungs.

- Other factors are involved:
  (a) The position of the body
  (b) Muscular contraction
  (c) The respiratory pump

7.9 BLOOD CIRCULATION

- Depending on the course of blood, circulation can be classified into:
  1. **Systemic circulation/ Greater circulation**
  2. **Pulmonary circulation/ Lesser circulation**
  3. **Portal circulation**

1. Systemic circulation

- Systemic circulation is the part of the cardiovascular system which carries oxygenated blood away from the heart to the body and returns deoxygenated blood back to the heart.
- The oxygenated blood pumped out from the left ventricle is carried by the branches of the aorta.
- From the aorta the blood divides into smaller systemic arteries that carry it to all organs throughout the body-except for the air sac alveoli of the lungs, which are supplied by pulmonary circulation.

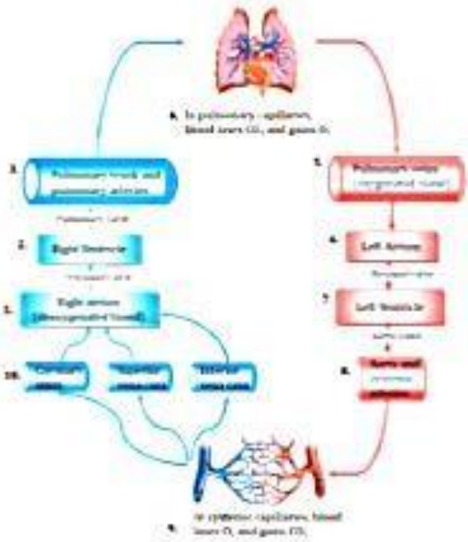


Fig.7.10: Blood Circulation

- In systemic tissues, arteries give rise to smaller diameter arterioles, which finally lead into extensive beds of systemic capillaries.
- The exchange of nutrients and gases occurs across the thin capillary walls.
- The blood **unloads O_2 (oxygen) and picks up CO_2 (carbon dioxide).** In most cases, blood flows through only one capillary and then enters a systemic venule.
- Venules carry deoxygenated blood away from tissues and merge to form larger systemic veins.
- Ultimately the deoxygenated blood flows back to the **right atrium.**
- The circulation of blood from left ventricle to the right atrium is called Systemic circulation.

2. Pulmonary circulation

- The right side of the heart is the pump for pulmonary circulation.
- The pulmonary circulation brings deoxygenated blood ejected from the right ventricle flows into the pulmonary trunk, which branches into pulmonary arteries that carry blood to the right and left lungs.
- On entering the lungs, the branches divide and subdivide until finally they form capillaries around the air sacs (alveoli) within the lungs.
- CO_2 passes from the blood into the air sacs and is exhaled and inhaled O_2 passes from the air within the lungs into the blood.
- The pulmonary capillaries unite to form venules and eventually pulmonary veins, which exit the lungs and carry the oxygenated blood to the left atrium.
- Two left and two right pulmonary veins enter the left atrium and the pulmonary veins are the only veins that carry oxygenated blood.
- Contractions of the left ventricle then eject the oxygenated blood into the systemic circulation.
- The circulation of blood from right ventricle to the left atrium is called Systemic circulation.

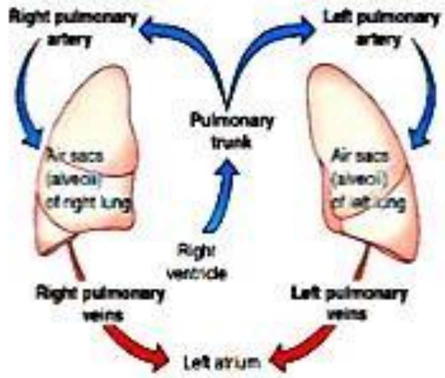


Fig.7.11: Pulmonary Circulation

2. Portal circulation

- In the portal circulation, venous blood passes from the capillary beds of the abdominal part of the digestive system, the spleen and pancreas are collected by the portal vein and content pours into the liver.
- A vein that carries blood from one capillary network to another is called a portal vein.
- The portal vein is formed by joining together the veins such as splenic vein from spleen, inferior mesenteric from rectum and colon, superior mesenteric vein from small intestine, gastric vein from stomach and cystic vein from gall bladder.
- In this way, blood with a high concentration of nutrients, absorbed from the stomach and intestines, goes to the liver first and liver supply oxygenated blood by hepatic artery.

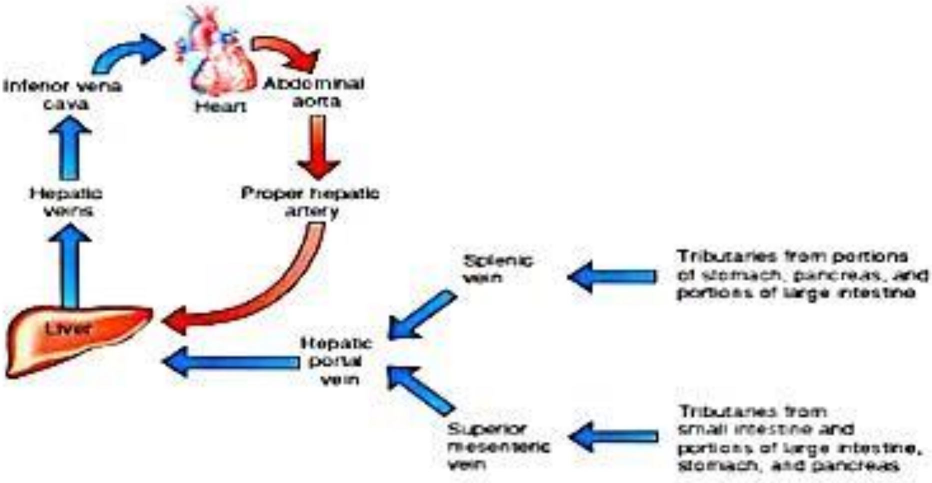


Fig.7.12: Scheme of principle blood vessels of hepatic portal circulation and the arterial supply and venous drainage of liver

7.10 BLOOD VESSEL

- Blood vessels are the components of the circulatory system that transport blood throughout the human body.
- Blood is carried through the body via blood vessels.
- An artery is a blood vessel that carries blood away from the heart where it branches into ever-smaller vessels.
- Eventually, the smallest arteries, vessels called arterioles, further branch into tiny capillaries, where nutrients and wastes are exchanged, and then combine with other vessels that exit capillaries to form venules, small blood vessels that carry blood to a vein, a larger blood vessel that returns blood to the heart.
- The walls of blood vessels may contain varying amounts of fibrous tissue, elastic tissue, and smooth muscle.
- Although the structure of the walls of arteries and veins displays important differences which reflect their different functions, both contain three layers of tissue:
  - **(i) Tunica interna (internal layer- epithelial lining)**
  - **(ii) Tunica media (middle lining- smooth muscles + elastic connective tissue)**
  - **(iii) Tunica externa/adventitia (outer lining –connective tissue) covering**

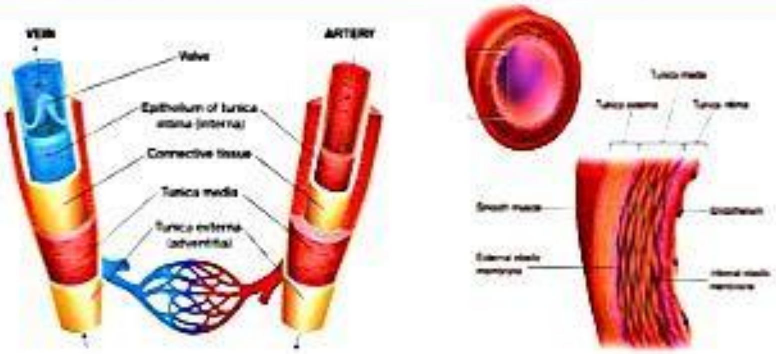


Fig. 7.13: Structure of an Artery and a Vein

- They consist of three layers of tissue:
- Blood vessels vary in structure, size and function, and there are several types: **arteries, arterioles, capillaries, venules and veins**

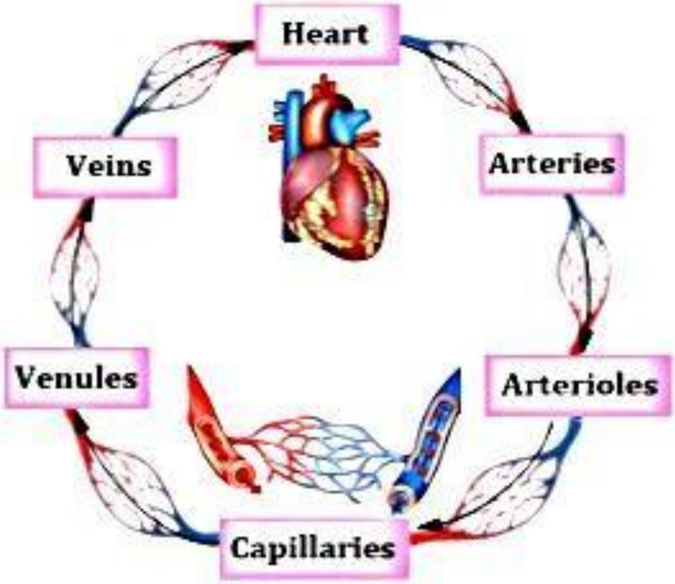


Fig.7.14: The relationship between the heart and the different types of blood vessel

- Arteries and their smaller branches, arterioles, carry blood away from the heart.
- Arterioles branch into enormous networks of thin-walled capillaries, tiny exchange vessels which allow nutrients, water and oxygen to diffuse into the tissues, and cellular wastes such as carbon dioxide to diffuse into the bloodstream and be transported away.
- Capillaries merge to form small venules, which in turn merge to form large veins, carrying blood back to the heart.

✓ Arteries

- Arteries are the main blood vessels that carry and transport oxygenated blood or oxygen-rich blood from the heart to other parts of the body.

- They are the strongest blood vessels with thicker walls and are muscular in nature.
- It consists of three distinct layers, which are rigid, thicker and highly muscular.
- Arteries are located deep within the body and are red in colour.
- These blood vessels are with high pressure and move in a downward direction from the heart to the body tissues.

✓ Arterioles

- Larger arteries leave the heart and divide into medium sized muscular arteries.
- Medium sized arteries then divide into small arteries which in turn divide into still smaller arteries called as arterioles.
- The approximately 400 million arterioles have diameters that range in size from 15 μm to 300 μm.
- It delivers blood and regulates the flow of blood to capillaries.
- The terminal end of the arteriole, the region called the metarteriole, tapers toward the capillary junction.
- Arterioles play a key role in regulating blood flow from arteries into capillaries by regulating resistance, the opposition to blood flow due to friction between blood and the walls of blood vessels.

✓ Capillaries

- Capillaries, the smallest of blood vessels, have diameters of 5– 10 μm, and form the U-turns that connect the arterial outflow to the venous return.
- In capillaries, nutrients, gases, and wastes are exchanged between the blood and interstitial fluid.
- These blood vessels also function by connecting arterial systems to the venous system and help in exchange of substances across cells.

✓ Venules

- Venules drain the capillary blood and begin the return flow of blood back toward the heart.
- They are the smallest venules, measuring 10 μm to 50 μm in diameter,
- They collect blood from capillaries and deliver it to veins.

✓ **Veins**

- Veins are blood vessels that return blood at low pressure to the heart.
- The walls of the veins are thinner than those of arteries but have the same three layers of tissue.
- They range in size from 0.5 mm in diameter for small veins to 3 cm in the large superior and interior venae cavae entering the heart.
- They are thinner because there is less muscle and elastic tissue in the tunica media, because veins carry blood at a lower pressure than arteries.

7.11 BLOOD PRESSURE

- Blood pressure is the force or pressure that the blood exerts on the walls of the blood vessels.
- If it becomes too high, blood vessels can be damaged, causing clots or bleeding from sites of blood vessel rupture.
- If it falls too low, then blood flow through tissue beds may be inadequate.
- This is particularly dangerous for such essential organs as the heart, brain or kidneys.
- The systemic arterial blood pressure, usually called simply arterial blood pressure, is the result of the discharge of blood from the left ventricle into the already full aorta.
- Blood pressure varies according to the time of day, the posture, gender and age of the individual. Blood pressure falls at rest and during sleep.
- It increases with age and is usually higher in women than in men.
- It has two types of blood pressure:
  1. **Systolic blood pressure:** It is the maximum blood pressure. This occurs during the systole of the heart. (Range 100 to 120 mm Hg.)
  2. **Diastolic blood pressure:** It is the minimum pressure. It occurs during the diastole of the heart (Range 60 to 80 mm Hg.)
- The pulse pressure is the difference between the systolic and diastolic pressures:

Pulse pressure = Systolic pressure - Diastolic pressure

Therefore, using the average values of 120 mmHg (systolic) and 80 mmHg (diastolic), the pulse pressure is

Pulse pressure = 120 mmHg – 80 mmHg = 40 mmHg

✓ Factors determining Blood Pressure

- Blood pressure is determined by cardiac output and peripheral resistance.
- Change in either of these parameters tends to alter systemic blood pressure, although the body's compensatory mechanisms usually adjust for any significant change.

Blood Pressure = Cardiac Output x Peripheral Resistance

➢ Cardiac Output (CO)

- Cardiac output is determined by the stroke volume and the heart rate.
- Factors that affect the heart rate and stroke volume and they may increase or decrease cardiac output and, in turn, blood pressure.
- An increase in cardiac output raises both systolic and diastolic pressures.
- An increase in stroke volume increases systolic pressure more than it does diastolic pressure.

➢ Peripheral or arteriolar resistance

- Arterioles are the smallest arteries and they have a tunica media composed almost entirely of smooth muscle, which responds to nerve and chemical stimulation.
- Constriction and dilation of the arterioles are the main determinants of peripheral resistance.
- Vasoconstriction causes blood pressure to rise and vasodilation causes it to fall.
- When elastic tissue in the tunica media is replaced by inelastic fibrous tissue as part of the ageing process, blood pressure rises.

➢ Autoregulation

- Systemic blood pressure rises and falls constantly, according to levels of activity, body position, etc.
- However, the organs of the body are capable of adjusting blood flow and blood pressure in their own local vessels independently of systemic blood pressure.
- This property is called autoregulation, and protects the tissues against swings in systemic pressures.

✓ Control of Blood Pressure (BP)

- Blood pressure is controlled in two ways:
  (i) Short-term control, on a moment-to-moment basis, which mainly involves the baroreceptor reflex, and also chemoreceptors and circulating hormones.
  (ii) Long-term control, which involves regulation of blood volume by the kidneys and the renin–angiotensin– aldosterone system.

➢ Baroreceptors:

- The baroreceptors provide the most important source of input to the vasomotor center; these receptors monitor blood pressure in the systemic circulatory system.
- They are found in two locations: the arch of the aorta and the carotid sinuses.
- As the aorta exits the left ventricle, it curves over the top of the heart, forming an arch, and then descends through the thoracic and abdominal cavities.
- Baroreceptors respond to stretch or distension of the blood vessel walls, they are also referred to as stretch receptors.
- A change in blood pressure will elicit the baroreceptor reflex, which involves negative feedback responses that return blood pressure to normal.

➢ Chemoreceptors:

- These are nerve endings situated in the carotid and aortic bodies, and are primarily involved in control of respiration
- They are sensitive to changes in the levels of carbon dioxide, oxygen and the acidity of the blood (pH)
- Chemoreceptors are found on the brain surface in the medulla oblongata, and they measure carbon dioxide/oxygen levels and pH of the surrounding cerebrospinal fluid.
- Chemoreceptor input to the cardiovascular centre influences its output only when severe disruption of respiratory function occurs or when arterial BP falls to less than 80 mmHg.

- **Higher centres in the brain:**

- Input to the CVC from the higher centres is influenced by emotional states such as fear, anxiety, pain and anger that may stimulate changes in blood pressure.
- The hypothalamus in the brain controls body temperature and influences the CVC, which responds by adjusting the diameter of blood vessels in the skin.
- This is an important mechanism in determining **heat loss and retention.**

7.12 PULSE

- The pulse is a wave of distension and elongation felt in an artery wall each time the left ventricle ejects blood into the system.
- Each contraction of the left ventricle forces about 60 to 80 millilitres of blood through the already full aorta and into the arterial system.
- The number of pulse beats per minute normally represents the heart rate and varies considerably in different people and in the same person at different times. An average of 60 to 80 is common at rest.
- Information that may be obtained from the pulse includes:
  (i) The rate at which the heart is beating
  (ii) The regularity of the heartbeat – the intervals between beats should be equal
  (iii) The volume or strength of the beat – it should be possible to compress the artery with moderate pressure, stopping the flow of blood; the compressibility of the blood vessel gives some indication of the blood pressure and the state of the blood vessel wall
  (iv) The tension – the artery wall should feel soft and pliant under the fingers.

✓ Factors affecting the pulse rate

(i) Age: As age increases, the pulse rate gradually decreases overall.
(ii) Sex: After puberty, the average male's pulse rate is slightly lower than the female's.
(iii) Exercise: Pulse rate increases with activity.
(iv) Fever: Pulse rate increases with elevated body temperature because of the increased metabolic rate.

(iv) **Medications:** Some medications decrease the pulse rate, and some increase

7.13 DISORDERS OF BLOOD PRESSURE

✓ Hypertension

- Hypertension is defined as a consistent elevation in blood pressure such that systolic/diastolic pressures
- It is classified into the following: Essential (primary, idiopathic) and Secondary to other diseases.

(i) Essential hypertension

➢ Benign (chronic) hypertension:

- The rise in blood pressure is usually slight to moderate and continues to rise slowly over many years.
- Sometimes complications, such as heart failure, cerebrovascular accident or myocardial infarction are the first indication of hypertension, but often the condition is symptomless
- Risk factors for hypertension include obesity, diabetes mellitus, family history, cigarette smoking, a sedentary lifestyle and high intakes of salt or alcohol.
- Stress may increase blood pressure.

➢ Malignant (accelerated) hypertension

- This is a rapid and aggressive acceleration of hypertensive disease. Diastolic pressure in excess of 120 mmHg is common.
- The effects are serious and quickly become apparent
- E.g. haemorrhages into the retina, papilloedema (oedema around the optic disc), encephalopathy (cerebral oedema) and progressive renal disease, leading to cardiac failure.

(ii) Secondary hypertension

- Hypertension resulting from other diseases accounts for 5% of all cases.

➢ Kidney disease

- Raised blood pressure is a complication of many kidney diseases.
- In kidney disease, there is salt and water retention, sometimes with excessive renin activity.

Endocrine disorders

(i) Adrenal cortex

- Secretion of excess aldosterone and cortisol stimulates the retention of excess sodium and water by the kidneys, raising the blood volume and pressure.
- Oversecretion of aldosterone (Conn's syndrome) is due to a hormone secreting tumour.
- Oversecretion of cortisol may be due to overstimulation of the gland by adrenocorticotrophic hormone secreted by the pituitary gland, or to a hormone-secreting tumour.

(ii) Adrenal medulla

Secretion of excess adrenaline (epinephrine) and noradrenaline (norepinephrine) raises blood pressure, e.g. phaeochromocytoma.

Structure of the aorta

- Hypertension develops in branching arteries proximal to the site of a stricture, e.g congenital coarctation.

Drug treatment

- Hypertension may be a side-effect of some drugs, e.g. corticosteroids and oral contraceptives.

Effects and complications of hypertension

- The effects of long-standing and progressively rising blood pressure are serious.
- The excessive pressure on the artery walls caused by high blood pressure can damage blood vessels and body organs.
- The higher the blood pressure and the longer it goes uncontrolled, the greater the damage.
- Hypertension predisposes to atherosclerosis and has specific effects on particular organs.

(i) **Heart:** The rate and force of cardiac contraction are increased to maintain the cardiac output against a sustained rise in arterial pressure. Hypertension raises the risk of aneurysm formation and ischemic heart disease.

(ii) Brain: Brain Stroke, caused by cerebral haemorrhage, is common, the effects depending on the position and size of the ruptured vessel. When a series of small blood vessels rupture, e.g. microaneurysms, at different times, there is progressive disability.

(iii) Kidneys: Essential hypertension causes kidney damage. If sustained for only a short time recovery may be complete. Kidney damage causes further hypertension owing to activation of the renin-angiotensin-aldosterone system, progressive loss of kidney function and kidney failure.

(iv) Blood vessels: High blood pressure damages blood vessels. The walls of small arteries become hardened, and in larger arteries, atheroma is accelerated. If other risk factors for vascular disease are present, such as diabetes or smoking, damage is more extensive.

7.14 DISORDERS OF CARDIOVASCULAR SYSTEM

(i) Heart (cardiac) failure

- The heart is described as failing when the cardiac output is unable to maintain the circulation of sufficient blood to meet the needs of the body.
- Heart failure can affect the left or right side of the heart, but because the two sides are connected by a single circuit, when one side of the pump fails, it usually causes the other side to become more stressed and eventually fail as well.
- The main clinical manifestations depend on which side of the heart is most affected.
- Due to the left ventricle's higher workload, left ventricular failure is more common than right ventricular failure.

(ii) Ischaemic Heart Disease

- Ischaemic heart disease (IHD), also known as coronary artery disease (CAD) or coronary heart disease (CHD),
- This condition that occurs when the blood supply to the heart muscle is reduced or obstructed, usually due to the build-up of fatty deposits (atherosclerosis) in the coronary arteries.
- These arteries supply oxygen-rich blood to the heart muscle, and when they become narrowed or blocked
- This either leads to Angina pectoris and Myocardial infraction

(a) Angina pectoris

- This is sometimes called angina of effort because the increased cardiac output required during extra physical effort causes severe chest pain, which may also radiate to the arms, neck and jaw.
- Other factors that may precipitate angina include cold weather and emotional states.

(b) Myocardial infarction (MI)

- Myocardial infarction (MI), commonly known as a heart attack, occurs when blood flow to a part of the heart muscle is blocked, leading to damage or death of the heart tissue.
- The blockage is often caused by a blood clot that forms in a coronary artery, which supplies blood to the heart muscle.

(iii) Rheumatic heart disease

- Rheumatic fever is an inflammatory illness that sometimes follows streptococcal throat infections, most commonly in children and young adults.
- It is an autoimmune disorder; the antibodies produced to combat the original infection damage connective tissues, including the heart, joints and skin.
- Death rarely occurs in the acute phase, but after recovery there may be permanent damage to the heart valves, eventually leading to disability and possibly cardiac failure

(iv) Infective endocarditis

- Infectious endocarditis is the inflammation of the endocardium, the inner lining of the heart, as well as the valves that separate each of the four chambers within the heart.
- Causative organism is usually bacteria, rickettsia, chlamydia or fungus.
- The cause is typically a bacterial infection and less commonly a fungal infection.
- The main predisposing factors are bacteraemia, depressed immune response and heart abnormalities.

(v) Cardiac arrhythmias

- A cardiac arrhythmia is any disorder of heart rate or rhythm, and is the result of abnormal generation or conduction of impulses.
- The normal cardiac cycle gives rise to normal sinus rhythm, which has a rate of between 60 and 100 bpm.
- The heart's normal rhythm is coordinated by electrical signals that regulate the contraction and relaxation of the heart muscle.
- When this electrical system is disrupted, it can lead to a variety of arrhythmias, which can be classified into different types based on their origin and characteristics.
- Fibrillation is the contraction of the cardiac muscle fibres.
- In atrial fibrillation, contraction of the atria is uncoordinated and rapid, pumping is ineffective and stimulation of the AV node is disorderly.
- Ventricular fibrillation is a medical emergency that will swiftly lead to death if untreated, because the chaotic electrical activity within the ventricular walls cannot coordinate effective pumping action (cardiac arrest).
- Blood is not pumped from the heart into either the pulmonary or the systemic circulation. No pulses can be felt, consciousness is lost and breathing stops.

(vi) Congenital abnormalities

- These are morphological defects that are present at birth.
- It estimated that about 3% of newborns have a major malformation which causes 20-25% of infant dying in perinatal period.
- Moreover, they continue to be a significant cause of illness, disability & death throughout the early years of life.
- The most common severe congenital disorders are heart defects, neural tube defects and Down syndrome.