

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

Chapter

11

HUMAN CIRCULATORY SYSTEM

Student Learning Outcomes (SLOs)

After studying this chapter, the students will be able to:

- State the location of heart in the body and define the role of pericardium.
- Describe the structure of the walls of heart and rationalize the thickness of the walls of each chamber.
- Trace the flow of blood through the heart as regulated by the valves.
- State the phases of heartbeat.
- Explain the role of SA node, AV node and Purkinje fibers in controlling the heartbeat.
- List the principles and uses of Electrocardiogram.
- Describe the detailed structure of arteries, veins and capillaries.
- Describe the role of arterioles in vasoconstriction and vasodilation.
- Describe the role of precapillary sphincters in regulating the flow of blood through capillaries.
- Trace the path of the blood through the pulmonary and systemic circulation (coronary, hepaticportal and renal circulation).
- Compare the rate of blood flow through arteries, arterioles, capillaries, venules and veins.
- Define blood pressure.
- State the role of baroreceptors and volume receptors in regulating the blood pressure.
- Define the term thrombus and differentiate between thrombus and embolus.
- Identify the factors causing atherosclerosis and arteriosclerosis.
- Categorize Angina pectoris, heart attack, and heart failure as the stages of cardiovascular disease development.
- State the congenital heart problem related to the malfunctioning of cardiac valves.
- Describe the principles of angiography.
- Outline the main principles of coronary bypass, angioplasty and open-heart surgery.
- Define hypertension and describe the factors that regulate blood pressure and can lead to hypertension and hypotension.
- List the changes in lifestyles that can protect man from factors that regulate blood pressure and can lead to hypertension and hypotension.
- List the changes in lifestyles that can protect man from hypertension and cardiac problems.
- Describe the formation, composition and function of intercellular fluid.
- Compare the composition of intercellular fluid with that of lymph.
- State the structure and role of lymph capillaries, lymph vessels and lymph trunks.
- Describe the functions of lymph nodes and state the role of spleen as containing lymphoid tissue.

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➤ Types of Transport Systems in Human:

- Humans have **two systems** for the transport of different materials in different parts of body:
(a) **Blood circulatory system** (b) **Lymphatic system**
- The **closed blood circulatory system** of humans consists of **blood, heart, and blood vessels** (arteries, capillaries and veins).

Recalling Composition of Blood

- Blood is the medium in which dissolved nutrients, gases, hormones, and wastes are transported throughout the body.
- It is composed of two main components:
(i) **Plasma** (ii) **Cells or cell-like bodies** (white blood cells, red blood cells, platelets).
- In a healthy person, **plasma** constitutes about **55% by volume** of the **blood**, and cells or cell-like bodies about **45% by volume** of the blood.

STRUCTURE AND FUNCTIONING OF HEART

- Heart As Pump:** Human heart is a hard-working pump that moves blood **through body**.
- Location of Heart:** It is situated in the **middle** of chest cavity (between the lungs).
- Its **back surface** is near vertebral column while its **front surface** is behind sternum and rib cartilages.

➤ Pericardium:

Heart is enclosed in a sac called **pericardium** (Figure). Pericardium separates heart from surrounding organs.

➤ Layers of Pericardium:

- It is composed of the following two layers:
 - Outer Layer of Pericardium:** It is called fibrous pericardium. It is made of strong connective tissue. It protects heart against external **pressure and shocks**. It also prevents excessive dilation of heart.
 - Inner Layer of Pericardium:** It is called serous pericardium. It is a sac, made of further two layers i.e.,
 - Outer Parietal Pericardium:** Present beneath fibrous pericardium.
 - Inner Visceral Pericardium:** Also called epicardium (closely attached to the underlying heart).
- Pericardial Cavity:** The space between parietal and visceral pericardium is called **pericardial cavity**.
- It contains up to **50 mL** pericardial fluid. It lubricates heart and protects it from **infections**.

Feeling of Heart Left Side

- The heart is usually felt to be on the left side because the **left side of heart** is stronger and larger, since it **pumps to all body parts**.
- Because the heart is between the lungs, the left lung is smaller than the right lung and has a cardiac notch in its border to accommodate the heart.

Check Understanding!

1. The protective membrane of human heart is:

- (A) Epicardium (B) Endocardium
(C) Myocardium (D) Pericardium

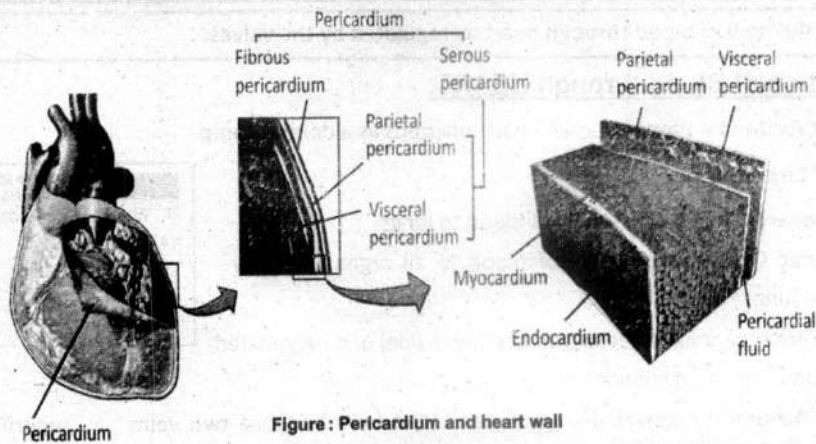
Q. Describe the structure of the walls of heart and rationalize the thickness of the walls of each chamber.

[Exercise L.Q.1]

➤ Wall of the Heart:

- The wall of heart is composed of **three layers**.
 - Epicardium:** The inner layer of pericardium, it makes the outer lining of heart wall.
 - Myomycardium:** Beneath epicardium, there is the **thickest** layer of heart wall i.e., **myocardium**. Myocardium is made of cardiac muscles.
 - Endocardium:** It is present beneath myocardium. It is a single layer of epithelial cells and make the inner linings of heart chambers (Figure).

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Chambers and Valves of Heart

- **Chambers of Heart:** There are four chambers of heart:
 - (a) Two Upper Thin-Walled Atria.
 - (b) Two Lower Thick-Walled Ventricles.
- Atria receive blood from body and pass it to **ventricles**, which distribute blood to body.
- **Atrioventricular Septum:** Atria and ventricles are separated by atrioventricular septum.
- **Interatrial Septum:** The left and right atria are separated from each other by an interatrial septum.
- **Interventricular Septum:** The left and right ventricles are separated from each other by an interventricular septum. It is much thicker than the **interatrial septum**.
- At the entrance points of ventricles (in atrioventricular septum), there are two atrioventricular valves i.e., a tricuspid valve and a bicuspid valve.
- **Tricuspid Valve:** It is made of three cusps present between right atrium and right ventricle.
- **Bicuspid (Mitral) Valve:** It is made of two cusps present between left atrium and left ventricle.
- When ventricles contract, tricuspid and bicuspid valves close and prevent the back flow of blood into atria.
- **Semilunar Valves:** At the exit points of ventricles, there are two semilunar valves (with shapes like a half-moon). These are called **pulmonary valve** and **aortic valve**.
- **Pulmonary Valve:** It is located at the base of pulmonary artery.
- **Aortic Valve:** It is present at the base of aorta. When ventricles relax, pulmonary and aortic valves close. So, they prevent back flow of blood from pulmonary artery and aorta into ventricles.

Check Understanding!
2. Why are valves essential in the human heart, and what could happen if they malfunction?

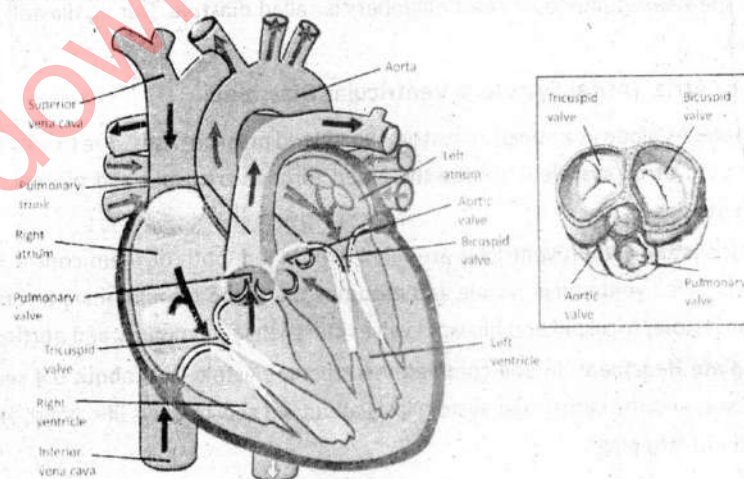


Figure: Human Heart and valves

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Q. Describe the flow of blood through heart as regulated by the valves.

[Exercise L.Q.2]

➤ Circulation of Blood through HEART:

- **Heart As Double Pump:** Human heart functions as a double pump.

➤ Types of Circulation:

(i) **Pulmonary Circulation:** Supply of blood to lungs.

(ii) **Systemic Circulation:** Supply of blood to all organs of body - except lungs.

- Complete separation of deoxygenated (right side) and oxygenated (left side) blood is maintained in heart.
- **Right Atrium:** It receives deoxygenated blood from body via **two veins** i.e., **superior vena cava** and **inferior vena cava**. Right atrium passes this blood to **right ventricle** via tricuspid valve.
- When **right ventricle** contracts, deoxygenated blood is passed to **pulmonary trunk** via semilunar pulmonary valve.
- The pulmonary trunk divides into left and right **pulmonary arteries** which carry this blood to lungs, for oxygenation.
- The **oxygenated** blood from lungs is brought to left atrium by pulmonary veins.
- Left atrium passes this blood to **left ventricle** via bicuspid (or mitral) valve. When left ventricle contracts, oxygenated blood is passed to aorta via semilunar aortic valve. Aorta carries this blood to all parts of body (except lungs).

Check Understanding!

3. Which vein has oxygenated blood?

- (A) Femoral vein
- (B) Pulmonary vein
- (C) Subclavian vein
- (D) Jugular vein

Walls of Ventricle

- The wall of left ventricle is thicker (about 3 times) than that of the right ventricle because it has to push the blood to all over body.

➤ Cardiac Cycle Heartbeat:

- The alternating **relaxations** and **contractions** of heart are collectively called a **cardiac cycle** or one heartbeat.
- Heart works in continuous cycles. Its chambers **relax** and are **passively** filled with blood from large veins. Then, its chambers contract and propel the blood throughout body.
- **Relaxation of Atria & Ventricles:** While atria are relaxed and being filled with blood, the ventricles are also relaxed.
- **Diastole:** The relaxed period of heart chambers is called **diastole**. During diastole, both atria are filled with blood.

➤ Contraction of Atria (Atrial Systole & Ventricular Diastole):

- **Atrial Systole:** As blood accumulates in atria, their blood pressure rises, due to which **both atria contract**, which is called **atrial systole** it passes the blood through **tricuspid** and **bicuspid** valves into the two **relaxed ventricles**.
- **Ventricular Systole:** When ventricles are filled with blood, both of them contract. This contraction of ventricles is called ventricular systole and it **pumps the blood** to pulmonary arteries and aorta. During ventricular systole, tricuspid and bicuspid valves close while pulmonary and **aortic valves open**.
- **One Complete Heartbeat:** In one complete heartbeat, diastole lasts **about 0.4 sec**, atrial systole takes about **0.1 sec**, and the ventricular systole lasts about **0.3 sec**. In one's life, heart beats about **2.5 billion** times, without stopping.

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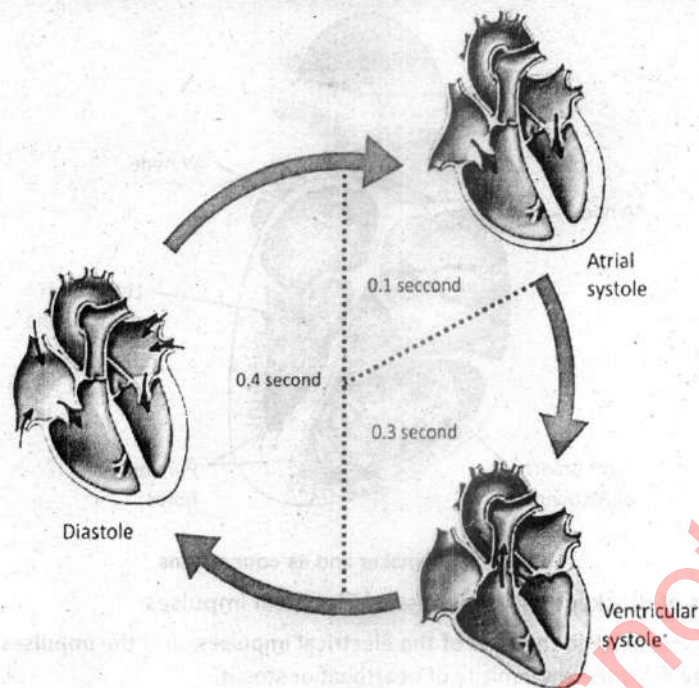


Figure: Cardiac cycle (one heartbeat)

☞ **Sounds of a Heartbeat:**

- **Lubb Sound:** When both ventricles contract simultaneously to pump the blood to pulmonary arteries and aorta, the **tricuspid** and **bicuspid** valves close and "lubb" sound is made.
- **Dubb Sound:** When ventricular systole ends and both ventricles relax simultaneously, the pulmonary and aortic semilunar valves close and "dubb" sound is made. Lubb dubb can be heard with the help of a stethoscope.
- **Murmur Heart Sound:** If the valves are **not closing fully**, or if they open narrowly, turbulence is created within the heart. This turbulence can be heard as a **heart murmur**. A murmur sounds like a hiss.

- Most cases of heart murmurs are not serious, and those that prove serious can be corrected by replacing the damaged valves with artificial ones or with valves taken from an organ donor.

Check Understanding!

4. How heart sound is produced?

Q. Explain how a heartbeat is initiated and controlled.

[Exercise L.Q.3]

☞ **Control of Heartbeat: (Heart Excitation and Contraction)**

- The pumping of heart is initiated by the **Sinoatrial Node (SA node)** or pacemaker.
- **SA-Node:** The sinoatrial node consists of a small cluster of **cardiac muscle cells**. It is embedded in the upper wall of right atrium. **Heartbeat starts** when SA node sends **electrical impulses** to the walls of atria. It causes both atria to contract simultaneously.
- **AV-Node:** The impulses from SA-Node travel to an **atrioventricular node (AV node)**. It is also made of small cluster of cardiac muscle cells. It lies at the lower portion of interatrial septum.
- **Bundle of His (Atrioventricular Bundle):** From AV node, the impulses reach an atrioventricular bundle or **bundle of His**. It is a network of fibres present in interventricular septum.
- **Branches of AV-Bundle:** AV bundle divides into **left and right branches**, which end at the **Purkinje fibres** in the walls of the ventricles. Stimulation of **these fibres** causes the ventricles to contract almost simultaneously (Figure).
- **Delay Between SA-Node to AV-Node:** There is a delay of **about 0.15 second** in conductance of impulses from the **SA node to AV node**, permitting atrial systole to be completed before ventricular systole begins.

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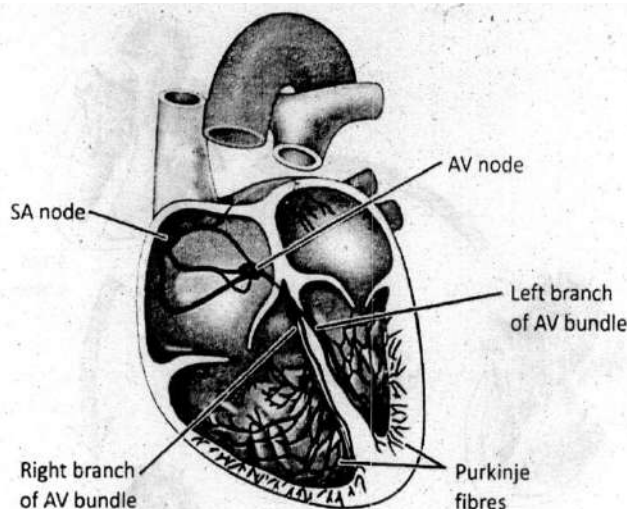


Figure: Pacemaker and its connections

➤ Consequences of Blockage or Weakness of Electrical Impulses:

- If there is some block in the **flow of the electrical impulses**, or if the **impulses** initiated by SA node are weak; it may delay the rhythmicity of heartbeat or stop it.
- In such patients of weak SA node, artificial pacemaker is used.
- It is a **battery-operated** device that is surgically transplanted **near the AV node**. It emits electrical signals that trigger normal heartbeats.

➤ Rate of Heartbeat:

- The heart of an average adult beats about **70 times** per minute.
- It **pumps** the entire blood volume (about 5 litres) every minute.
The normal speed of heartbeat is made and maintained by **pacemaker and AV node**.
- **Influence of Brain on Heart Rate:** Brain also exerts some **influence** on heart rate. During fever and exercise, the control centre in **brain sends** nerve signals to both the pacemaker and the AV node, making them to increase the **heart rate**.
- It is to cope with the situation. In contrast, when we are asleep or at rest, the brain's control centre slows down the activity of **pacemaker and AV node**.

• In an adult, about **8,000 litres** of blood move through **96,000 km** of blood vessels every day.

➤ Electrocardiogram:

- The recording of electrical potentials, generated by the currents of cardiac impulses, is known as **electrocardiogram (ECG)** and machine which record these impulses is called "**Electrocardiograph**".
- When cardiac impulse passes over the surface of heart, a minute electrical current is generated. This current spreads into the tissues surrounding heart. This minute electrical current also travels to the surface of body.
- **Recording of Electrical Impulse:** In ECG, the **electrical potentials** generated by this current are measured and recorded. For this purpose, electrodes are placed on skin on the opposite sides of heart.
- The electrodes are attached to a machine called electrocardiograph that records electrical potentials generated by this current.
- **Importance of ECG:** ECG helps to **diagnose the abnormalities** in conduction system of heart.
- ECG shows the following waves of **electrical impulses** produced at specific events of cardiac cycle. (Figure).

Check Understanding!

5. Electrocardiogram is important to diagnose the abnormalities in conduction system of:

- (A) Brain (B) Lungs
(C) Heart (D) Muscles

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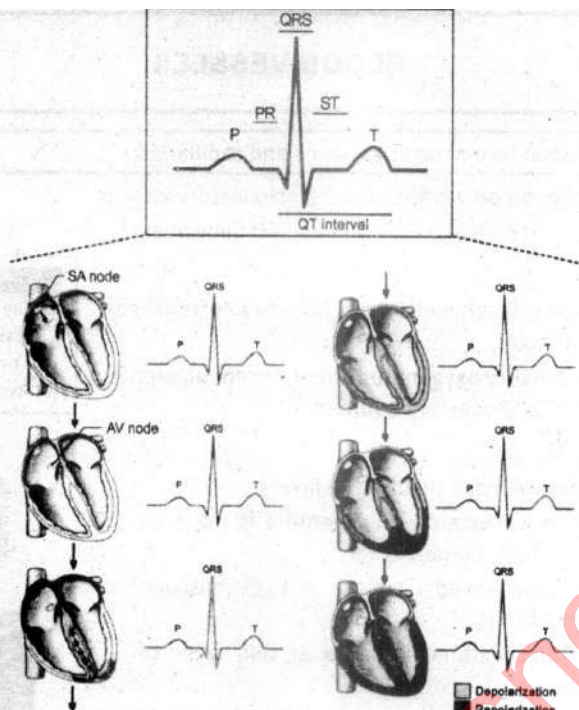


Figure: ECG reading of a single heartbeat

- **P Wave (Beginning of Atrial Depolarization):** It is initiated by SA node. It causes atrial contraction. Irregular or absent P waves may indicate arrhythmia (lack of rhythmicity).
- **PR segment:** It shows the completion of atrial depolarization. It is usually 0.12 to 0.20 seconds. A prolonged PR indicates a first-degree heart block.
- **QRS (Beginning of Depolarization of Ventricles):** Atrial repolarization also occurs during this phase. Abnormalities in the QRS complex may indicate bundle branch block, ventricular tachycardia (faster rate of contraction), or other ventricular abnormalities.
- **ST Segment (Completion of Depolarization of Ventricles):** It can be depressed in ischemia (decreased flow of blood and oxygen to heart muscles) and elevated in myocardial infarction. This segment ordinarily lasts about 0.08 second.
- **T wave (Beginning of Repolarization of Ventricles):** T wave abnormalities may indicate electrolyte disturbance. The hyper-acute T wave shows the earliest findings of acute myocardial infarction.
- **QT interval:** The QT interval is from the beginning of the QRS complex to the end of the T wave. A normal QT interval is usually about 0.40 seconds.

Check Understanding!

6. What is Cardiac Cycle?

Blue Babies (Cyanosis)

- Some abnormal babies may have **blueness (cyanosis)** of skin. They are called blue babies.
- **Causes:** It is due to the mixing of oxygenated and deoxygenated blood between two atria. Mixed blood is supplied to the body of new born babies resulting in blueness of skin.
- **Reason of Blueness:** Cyanosis results due to the failure of interatrial foramen to close, during development. Interatrial foramen is a temporary opening in the embryonic heart between right and left atria.
- Normally, it is **closed during development**. Cyanosis may also happen due to failure of ductus arteriosus to fully constrict, during development.
- Ductus arteriosus is a temporary channel between the embryonic pulmonary artery and aorta. Normally, it constricts during development.

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BLOOD VESSELS

Q. Describe the detailed structure of arteries, veins and capillaries.

[Exercise L.Q.4]

- There are three **main blood vessels** in human circulatory system.
- (1) Arteries (2) Veins (3) Capillaries

(1) Arteries:

- Arteries are the blood vessels which **carry blood** away from heart to different parts of body.
- **Function:** All arteries carry **oxygenated blood**, except pulmonary arteries. The central core of artery is **lumen**.

Check Understanding!

7. The discharge of blood from blood vessels is called:

(A) Stroke (B) Haemorrhage
(C) Hypertension (D) Hypotension

➤ **Layer of Arterial Walls:**

- The walls of arteries are made up of **three layers**.
- (a) **Outer Layer:** Tunica externa or adventitia is made of connective and elastic tissue.
- (b) **Middle Layer:** Tunica media is made of thick muscular tissue and elastic fibres.
- (c) **Inner Layer:** Tunica intima is made of thin layer of endothelial cells.
- Middle layer is important and it can withstand **higher blood pressure** during ventricular systole.
- **Division of Arteries:** Arteries divide into smaller vessels called arterioles. Arterioles divide repeatedly until they form a dense network of very fine branches i.e., capillaries.



Figure: Structure of artery

(2) Capillaries:

- These vessels are formed by the **division of arterioles**.
- Capillaries join to form **venules**. Capillaries penetrate all tissues and **have approach** to the cellular level.
- **Walls of Capillaries:** The walls of capillaries are made of a **single layer** of endothelial cells.
- **Diameter:** The **internal diameter** of a capillary is about **8 micrometres**.
- **Function:** Capillaries are the sites where materials are exchanged between blood and body tissues by diffusion or active transport. Water and diffusible substances can pass through capillary walls.
- Materials pass through the endothelial cells or through the intercellular spaces of capillary wall. Some materials are also taken up by capillary wall cells by endocytosis.
- The capillary wall cells then pass these materials to the other side by exocytosis.

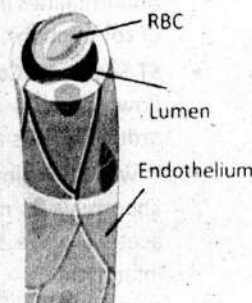


Figure: Structure of capillary

Importance of Capillaries of Network

- No cell of the body is more than **100 micrometres** away from a capillary.
- Capillaries are so narrow that RBCs must pass through them in single line.
- It is estimated that the total length of capillaries in an adult human is over **80, 600 kilometres**, enough to encircle the globe twice!

- **Interstitial Fluid:** The pressure within **capillaries** causes a continuous leakage of fluid from the blood plasma into tissues. This fluid, known as **interstitial fluid** consists of water with dissolved nutrients, hormones, gases, wastes and small proteins.
- Large proteins, RBCs and platelets **remain within capillaries**.
- But some WBCs can squeeze out through the intercellular spaces of capillary wall.

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(3) Veins:

- These blood vessels **carry blood** from different parts of the body towards heart.
- **Carry Deoxygenated Blood:** All veins carry deoxygenated blood, except pulmonary veins.
- **Walls of Veins:** The wall of veins has same **three layers** as are present in arteries.

Check Understanding!

8. Give three basic components of human circulatory system.

 - (a) **Outer layer:** Tunica externa (adventitia) is made of connective and elastic tissue.
 - (b) **Middle Layer:** Tunica media is relatively thin and only slightly muscular, with few elastic fibres.
 - (c) **Inner Layer:** Tunica intima is made of thin layer of endothelial cells.
- Middle layer of veins is **relatively thinner** than that of arteries because veins do not have to withstand high blood pressure.
- An empty artery is still a hollow tube but an empty vein collapses like an empty balloon.
- **Valves Present in Veins:** Semilunar valves are present in veins to prevent the back flow of blood, as it is moving towards heart.
- The pressure generated by the contraction of **surrounding muscles** presses veins and assists in the return of blood towards heart.
- **Formation of Inferior + Superior Vena Cava:** Smaller veins join to form **larger veins** and **ultimately** from vena cavae (inferior vena cava and superior vena cava), which pour blood into the **right atrium** of heart.
- Pulmonary veins from lungs empty in left atrium.

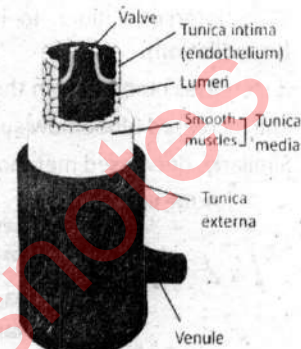


Figure: Structure of vein

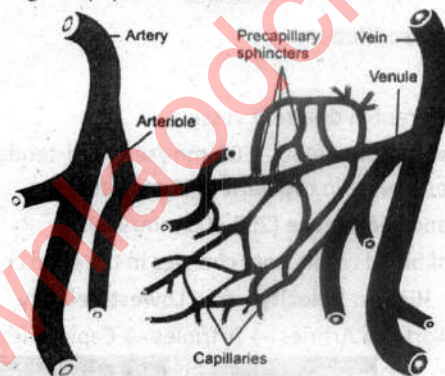


Figure: Relationship of arterioles, capillaries & venules

Q. Describe the role of precapillary sphincters in regulating the flow of blood through capillaries. [Exercise L.Q.5]

☞ Regulation of Blood Flow in Capillaries:

- The amount of blood flowing in capillaries is controlled by constricting or dilating the capillaries.
- **Role of Histamine:** Nervous stimulation can constrict capillaries and certain chemicals such as **histamine** can dilate them.
- Some capillaries are connected with arterioles and venules through loops of other capillaries. The entry of each loop is guarded by a ring of muscles called a **pre-capillary sphincter**.
- These sphincters regulate the amount of blood flowing through capillaries.

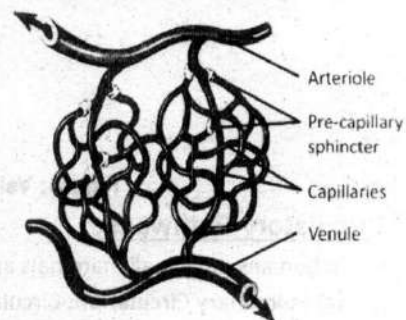


Figure : Pre-capillary sphincters

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➤ Vasoconstriction and Vasodilation in Arterioles:

- In the walls of **arterioles**, there are more circular muscles than **elastic tissue**.
- The contraction of the circular muscles of arterioles is under the control of nervous and endocrine systems vasoconstriction. When the muscles in arteriole contract, arterioles are constricted this constriction of arteriole is called **vasoconstriction** which reduces the **flow of blood in arterioles**.
- **Vasodilation:** When the muscles in arteriole are relaxed, arterioles are dilated, which is called vasodilation and it increases blood flow in them.

➤ Causes of Vasoconstriction & Vasodilation:

- Vasoconstriction and vasodilation happen in response to changes in **metabolic activity of tissues**.
- For example, when metabolic activity in a **tissue rises**, oxygen decreases and carbon dioxide increases in its interstitial fluid. In its response, the circular muscles of the arterioles in that **tissue relax (vasodilation)**.
- It increases blood flow in **these arterioles and also in capillaries**.
- The increased blood flow supplies more oxygen and removes more carbon dioxide.
- Similarly, decreased metabolic activity causes vasoconstriction of arterioles.

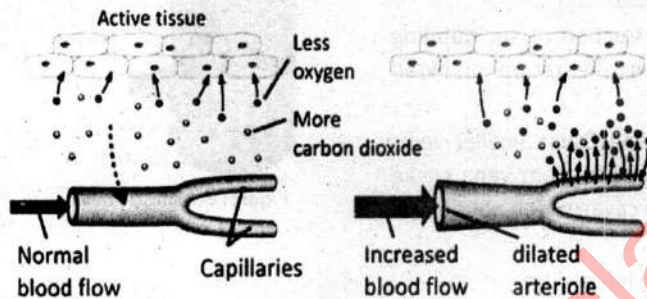


Figure: Vasodilation

Check Understanding!

9. The arteries divide into smaller vessels called:

(A) Veins	(B) Venules
(C) Capillaries	(D) Arterioles

➤ Rate of Blood Flow:

- The velocity of blood flow is different in different vessels.
- **Velocity in Blood:** It is **highest in aorta** (450–500 mm/sec) and tends to fall along the network of arteries, arterioles and becomes **lowest in capillaries** (01 mm/sec).
- It rises again in venules, veins and **vena cavae** (250–300 mm/sec).
- These changes in the velocity of blood result from changes in the total cr.

Highest Velocity – to – Lowest Velocity

Aorta → Arteries → Arterioles → Capillaries

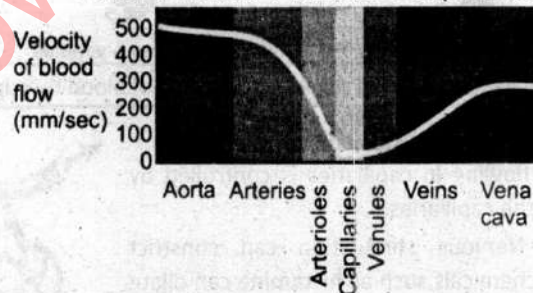


Figure: Velocity of blood, moving in different vessels

➤ Circulatory Pathways:

- In humans (and in all mammals and birds), blood circulates throughout body in two main pathways.
 - (a) **Pulmonary Circulation:** Circulation of blood to and from lungs.
 - (b) **Systemic Circulation:** Circulation of blood to and from the other body parts.

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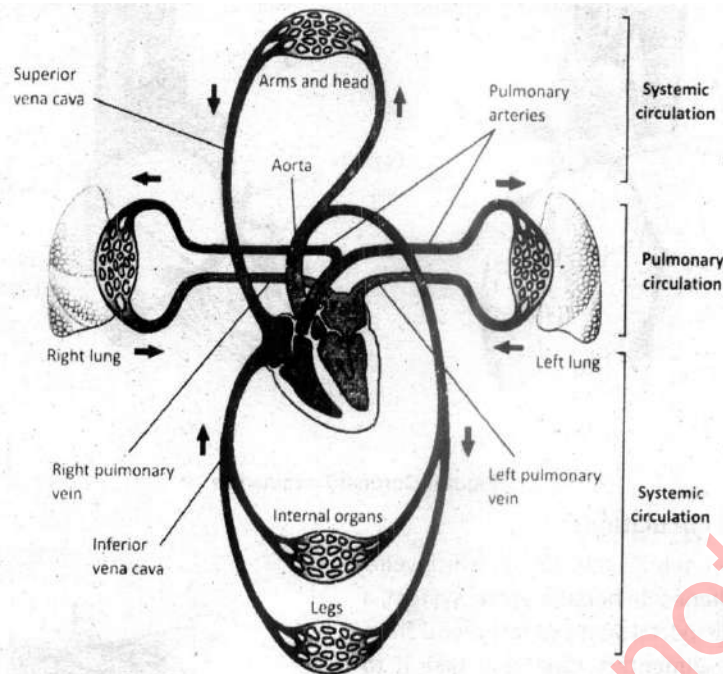


Figure: Pulmonary and systemic circulations

Q. Write the components of pulmonary circulation.

[Exercise L.Q.6]

(a) Pulmonary Circulation:

- Pulmonary circulation supplies **deoxygenated** blood to lungs and returns oxygenated blood to heart.
- **Pulmonary Trunk (A Big Artery):** Which carries deoxygenated blood from the right ventricle of heart.
- **Pulmonary trunk** divides into **right** and **left** pulmonary arteries, which carry deoxygenated blood to the right and left lungs.
- Inside each lung, the pulmonary artery divides and makes **pulmonary arterioles** and **lung capillaries**. In lung capillaries, blood is oxygenated.
- Lung **capillaries** join to form **pulmonary venules**, which join to form **pulmonary vein**.
- Left and right pulmonary veins from lungs open in left atrium.

Check Understanding!

10. Briefly describe pulmonary circulation.

(b) Systemic Circulation:

- A type of circulation which supplies oxygenated blood to **all the cells**, tissues, and organs of the **body** (except lungs) and returns deoxygenated blood to heart.

Q. What are the main components of coronary, hepatic-portal and renal circulation?

[Exercise L.Q.7]

➤ **Components of Systemic Circulation:**

It consists of the following components:

(1) Coronary Circulation: (Blood Supply to Heart)

- The heart walls are supplied with blood through a small portion of the systemic circulation.
- **Two coronary arteries:**
 - (a) Right coronary Artery
 - (b) Left Coronary Artery
- Both left and right coronary arteries arise from aorta, near its origin.
- These arteries divide into many smaller arteries, arterioles and then into **capillaries**.
- After supplying oxygenated blood to heart muscles, the capillaries unite to form venules which make many coronary veins. The coronary veins join to form a coronary sinus which opens in right atrium.
- Small coronary veins drain directly into right atrium.

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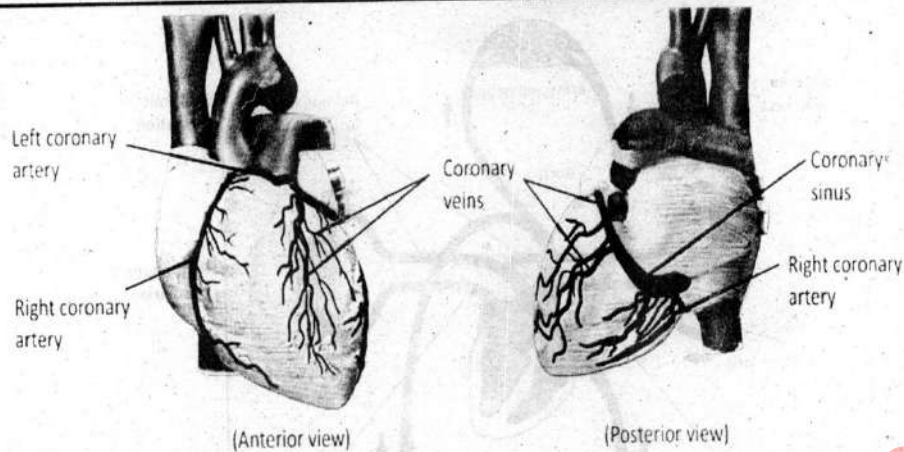


Figure: Coronary circulation

(2) Hepatic Portal Circulation:

- A portal system is a circulation in which veins **end in capillaries**. In **hepatic portal system**, a large hepatic portal vein **collects blood from spleen and alimentary canal** and take it to **liver**.
- The blood from liver is taken to heart through hepatic veins
- The blood that comes from alimentary canal to liver contains substances that are absorbed from small intestine. These **substances pass through liver** before going to heart.
- Liver **removes** harmful substances from blood and absorbs nutrients for storage before sending this blood to heart. Hepatic portal system extends from the lower portion of oesophagus to the upper part of anal canal

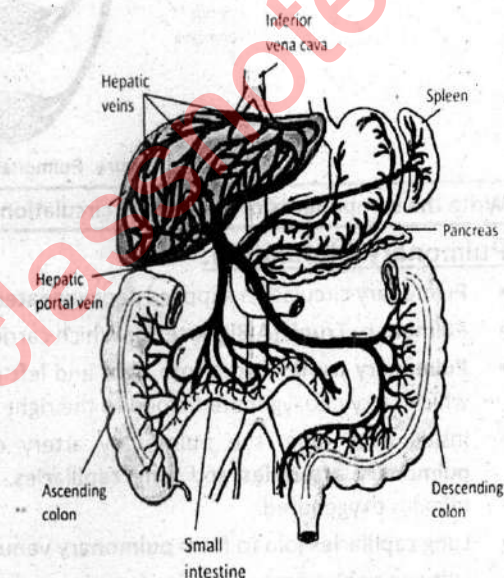


Figure: Hepatic portal system

(3) Renal Circulation: (Blood Supply to Kidneys)

- It is another important component of the **systemic circulation**.
- **Right and left renal arteries** carry oxygenated blood to the right and left **kidneys**.
- Inside the **kidney**, each renal artery divides repeatedly to make smaller arteries.
- **Afferent Arteriole**: The smaller arteries branch into several afferent arterioles, which supply blood to nephrons (units of kidney). Each afferent arteriole divides to make the capillaries of glomeruli.
- **Efferent Arteriole**: The capillaries of **glomeruli** unite to make efferent arteriole, which **divides** to make two sets of capillaries:
 - (i) **Peri-tubular Capillaries**: Capillaries around nephron tubule in cortical portion of kidney.
 - (ii) **Vasa Recta**: Which are present around nephron tubule in the medulla of kidney.
- **Peri-tubular & Vasa Recta** capillaries unite to form venules that converge and make smaller veins. The smaller veins unit to form a renal vein.

Check Understanding!

11. Which of the following blood vessels carries blood away from the glomerulus in the renal circulation?

- A) Renal artery
- B) Afferent arteriole
- C) Efferent arteriole
- D) Peritubular capillaries

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

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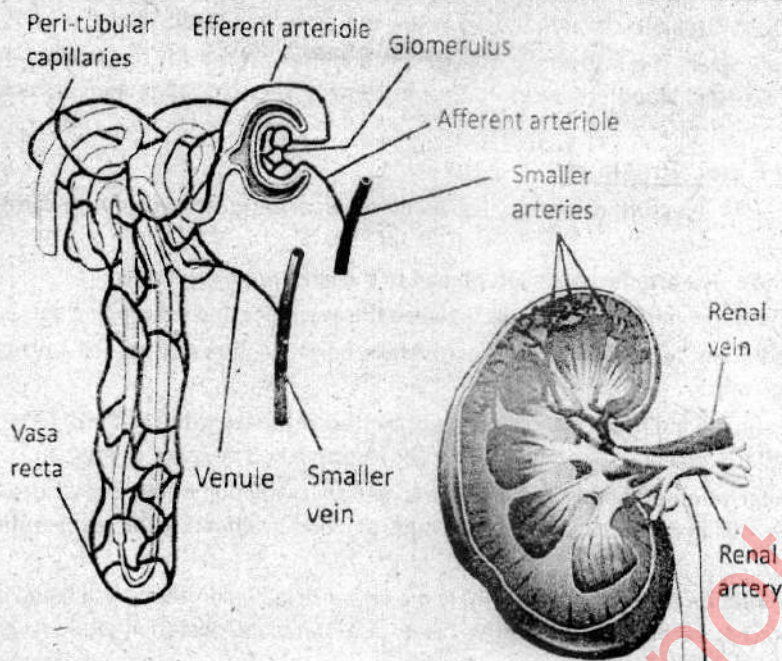


Figure : Renal portal system

BLOOD PRESSURE

Q. Define blood pressure and explain systolic and diastolic pressure.

[Exercise L.Q.8]

- Blood pressure is the measure of **force exerted** by blood against the inner walls of blood vessels.
- This force keeps blood flowing from heart to the **entire capillary network** in body.
- Highest Blood Pressure in Aorta:** Although such a pressure occurs throughout the vascular system, the term blood pressure most commonly refers to **systemic arterial blood pressure**. Blood pressure is highest in aorta and then gradually reduces in systemic arteries.
- The walls of arteries are **elastic**.
- Pulse:** The flow of blood creates **rhythmical throbbing of arteries**, which is called as **pulse**.
- Fall & Rise in Blood Pressure:** Arterial blood pressure rises and falls corresponding to the phases of cardiac cycle. When ventricles contract (ventricular systole), heart forces blood into pulmonary arteries and aorta. As a result, the pressure in these arteries rises sharply.
- Systolic Pressure:** The maximum pressure during ventricular systole is called systolic pressure. Systolic pressure in a normal young adult is **120 mm Hg**.
- Diastolic Pressure:** When ventricles relax (diastole), the arterial pressure drops. The lowest pressure that remains in arteries before the next ventricular contraction is called diastolic pressure. Diastolic pressure in a normal young adult is **75 – 85 mm Hg**.

Check Understanding!

12. Define blood pressure and write normal blood pressure of humans.

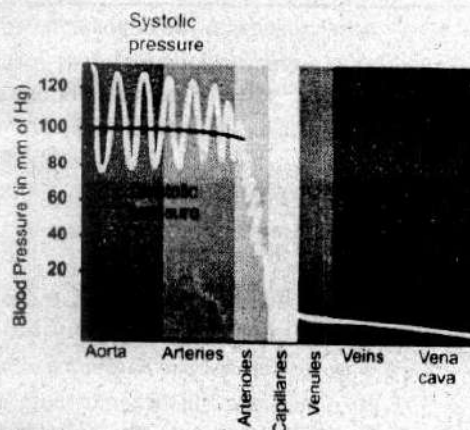


Figure: Systolic & diastolic blood pressures

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

- Conventionally, the readings of blood pressure are expressed as 120/80.
- **Sphygmomanometer:** The instrument sphygmomanometer is used for the manual measurement of systolic and diastolic blood pressures. In this instrument, rise and fall in mercury column shows the readings of blood pressure.

21
21

☉ Regulation of Blood Pressure:

- **Baroreceptor:** The Pressure receptors, known as baroreceptors, are present in carotid arteries and aortic arch.
- **Carotid Arteries:** The arteries that supply blood to the head region and brain.
- **Aortic Arch:** Portion of artery that bends between the ascending and descending aorta.
- **Activation of Barometer:** When blood pressure falls, baroreceptors activate sensory neurons that send information to brain.
- The control centre in brain reacts by increasing the rate and force of contraction of heart, and by causing vasoconstriction in arterioles. Both these changes restore blood pressure to normal.
- **Long Term Regulation of Blood Pressure:** The long-term regulation of blood pressure is done through hormones. Certain hormones regulate the volume of blood by effecting the reabsorption of water and salt in kidneys.
- **When Blood Volume Decreases:** When there is a decrease in blood volume and blood pressure, special receptors present in brain create thirst. They also stimulate posterior pituitary gland to secrete antidiuretic hormone (ADH).
- ADH stimulates kidneys to retain more water in blood, excreting less in urine. It restores the blood volume and ultimately blood pressure. ADH also constricts arterioles, which raises arterial blood pressure.
- **Role Atrial Natriuretic Hormone (ANH):** The walls of right atrium contain endocrine cells that secrete atrial natriuretic hormone (ANH). When there is stretching of the atrium by an increased blood volume, the right atrium secretes ANH.
- ANH speeds up the excretion of salts and water through urine, which lowers the blood volume and pressure.

CARDIOVASCULAR DISORDERS

- **Definition:** Cardiovascular disorders are the leading cause of death in developed and developing countries. These involve the disorders of blood vessels and heart.
- Atherosclerosis and arteriosclerosis are the major contributors to cardiovascular disorders.

Q. Identify the factors causing atherosclerosis and arteriosclerosis.

[Exercise L.Q.9]

(i) **Atherosclerosis:** The deposition within arteries is called atherosclerosis.

- **Causes:** Various materials may accumulate in arteries e.g., fatty materials, abnormal amounts of smooth muscle cells, cholesterol, fibrin, and cellular debris of various kinds. All these build-ups impair the proper functioning of arteries.

Check Understanding!

13. The condition causes narrowing and hardening of arteries is called:
(A) Atherosclerosis (B) Necrosis
(C) Sclerosis (D) Apoptosis

- **Consequences:** The accumulation of cholesterol is thought to be the prime contributor to atherosclerosis.
- Atherosclerosis can lead to heart attacks, because it causes the narrowing of arteries and increases the risk of the formation of thrombus.

(ii) **Arteriosclerosis:** The hardening of arterial walls is called arteriosclerosis.

- **Cause:** It occurs when calcium is deposited in arterial walls.
- **Consequence:** The blood flow through these arteries is restricted and arteries cannot expand normally. This forces the heart to work harder. Severe atherosclerosis usually leads to arteriosclerosis.

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

➤ Diagnosis of Cardiovascular Disorders:

- Various **diagnostic tests** are performed on cardiovascular patients to locate the exact problem and to measure the severity of disease.
- **ECG + Angiography:** The important tests are ECG and angiography. You have learnt about the readings of ECG, and here you would go through the basic learning of angiography.

(i) Coronary Angiography:

- Coronary angiography is an **X-ray examination** of blood vessels or chambers of heart.

Steps Involve in Angiography:

- In order to create the **X-ray pictures**, a physician guides a small **tube-like** device called catheter through the large arteries of body.
- When the tip of **catheter** reaches the opening of coronary arteries, a special fluid (called a contrast medium or dye) is injected in catheter. This fluid is visible in X-ray machine. Pictures (angiograms) of fluid in coronary artery are obtained.
- If clots are present in the lumen of a coronary artery, the artery appears narrow.
- By changing the diagnostic catheter to a guiding catheter, physicians can also pass an instrument into coronary artery through the **catheter**.
- The most commonly used instruments are guide wires and **balloon dilation catheters** (see angioplasty).

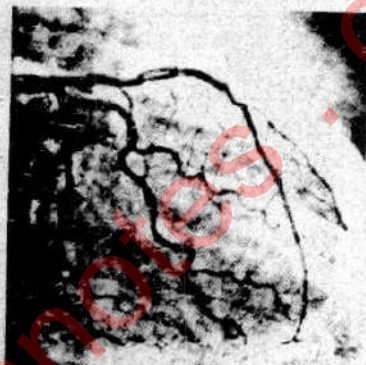


Figure: An angiogram, showing blood flow in coronary arteries

(ii) Thrombosis

- The formation of thrombus is called **thrombosis**.
- **Thrombus:** It is a solid mass or plug of blood constituents (clot) in a blood vessel. This mass may block (wholly or only in part) the vessel.
- **Causes of thrombus formation may be due to:**
 - (i) Irritation or infection of lining of blood vessels
 - (ii) Reduced rate of blood flow, due to long periods of inactivity.
 - (iii) Pneumonia, tuberculosis, emphysema etc.

Thromboembolism

- Formation of thrombus in a blood vessel and then its carriage to any other location is called

Check Understanding!

14. Differentiate between Thrombus and Embolus.

➤ Consequences:

- Thrombosis **blocks** the blood flow to organs.
- A thrombosis in coronary arteries causes **heart attack**.
- Similarly, a thrombus in the vessels of **brain** causes **stroke**.
- **Embolus:** A thrombus may be dislodged and carried to some other locations in the circulatory system. Such a thrombus is called embolus.

➤ Heart Problems and Treatments:

- We know that coronary arteries supply **oxygen** and nutrients to **cardiac muscles**. If blood flow is blocked in coronary arteries, it results in insufficient supply of blood to one or more parts of cardiac muscle.
- **Myocardial Infarction:** If heart muscles die due to no supply of oxygen and nutrients, the condition is known as myocardial infarction (heart attack).
- **Causes of Blockage of Coronary Arteries:** It is usually due to gradual build-up of lipids (especially cholesterol) in the inner wall of coronary artery.

- Heart disease and **coronary artery** disease are the leading causes of death in developed countries.

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

- **Consequences:** If such conditions persist, **chest pain**, called **angina pectoris**, can result during periods of stress or physical exertion.
- Angina indicates that oxygen demands are greater than its delivery and a heart attack may occur in future.
- If lifestyle changes and medication haven't relieved the symptoms or if the narrowed coronary arteries are at imminent risk of a heart attack, coronary bypass surgery or angioplasty is performed.

• Recovery from a heart attack is possible if the damaged portion of heart is small enough that the other blood vessels in heart can enlarge their capacity and resupply the damaged tissues.

• The open or beating-heart surgery is done when heart is still beating.

Q. Outline the main principles of coronary bypass and angioplasty.

[Exercise L.Q.11]

○ Treatments of Heart Problems:

(1) Coronary Bypass Surgery:

- It is the **most common** and effective procedures to compensate the blockage of blood to cardiac muscles.
- In this surgery, **surgeon takes** a healthy blood vessel from **leg, arm, chest** or abdomen of the patient. He attaches the ends of blood vessel above and below the blocked coronary artery. So, blood is bypassed around the damaged or blocked area.
- **Limitation or Drawback of Coronary Bypass Surgery:** Coronary bypass surgery doesn't cure the underlying disease process i.e., atherosclerosis or coronary artery disease.

➤ Precautions to Reduce the Coronary Artery Blockage:

- **Stop Smoking:** Lifestyle changes especially stop the smoking are crucial to reduce the chance of future blockages and heart attacks, even after successful bypass surgery.
- **Reduce fats:** In addition, patients need to make other lifestyle changes, such as reducing certain types of fat in diet, increasing physical activity.
- **Controlling high blood pressure, diabetes** and other risk factors for heart disease.

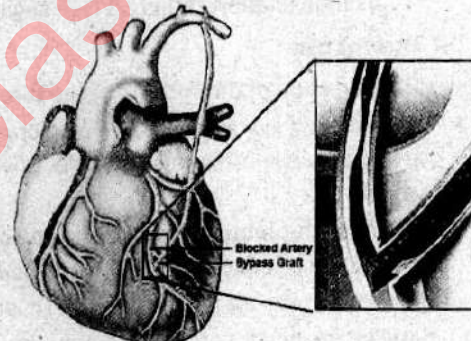


Figure: Coronary bypass

(2) Angioplasty and Stenting:

- A procedure to open the **blocked or narrowed artery** is called **angioplasty**.
- **During an angioplasty**, a small wire called a catheter, under x-ray guidance, is passed through the **narrowed coronary artery**.
- **Inflation of Balloon:** A small **sausage shaped** balloon is then advanced **over the wire** (discuss earlier) into the narrowed section of artery. The balloon is then inflated to **dilate** the narrowed section of the artery. Once the artery is dilated, a small amount of dye is injected to confirm the **successful dilatation**.
- **Stenting** may also be done during angioplasty.
- **Stent:** A stent is an **expandable stainless steel mesh tube**, mounted on a balloon catheter. When the stent/balloon is positioned within the narrowed artery, the **balloon is inflated**.
- The inflated balloon expands the stent and the artery.
- The balloon is removed and the **stent remains in place**.
- The stent supports the artery walls and keep the artery open and dilated.

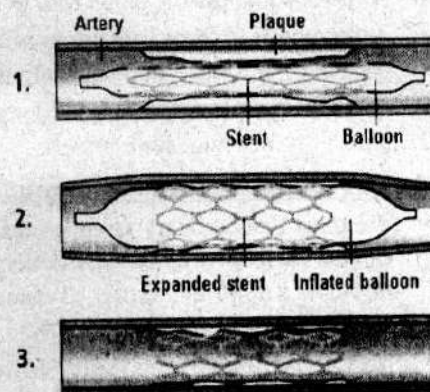


Figure: Angioplasty and stenting

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

Q. Define hypertension and describe the factors that regulate blood pressure and can lead to hypertension and hypotension. [Exercise L.Q.12]

⇒ Hypertension:

- A **chronic (long lasting)** elevation in blood pressure is called hypertension.
- It occurs when blood pressure consistently remains **above 140/90**,

➤ Causes of Hypertension:

i. Nervous + Hormonal Issue:

- Any abnormality in **nervous** or hormonal mechanisms of blood pressure regulation may cause hypertension.
- Include stress, obesity, high salt intake, and smoking. There may also be hereditary reasons of hypertension.

Check Understanding!
16. Define hypertension and its cause.

ii. Brain Haemorrhage:

- Whenever blood pressure is chronically elevated, there is an increased chance of the rupture of blood vessels.
- When this occurs in brain, it is called brain haemorrhage.
- It damages the delicate structure of brain.

• Chest pain, including angina, does not occur during congestive heart failure.

iii. Consequences of Hypertension:

- Hypertension also weakens cardiac muscles.
- If hypertension is prolonged, heart is unable to pump effectively and blood flow cannot be maintained to meet needs of tissues. In such conditions, blood may be retained in heart and lungs. It is called **congestive heart failure**.
- Hypertension can also damage the nephrons of **kidneys**. It leads to further retention of salts and water in blood and therefore further hypertension.

LYMPHATIC SYSTEM OF HUMAN

- **Definition:** In human, along with **blood circulatory system**, there is another system responsible for the transport of materials. Which returns the materials from tissues to blood is called **lymphatic system**.

➤ Components of Lymphatic System:

- It consists of:
(a) **Lymph Vessels** (b) **Lymphoid Masses**
(c) **Lymph Nodes** (d) **Lymph**-the fluid which flows in the system.

Recalling: (Lacteals)

- The branches of lymph capillaries in villi, are called lacteals.
- Fatty acids and glycerol are absorbed into the epithelial cells of villi where they form triglycerides.
- The triglycerides are coated with proteins to form chylomicrons, which enter the lacteals of villi.

Q. Describe the structure and role of lymph capillaries, lymph vessels and lymph ducts. [Exercise L.Q.14]

(a) Lymph Vessels and Lymph

- Lymphatic system begins with **small vessels** called **lymph capillaries** which have blind endings in extracellular fluid (interstitial fluid).
- Pressure of the interstitial fluid forces it to enter into lymph capillaries.
- Lymph capillaries are more **permeable** than blood capillaries. So, larger molecules can also enter lymph capillaries.
- **Lymph:** When interstitial fluid enters lymph capillaries, it is called **lymph**.
- **Lymphatic Vessels:** Lymph capillaries join to form larger **lymphatic vessels** (or lymphatics or lymph vessels).
- **Lymph Ducts:** Lymph vessels join to form larger lymph ducts.

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

➤ Types of Lymph Ducts:

- There are two main lymph ducts:
(a) Right lymphatic duct (b) Thoracic duct
- These vessels open into right and left subclavian veins (veins that drain blood from the arms and shoulders to the heart), respectively.

The painful swelling of lymph nodes in certain diseases (e.g., mumps) is largely a result of the accumulation of dead lymphocytes and macrophages.

➤ Flow of Lymph:

- The flow of lymph is always from body tissues towards thoracic duct.
- It is maintained by the activity of skeletal muscles, movement of viscera and breathing movements.
- The valves present in lymph vessels prevent the back flow of lymph.

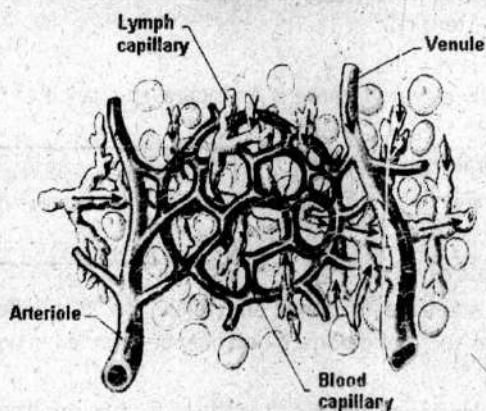


Figure: Formation of lymph

Check Understanding!

17. Lymph nodes have lymphocytes that destroy the bacteria, hence part of:

- (A) Respiratory system
- (B) Defence system
- (C) Excretory system
- (D) Digestive system

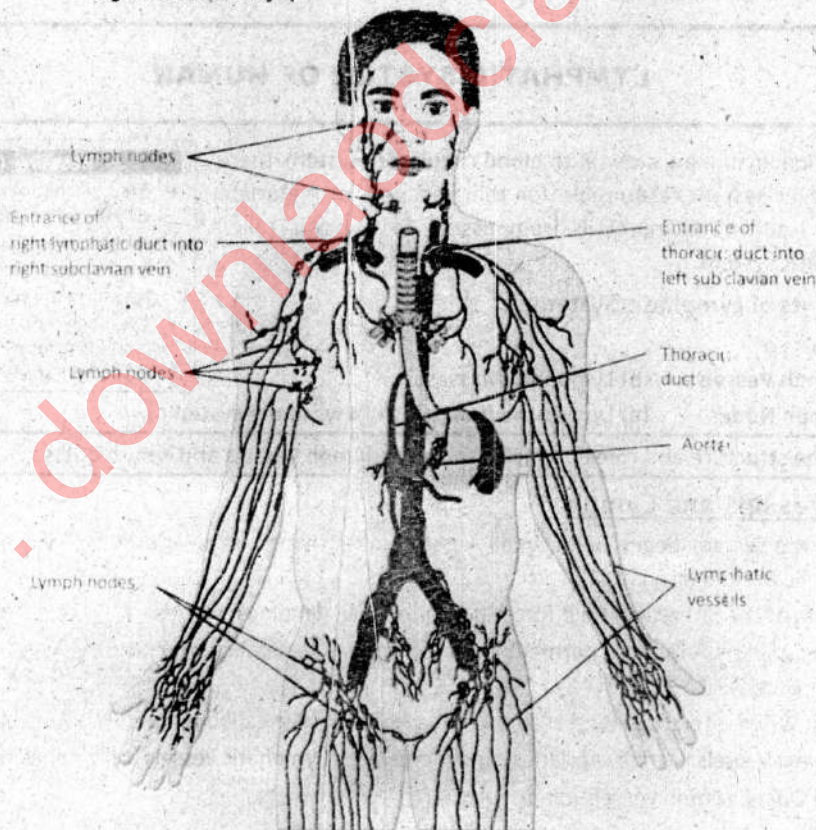


Figure: Human lymphatic system

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

☞ Functions of the Lymphatic System:

- **Returns Fluid + Proteins to Blood:** Lymphatic system returns the excess fluid and dissolved proteins and other substances to blood.
- In an average person, about three litres more fluid leaves blood capillaries daily.
- But it is absorbed by lymphatic capillaries and returned to bloodstream, before the blood enters heart.
- **Helps in Defence of Body (Filters Foreign Invaders):** Lymphatic system also helps to defend body against foreign invaders.
- Lymph nodes filter lymph. They have **lymphocytes** and **macrophages** that destroy bacteria and viruses present in lymph.
- **Spleen filters** blood through its **macrophages** and **lymphocytes** that destroy foreign particles and aged RBCs.
- Spleen also functions to **store RBCs**.

Check Understanding!
18. What are lymph nodes?

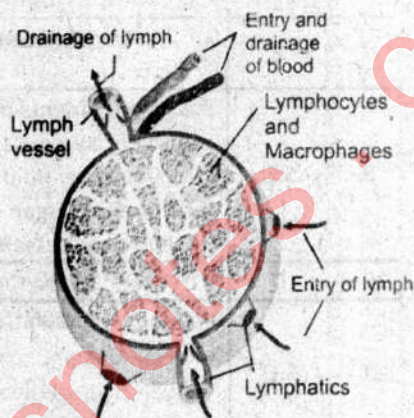


Figure: A lymph node

☞ Lymph Nodes and Lymphoid Masses:

- **Lymph Node:** At certain spots, the lymph vessels have masses of **connective tissue** where lymphocytes are present called **lymph nodes**.
- **Afferent Lymph Vessels:** Several afferent lymph vessels enter into **lymph node**.
- **Efferent Lymph Vessel:** The lymph is drained by a single **efferent lymph vessel**.
- **Locations of Lymph Nodes in Body:** Lymph nodes are present in the **neck region**, **axilla** and **groin** areas of man.
- **Lymphoid Masses in Body:** In addition to lymph nodes, several **lymphoid masses** are present in different areas e.g., in the **mucosa** and **submucosa** of **alimentary canal**.
- **Examples of Lymphoid Masses:** The larger lymphoid masses are **spleen**, **thymus**, **tonsils** and **adenoids**. These produce lymphocytes.

Check Understanding (Solutions)

Sr. #	Option	Explanation
1.	D	• The pericardium is a double-layered sac that encloses and protects the heart, preventing friction and overexpansion during heartbeats.
2.	S.Q	• Valves ensure unidirectional blood flow through the heart chambers by opening and closing at the right time. • They prevent backflow of blood, maintaining efficient circulation. • If valves malfunction (e.g., stenosis or regurgitation), it can lead to poor blood flow, heart strain, and congestive heart failure over time.
3.	B	• The pulmonary vein carries oxygenated blood from the lungs to the left atrium of the heart, unlike most veins that carry deoxygenated blood.
4.	S.Q	Sound of Heart: • The rhythmic noises accompanying heartbeat are called heart sounds. • Normally, two distinct sounds are heard through the stethoscope. Lub Sound: • A low, slightly prolonged "lub" (first sound) occurring at the beginning of ventricular contraction, or systole, and produced by closure of the mitral and tricuspid valves. Dub Sound: • A sharper, higher-pitched "dub" (second sound), caused by closure of aortic and pulmonary valves at the end of systole.

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

5.	C	An ECG records the electrical activity of the heart, helping detect irregularities in its conduction system like arrhythmias or blockages.				
6.	S.Q	Cardiac Cycle: - The sequence of events, which take place during the completion of one heartbeat. - Heart beat completes in three distinct stages. (i) Relaxation Phase-Diastole (ii) Atria Contract-Atrial Systole (iii) Ventricles Contract-Ventricular Systole				
7.	B	Hemorrhage refers to the escape of blood from damaged blood vessels due to injury or rupture.				
8.	S.Q	Basic Components of Blood Circulatory System: The circulatory system of humans have three basic components. (a) Circulatory fluid – The blood. (b) Pumping Organ – The Heart (c) Pumping Vessels – The Arteries, Capillaries and Veins.				
9.	D	Arterioles are the smaller branches of arteries that regulate blood flow into capillaries.				
10.	S.Q	Pulmonary Circulations: Pulmonary Circulation is by pulmonary arch carrying deoxygenated blood from right ventricle of heart to lungs, and the blood returns to left atrium from lungs after oxygenation via pulmonary veins.				
11.	D	The efferent arteriole carries blood away from the glomerulus after filtration, while the afferent arteriole brings blood to the glomerulus. The renal artery supplies the kidney with blood, and the peritubular capillaries surround the tubules for reabsorption and secretion after the efferent arteriole.				
12.	S.Q	Blood Pressure: - The blood pressure is the force of blood against the wall of blood vessels. - Blood pressure is the force that keeps blood flowing from the heart to all the capillary the highest in aorta, and then gradually reduces in arteries. - During diastole, the relaxation phase of the cardiac cycle the heart is not exerting pressure of the blood in the arteries and pressure in them falls. - The pressure reaching its high point during systole (systolic pressure which in normal individuals is 120mm Hg) and its low point during diastole (diastolic pressure which in normal individuals ranges between 75-85 mmHg).				
13.	A	Atherosclerosis occurs when fatty deposits build up on artery walls, leading to narrowing and reduced elasticity.				
14.	S.Q	<table><tr><th>Thrombus</th><th>Embolus</th></tr><tr><td> - Thrombus is a solid mass or plug of constituents in a blood vessel. - This plug of blood constituent or blood clot may, block wholly or partially the vessels in which it forms. - Thrombosis is the process of formation of thrombus. </td><td> - The blood clot may be dislodged and carried to some other location in the circulatory system in which case it is called an embolus. </td></tr></table>	Thrombus	Embolus	- Thrombus is a solid mass or plug of constituents in a blood vessel. - This plug of blood constituent or blood clot may, block wholly or partially the vessels in which it forms. - Thrombosis is the process of formation of thrombus.	The blood clot may be dislodged and carried to some other location in the circulatory system in which case it is called an embolus.
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15.	D	Myocardial infarction (heart attack) affects the heart due to blocked blood supply causing damage to heart muscle tissue.				
16.	S.Q	Hypertension: It is a condition of high blood pressure.				

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

		Causes: - Poor physical activity. - Obesity and diabetes. - Stress - Higher body cholesterol
17.	B	Lymph nodes act as filters with lymphocytes that destroy invading microbes, making them essential to the body's defence system.
18.	S.Q	Lymph Nodes: - Lymph nodes are masses of connective tissue that contain lymphocytes and through which lymph is filtered. - Lymph nodes are present in the neck region, axilla (armpit) and groin area between abdomen and upper thighs of humans.

Exercise

Exercise

MULTIPLE CHOICE QUESTIONS (MCQs)

Section 01

- Compared to vein, an artery;**
 - Has thinner walls
 - Is located more superficially
 - Carries blood away from an organ
 - Has no internal valves
- Bicuspid valve guards the opening between;**
 - Stomach and intestine
 - Pulmonary vein and left atrium
 - Right atrium and right ventricle
 - Left atrium and left ventricle
- What is the state of bicuspid and tricuspid valves at the end of the first heart sound?**
 - Bicuspid is closed, tricuspid is open
 - Bicuspid is open, tricuspid is closed
 - Both are open
 - Both are closed
- By beating at normal speed, our heart pumps how much blood per minute?**
 - 2 litres
 - 3 litres
 - 5 litres
 - 8 litres
- Closure of tricuspid and bicuspid valves produces sound;**
 - "Lubb"
 - "Dubb"
 - "First Lubb" then "Dubb"
 - None of these but "murmurs"
- SA-node initiates heartbeat in;**
 - Right atrium only
 - Right atrium and partially left also
 - Right and left both
 - Left atrium and partially right also
- Systolic pressure in young man is;**
 - 60 mm of Hg
 - 80 mm of Hg
 - 100 mm of Hg
 - 120 mm of Hg
- Blood pressure is highest in and blood moves most slowly in;**
 - Veins, capillaries
 - Arteries, capillaries
 - Capillaries, arteries
 - Veins, arteries
- Instead of normal "lub-dubb" sound, a "lub-hiss, lub-hiss" sound indicates;**
 - Blocked coronary artery
 - Damaged pacemaker
 - Defective semilunar valve
 - High blood pressure
- In humans which one is the other system for the transport of materials, than blood circulatory system?**
 - Lymphatic system
 - Digestive system
 - Nervous system
 - Respiratory system

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

Answer Key with Explanations

Sr.No.	Option	Answer	Explanations
1.	(c)	Carries blood away from an organ	• Arteries carry blood away from the heart, typically oxygen-rich, while veins return blood to the heart.
2.	(d)	Left atrium and left ventricle	• The bicuspid (mitral) valve is between the left atrium and left ventricle, preventing backflow.
3.	(c)	Both are closed	• The first heart sound is due to the closure of both AV valves (bicuspid and tricuspid).
4.	(c)	5 litres	• The heart pumps approximately 5 liters of blood per minute in a resting adult.
5.	(a)	Lubb	• The "lubb" sound (S1) is produced when AV valves close at the start of ventricular contraction.
6.	(a)	Right atrium only	• The sinoatrial (SA) node is located in the right atrium and initiates electrical impulses.
7.	(d)	120 mm of Hg	• Normal systolic blood pressure is about 120 mm Hg in healthy young adults.
8.	(c)	Capillaries, arteries	• Blood pressure is highest in arteries; however, blood flow is slowest in capillaries for exchange.
9.	(c)	Defective semilunar valve	• A "hiss" sound (murmur) suggests valve leakage, often due to a faulty semilunar valve.
10.	(a)	Lymphatic system	• The lymphatic system transports excess fluid, proteins, and immune cells.

Exercise

SHORT ANSWER QUESTIONS

Section 02

Q.1 What is the main difference between the walls of an artery and a vein?

Ans. Difference between the Walls of an Artery and a Vein:

Layer of Arterial Walls	Walls of Veins
- The walls of arteries are made up of three layers. (a) Outer Layer: Tunica externa or adventitia is made of connective and elastic tissue. (b) Middle Layer: Tunica media is made of thick muscular tissue and elastic fibres. (c) Inner Layer: Tunica intima is made of thin layer of endothelial cells. - Middle layer is important and it can withstand higher blood pressure during ventricular systole.	- The wall of veins has same three layers as are present in arteries. (d) Outer layer: Tunica externa (adventitia) is made of connective and elastic tissue. (e) Middle Layer: Tunica media is relatively thin and only slightly muscular, with few elastic fibres. (f) Inner Layer: Tunica intima is made of thin layer of endothelial cells. - Middle layer of veins is relatively thinner than that of arteries because veins do not have to withstand high blood pressure.

Q.2 Enlist the four valves present in heart and also state their locations.

Ans. Four Valves Present in Heart:

- **Tricuspid valve:** Located between the right atrium and right ventricle.
- **Pulmonary valve:** Located between the right ventricle and pulmonary artery.
- **Mitral (bicuspid) valve:** Located between the left atrium and left ventricle.
- **Aortic valve:** Located between the left ventricle and aorta.
- These valves ensure unidirectional blood flow through the heart.

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

Q.3 State the phases of heartbeat.

Ans. Phases of the Heartbeat:

- **Diastole:** Relaxation phase where the heart chambers fill with blood.
- **Atrial systole:** Contraction of the atria to pump blood into the ventricles.
- **Ventricular systole:** Contraction of the ventricles to pump blood into the arteries.
- These phases ensure efficient pumping of blood throughout the body.

Q.4 List the principles and uses of Electrocardiogram.

Ans. Principles and Uses of Electrocardiogram:

Principles: Measures the electrical activity of the heart through electrodes on the skin.

Uses:

- Diagnosing arrhythmias and conduction disorders.
- Detecting myocardial infarction (heart attack).
- Monitoring heart health during surgery or stress testing.
- Assessing the effects of medications on heart function.

Q.5 Define angiography and angioplasty.

Ans.	Angiography	Angioplasty
	• A medical imaging technique that visualizes the inside of blood vessels using contrast dye and X-rays.	• A procedure to widen narrowed or obstructed blood vessels using a balloon catheter. • Angioplasty is often used to treat coronary artery disease.

Q.6 What is meant by Purkinje fibres?

Ans. Purkinje Fibres:

- Purkinje fibers are specialized cardiac conduction fibers.
- They are responsible for **rapidly transmitting** electrical impulses to the ventricular myocardium.
- This ensures synchronized contraction of the ventricles.
- Purkinje fibers play a crucial role in maintaining a regular heartbeat.

Q.7 What do you mean by vasoconstriction and vasodilation?

Ans.	Vasoconstriction	Vasodilation
	• Narrowing of blood vessels due to contraction of smooth muscle in their walls.	• Widening of blood vessels due to relaxation of smooth muscle. • These processes regulate blood flow and blood pressure.

Q.8 What is the rate of blood flow in different types of blood vessels?

Ans. Rate of Blood Flow:

- The velocity of blood flow is different in different vessels.
- **Velocity in Blood:** It is **highest in aorta** (450–500 mm/sec) and tends to fall along the network of arteries, arterioles and becomes **lowest in capillaries** (01 mm/sec).
- It rises again in venules, veins and **vena cavae** (250-300 mm/sec).
- These changes in the velocity of blood result from changes in the total cr

Highest Velocity – to – Lowest Velocity
Aorta → Arteries → Arterioles → Capillaries

Q.9 State the role of baroreceptors and volume receptors in regulating the blood pressure.

Ans. Role of Baroreceptors:

- **Baroreceptors:** Sense changes in blood pressure and send signals to the brain to adjust heart rate and vascular tone.

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

Role of Volume Receptors:

- **Volume receptors:** Respond to changes in blood volume and influence fluid balance and blood pressure.
- Both play crucial roles in maintaining blood pressure homeostasis.

Q.10 Differentiate between thrombus and embolus.

Ans.	Thrombus	Embolus
	• A blood clot that forms within a blood vessel.	• A clot or other particle that has broken loose and travels through the bloodstream. • An embolus can cause blockage in a distant vessel, leading to serious complications.

Exercise

LONG ANSWER QUESTIONS

Section 03

Q.1 Describe the structure of the walls of heart and rationalize the thickness of the walls of each chamber.

Ans. See Page No. (310)

Q.2 Describe the flow of blood through heart as regulated by the valves.

Ans. See Page No. (312)

Q.3 Explain how a heartbeat is initiated and controlled.

Ans. See Page No. (313)

Q.4 Describe the detailed structure of arteries, veins and capillaries.

Ans. See Page No. (316)

Q.5 Describe the role of precapillary sphincters in regulating the flow of blood through capillaries.

Ans. See Page No. (317)

Q.6 Write the components of pulmonary circulation.

Ans. See Page No. (319)

Q.7 What are the main components of coronary, hepatic-portal and renal circulation?

Ans. See Page No. (319)

Q.8 Define blood pressure and explain systolic and diastolic pressure.

Ans. See Page No. (321)

Q.9 Identify the factors causing atherosclerosis and arteriosclerosis.

Ans. See Page No. (322)

Q.10 Write notes on Angina pectoris, heart attack, and heart failure.

Ans. a) **Angina Pectoris**

- It is chest pain or discomfort caused by reduced blood flow to the heart muscles.
- Typically occurs during physical activity or stress.
- It is a warning sign of underlying coronary artery disease.
- Pain usually subsides with rest or medication like nitroglycerin.

b) **Heart Attack (Myocardial Infarction)**

- It occurs when blood flow to a part of the heart is completely blocked.
- It causes damage or death of heart muscle due to oxygen shortage.
- Symptoms include severe chest pain, shortness of breath, and sweating.
- Immediate medical treatment is crucial to prevent serious complications.

c) **Heart Failure**

- A condition where the heart cannot pump blood effectively to meet the body's needs.
- It can result from conditions like coronary artery disease, high blood pressure, or previous heart attacks.
- Symptoms include fatigue, swelling (especially in legs), and shortness of breath.

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

Q.11 Outline the main principles of coronary bypass and angioplasty.

Ans. See Page No. (324)

Q.12 Define hypertension and describe the factors that regulate blood pressure and can lead to hypertension and hypotension.

Ans. See Page No. (325)

Q.13 List the changes in life styles that can protect man from hypertension and cardiac problems.

Ans. Lifestyle Changes to Protect Against Hypertension and Heart Problems:

- **Eat a Heart-Healthy Diet:** Focus on fruits, vegetables, whole grains, lean proteins, and low-fat dairy.
- **Reduce Salt Intake:** Lower sodium consumption to help control blood pressure.
- **Exercise Regularly:** Aim for at least 30 minutes of moderate activity, like walking or cycling, most days.
- **Maintain a Healthy Weight:** Losing excess weight reduces the risk of high blood pressure and heart disease.
- **Quit Smoking:** Smoking damages blood vessels and increases heart disease risk.
- **Limit Alcohol Consumption:** Excess alcohol can raise blood pressure—drink in moderation.
- **Manage Stress:** Use techniques like meditation, yoga, or deep breathing to reduce stress levels.

Q.14 Describe the structure and role of lymph capillaries, lymph vessels and lymph ducts.

Ans. See Page No. (326)

Exercise

INQUISITIVE ANSWER QUESTIONS

Q.1 Why is the pressure in the pulmonary circulation lower than in the systemic circulation?

Ans. Pressure in the Pulmonary Circulation lower than in the Systemic Circulation:

- **Shorter Distance:** Pulmonary circulation only pumps blood from the heart to the lungs, which are close by, requiring less force.
- **Delicate Lung Capillaries:** Lower pressure prevents damage to the thin-walled capillaries in the lungs, allowing efficient gas exchange.
- **Reduced Resistance:** Pulmonary vessels offer less resistance compared to systemic arteries, so high pressure isn't needed.

Q.2 Why is it so important for the human heart to develop early and begin functioning within the developing embryo?

Ans. Importance of Early Heart Development in Embryo:

- **Oxygen and Nutrient Supply:** The developing embryo needs a constant supply of oxygen and nutrients, which the heart helps deliver via blood circulation.
- **Waste Removal:** The heart also helps remove carbon dioxide and other metabolic wastes from embryonic tissues.
- **Support Rapid Growth:** Early heart function supports rapid cell division and organ development by ensuring efficient transport of essential substances.
- **Foundation for Organ Systems:** A functioning circulatory system lays the groundwork for the development and coordination of other organ systems.

Q.3 Justify how vasoconstriction or vasodilation is reflective of emotions.

Ans. Reflection of Emotions in Vasoconstriction or Vasodilation:

- **Stress or Fear – Vasoconstriction:** Emotions like fear trigger the release of adrenaline, causing blood vessels to constrict and increase blood pressure.
- **Calm or Happiness – Vasodilation:** Relaxed or happy states lead to the release of hormones like serotonin, causing blood vessels to widen and lower blood pressure.
- **Emotional Signals:** These changes in blood vessel diameter reflect how the nervous system responds to different emotional states.

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

Q.4 Justify in what way the blood circulatory system is dependent on the lymphatic system.

Ans. Dependence of Blood Circulatory System on Lymphatic System:

- **Fluid Balance:** The lymphatic system returns excess tissue fluid to the bloodstream, maintaining blood volume.
- **Immune Defence:** Lymph nodes filter pathogens, supporting immune function linked to the circulatory system.
- **Fat Transport:** It also absorbs fats and delivers them to the blood, aiding nutrient distribution.

Q.5 Interpret why the swelling of the lymph nodes is a cause of concern.

Ans. Reasons of Lymph Nodes:

- **Sign of Infection:** Swollen lymph nodes often indicate the body is fighting an infection.
- **Immune Activity:** It shows increased immune cell production to combat pathogens.
- **Possible Disease Indicator:** Persistent swelling may signal serious conditions like lymphoma or autoimmune diseases.

Q.6 Trace the path of lymph from a lymph capillary until it is returned to the blood.

Ans. Path of Lymph:

- **Lymph Capillaries → Lymph Vessels:** Lymph starts in lymph capillaries and flows into larger lymph vessels.
- **Lymph Nodes:** It passes through lymph nodes where it is filtered.
- **Lymph Ducts → Subclavian Vein:** Finally, it drains into either the thoracic duct or right lymphatic duct and returns to the bloodstream via the subclavian vein.

ADDITIONAL MCQs

1. What is the primary function of the pericardium surrounding the heart?
A) To produce red blood cells
B) To filter waste products from the blood
C) To protect the heart and reduce friction between the heart and surrounding tissues
D) To regulate blood pressure
2. Which chamber of the heart has the thickest walls?
A) Right atrium B) Left atrium C) Right ventricle D) Left ventricle
3. What is the role of the SA node in controlling the heartbeat?
A) To transmit electrical impulses to the ventricles
B) To regulate blood pressure
C) To generate electrical impulses that control the heartbeat
D) To filter waste products from the blood
4. Which type of blood vessel is responsible for vasoconstriction and vasodilation?
A) Arteries B) Veins C) Capillaries D) Arterioles
5. What is the primary function of pre-capillary sphincters?
A) To regulate blood pressure B) To control the flow of blood through capillaries
C) To filter waste products from the blood D) To produce red blood cells
6. Which circulatory pathway is responsible for supplying oxygenated blood to the body's tissues?
A) Pulmonary circulation B) Systemic circulation C) Coronary circulation D) Hepatic portal circulation
7. What is the term for a blood clot that forms within a blood vessel?
A) Embolus B) Thrombus C) Atherosclerosis D) Arteriosclerosis
8. Which condition is characterized by the narrowing of arteries due to the buildup of plaque?
A) Atherosclerosis B) Arteriosclerosis C) Hypertension D) Hypotension
9. What is the congenital heart problem related to the malfunctioning of cardiac valves?
A) Heart failure B) Heart attack C) Angina pectoris D) Valvular heart disease
10. Which surgical procedure involves bypassing blocked coronary arteries?
A) Angioplasty B) Open-heart surgery C) Coronary bypass surgery D) Heart transplant

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

11. What is the term for high blood pressure?
A) Hypertension B) Hypotension C) Atherosclerosis D) Arteriosclerosis
12. Which lifestyle change can help protect against hypertension and cardiac problems?
A) Smoking B) Regular exercise C) High-sodium diet D) Sedentary lifestyle
13. What is the primary function of the lymphatic system?
A) To transport oxygenated blood
B) To remove waste products from the blood
C) To return proteins and excess fluids from the interstitial space to the bloodstream
D) To regulate blood pressure
14. Which type of fluid is found in the interstitial space?
A) Blood plasma B) Interstitial fluid C) Lymph D) Intracellular fluid
15. What is the role of lymph nodes in the lymphatic system?
A) To filter waste products from the blood B) To produce red blood cells
C) To trap pathogens and activate immune responses D) To regulate blood pressure
16. Which organ contains lymphoid tissue and plays a role in the immune system?
A) Spleen B) Liver C) Kidneys D) Heart
17. What is the term for a condition where the heart is unable to pump enough blood to meet the body's needs?
A) Heart attack B) Heart failure C) Angina pectoris D) Cardiac arrest
18. What is the primary function of the electrocardiogram (ECG)?
A) To measure blood pressure
B) To monitor heart rate
C) To diagnose heart conditions by measuring electrical activity
D) To filter waste products from the blood

ANSWER KEY

1. C)	2. D)	3. C)	4. D)	5. B)	6. B)	7. B)	8. A)	9. D)	10. C)	11. A)	12. B)
13. C)	14. B)	15. C)	16. A)	17. B)	18. C)						

ADDITIONAL SHORT ANSWER QUESTIONS

Q.1 What is meant by systemic circulation?

Ans. Systemic Circulation:

- The **systemic arch** or **aorta** distributes blood to different parts of the body and then returns the blood, in the **right atrium** via **precaval** and **postcaval veins**. This is **systemic circulation**.
- Hearts of amphibians, reptiles, birds and mammals have both pulmonary and systemic circulation.

Pulmonary Circulations:

- Pulmonary Circulation is by **pulmonary arch** carrying **deoxygenated** blood from right ventricle of heart to lungs, and the blood returns to left atrium from lungs after oxygenation via pulmonary veins.

Q.2 Where the human's heart is located in the body? Give names of layers that surround the heart.

Ans. Location of Human Heart:

- Heart of humans is located in the **chest cavity**.
 - Heart is enclosed in a **double membranous sac**-the **pericardial cavity**, which contains the pericardial fluid.
 - **Pericardium** protects the heart and prevents it from over extension.
 - Wall of the Heart is Composed of Three Layers.
- (i) Epicardium (ii) Myocardium (iii) Endocardium

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

Q.3 What is pericardium? Write its function.

Ans. **Pericardium:**

The pericardium is a double-layered, fibrous sac that surrounds the heart and roots of the great vessels, separating it from other thoracic organs.

Two Main Functions:

- (i) **Protective Function:** The pericardium provides a protective covering for the heart, anchoring it in place and preventing excessive movement.
- (ii) **Lubricating Function:** The pericardial cavity between the two layers produces pericardial fluid, which reduces friction between the heart and surrounding tissues, allowing for smooth cardiac contractions.

Q.4 How heart sound is produced?

Ans. **Sound of Heart:**

- The rhythmic noises accompanying heartbeat are called heart sounds.
- Normally, two distinct sounds are heard through the stethoscope.

Lub Sound:

- A low, slightly prolonged "lub" (first sound) occurring at the beginning of ventricular contraction, or systole, and produced by closure of the mitral and tricuspid valves.

Dub Sound:

- A sharper, higher-pitched "dub" (second sound), caused by closure of aortic and pulmonary valves at the end of systole.

Q.5 What are lymph nodes? What is their function?

Ans. **Lymph Nodes:**

- Lymph nodes are masses of connective tissue that contain lymphocytes and through which lymph is filtered.
- Lymph nodes are present in the neck region, axilla (armpit) and groin area between abdomen and upper thighs of humans.

Function of Lymph Nodes:

- The main function of lymph nodes is to filter the lymph because lymph nodes contain lymphocytes which help to provide immunity against the diseases.
- These are lymph nodes. Several afferent lymph vessels enter a lymph node which is drained by a single efferent lymph vessel.

Q.6 Define blood pressure and write normal blood pressure of humans.

Ans. **Blood Pressure:**

- The blood pressure is the force of blood against the wall of blood vessels.
- Blood pressure is the force that keeps blood flowing from the heart to all the capillary the highest in aorta, and then gradually reduces in arteries.
- During diastole, the relaxation phase of the cardiac cycle the heart is not exerting pressure of the blood in the arteries and pressure in them falls.
- The pressure reaching its high point during systole (systolic pressure which in normal individuals is 120mm Hg) and its low point during diastole (diastolic pressure which in normal individuals ranges between 75-85 mmHg).

Q.7 What is Cardiac Cycle?

Ans. **Cardiac Cycle:**

- The sequence of events, which take place during the completion of one heartbeat.
- Heart beat completes in three distinct stages.
 - (i) Relaxation Phase-Diastole
 - (ii) Atria Contract-Atrial Systole
 - (iii) Ventricles Contract-Ventricular Systole

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

Duration of Cardiac Cycle:

- Complete cardiac cycle or heart cycle consists of one systole and one diastole and lasts for about 0.8 seconds.
- In ones life heart contracts about 2.5 billion times without stopping.

22

Q.8 What is myocardial infarction (Heart attack)?

Ans. Heart Attack (Myocardial Infarction):

- Blockage of **blood vessel in the heart by an embolus** or by locally formed thrombus causes necrosis or damage to portion of heart muscles develops a **condition known as a heart attack or technically termed as myocardial infarction.**

Q.9 What is Atherosclerosis?

Ans. Atherosclerosis:

- It is **coexisting atheroma** and arteriosclerosis. Atheroma i.e., **deposition of hard yellow plaque** of lipoid material in the inner most layer of the arteries, may be due to high level of cholesterol in the blood.
- Arteriosclerosis is **degenerative arterial** change associated with advancing age, primarily a thickening of middle layer of arteries and usually associated with **some degree** of atheroma.
- **The atherosclerosis increases the risk of formation of thrombus or clot and if thrombus is formed in the brain or heart it is fatal and may lead to stroke or the heart attack respectively.**

Q.10 Differentiate between Thrombus and Embolus.

Ans.	Thrombus	Embolus
	• Thrombus is a solid mass or plug of constituents in a blood vessel. • This plug of blood constituent or blood clot may, block wholly or partially the vessels in which it forms. • Thrombosis is the process of formation of thrombus.	• The blood clot may be dislodged and carried to some other location in the circulatory system in which case it is called an embolus.
	• Thrombo-embolism is leading cause of death in western Civilization.	

Q.11 Define ECG.

Ans. Electrocardiogram:

- As the cardiac impulse passes through the heart, electrical currents spread into the tissues surrounding the heart and a small proportion of these spread all the way on the surface of the body.
- If electrodes are placed on the skin on opposite sides of the heart. Electrical potential generated by these currents can be recorded. This recording is known as electro-cardiogram, which is taken by electrocardiograph (E.C.G) machine.

Q.12 Write role of lymphatic system in defense of body.

Ans. Role of Lymphatic System in Defense of Body:

- The lymphatic system helps to defend the body against **foreign invaders.**
- Lymph nodes have lymphocytes and macrophages that **destroy bacteria and viruses.**



BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

SELF-ASSESSMENT

Chapter # 11

Total Mark: 30

(1 x 6 = 06)

21
21

Q.1 Encircle the correct option.

- i. By beating at normal speed, our heart pumps how much blood per minute?
(a) 2 litres (b) 3 litres (c) 5 litres (d) 8 litres
- ii. Systolic pressure in young man is;
(a) 60 mm of Hg (b) 80 mm of Hg (c) 100 mm of Hg (d) 120 mm of Hg
- iii. Which type of blood vessel is responsible for vasoconstriction and vasodilation?
(a) Arteries (b) Veins (c) Capillaries (d) Arterioles
- iv. What is the term for a blood clot that forms within a blood vessel?
(a) Embolus (b) Thrombus (c) Atherosclerosis (d) Arteriosclerosis
- v. Which surgical procedure involves bypassing blocked coronary arteries?
(a) Angioplasty (b) Open-heart surgery (c) Coronary bypass surgery (d) Heart transplant
- vi. Which lifestyle change can help protect against hypertension and cardiac problems?
(a) Smoking (b) Regular exercise (c) High-sodium diet (d) Sedentary lifestyle

Q.2 Write short answers of the following questions.

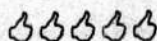
(2 x 8 = 16)

- i. Trace the flow of blood through the heart as regulated by the valves.
- ii. Describe the detailed structure of arteries, veins, and capillaries.
- iii. Define thrombus and differentiate between thrombus and embolus.
- iv. State the congenital heart problem related to the malfunctioning of cardiac valves.
- v. Enlist the four valves present in heart and also state their locations.
- vi. List the principles and uses of Electrocardiogram.
- vii. Define blood pressure and write normal blood pressure of humans.
- viii. What is Atherosclerosis?

Q.3 Extensive Questions.

(4 x 2 = 8)

- (a) Describe the flow of blood through heart as regulated by the valves.
- (b) Define blood pressure and explain systolic and diastolic pressure.

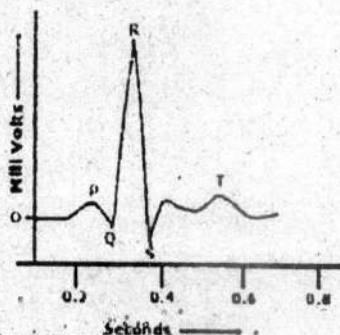


BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

ENTRANCE TEST

MCQs (UHS)

1. The lymph vessel of villi is called:
A. Epithelium B. Adenoids C. Afferent lymph vessel D. Lacteal
2. Right atrium is separated from right ventricle by:
A. Bicuspid valve B. Tricuspid valve C. Semilunar valve D. Interatrial septum
3. The flaps of tricuspid valves are attached to the muscular extensions of right ventricle known as:
A. Smooth muscles B. Intercoastal muscle C. Papillary muscles D. Skeletal muscles
4. One complete heart beat consists of one systole and one diastole and lasts for about.
A. 0.8 sec B. 0.4 sec C. 0.2 sec D. 0.5 sec
5. In _____ response, B-cells produce plasma cells that synthesize antibodies and release in blood plasma and tissue fluid.
A. Cell mediated B. Humoral C. Hormonal D. Phototactic
6. The heart beat cycle starts when electric impulses are generated from:
A. AV node B. SA node C. SV node D. PQ node
7. Response of body against transplanted organs is:
A. Homestatic response B. Primary response C. Behavioral response D. Cell mediated response
8. In human the closed sac which surrounds the heart is:
A. Endocardium B. Pericardium C. Myocardium D. Epicardium
9. Chordae tendineae are fibrous cords attached with:
A. Cardiac end of stomach valve B. Pyloric sphincter of stomach
C. Tricuspid valve of heart D. Eye lid
10. Bicuspid valve controls the flow of blood from:
A. Right atrium to right ventricle B. Left ventricle to aorta
C. Right ventricle to pulmonary artery D. Left atrium to left ventricle
11. Elastic fibres are absent in the wall of:
A. Aorta B. Capillaries C. Arteries D. Veins
12. Thoracic lymph duct of the lymphatic system opens into:
A. Superior vena cava B. Inferior vena cava C. Subclavian vein D. Renal vein
13. In ECG, QRS wave represents:



- A. Ventricular systole B. Diastole C. Atrial systole D. Recovery systole
14. _____ cells survive for few days and they secrete huge number of antibodies in blood, tissue fluid or lymph:
A. Memory cells B. T lymphocytes C. B lymphocytes D. Plasma cells

BIOLOGY NOTES FOR CLASS-11 (FOR PUNJAB)

15. The thickest chamber of human heart is:
A. Left atrium B. Right ventricle C. Right atrium D. Left ventricle
16. Cell mediated immune response is given by:
A. T lymphocytes B. Neutrophils C. B lymphocytes D. Macrophages
17. The capillaries of glomerulus rejoin to form an ____:
A. Efferent arteriole B. Peritubular capillaries C. Afferent arteriole D. Collecting duct
18. Which one of the following act as a PACEMAKER in heart?
A. Bundles of his B. Atrio ventricular bundles of fibers
C. Atrio ventricular node D. Sino atrial node
19. Which statement is correct about atrial systole:
A. Atria relax and ventricles contract B. Ventricles remain relax while atria contract
C. Atria contract and ventricle also contract D. Atria and ventricles are relaxed
20. Large lymph vessels ultimately form larger lymph duct , which drains its lymph into:
A. Carotid and Aorta B. Subclavian vein C. Vena Cava and Aorta D. Subclavian artery

ANSWERS KEY

1. D	2. B	3. C	4. A	5. B	6. B	7. D	8. B	9. C	10. D	11. B	12. C
13. A	14. D	15. D	16. A	17. A	18. D	19. B	20. B				