

Table of Contents

1. Introduction
2. Blood
3. Plasma
4. Formed Elements (Blood Corpuscles)
5. Blood Groups
6. Coagulation of Blood
7. Lymph (Tissue Fluid)
8. Circular Pathways
9. Human Circulatory System
10. Cardiac Cycle
11. Electrocardiogram (ECG)
12. Double Circulation
13. Regulation of Cardiac Activity
14. Disorders of Circulatory System
15. Atherosclerosis and Coronary Artery Disease
16. Angina
17. Heart Failure
18. Cardiac Arrest
19. Heart Attack
20. Human Heart Structure

Introduction

Overview

- Living cells require nutrients, oxygen, and waste removal for healthy function.
- Complex organisms use body fluids for transport of substances.
- **Blood** is the primary transport fluid in higher organisms including humans.
- **Lymph** also aids in transport of certain substances.

Memory Aids

- Blood = main transport fluid in humans.
- Lymph = secondary transport fluid.

Quick Checkpoints

- What are the main transport fluids in humans?
- Why is a transport system essential?

Blood

Composition and Properties

- Blood is a mobile connective tissue with plasma (fluid matrix) and formed elements.
- Adult human blood volume: 5-5.5 litres, 30-35% of extracellular fluid.
- Blood is slightly alkaline with pH 7.4.

Memory Aids

- Blood volume ~5 litres in adults.
- pH ~7.4 (alkaline).

Quick Checkpoints

- What is the pH of blood?
- What percentage of extracellular fluid does blood constitute?

Plasma

Composition and Functions

- Plasma is a pale yellow, viscous, non-living intercellular fluid making up 55% of blood.
- 90-92% water; 6-8% plasma proteins including albumin, globulin, immunoglobulin, prothrombin, fibrinogen.
- Fibrinogen aids blood clotting; globulins aid defense; albumins maintain osmotic balance.
- Contains minerals (Na^+ , Ca^{2+} , Mg^{2+} , HCO_3^- , Cl^-), glucose, amino acids, lipids in transit.
- Clotting factors are inactive in plasma; plasma without clotting factors is called **serum**.

Memory Aids

- Plasma = 55% blood, mostly water.
- Serum = plasma minus clotting factors.

Quick Checkpoints

- What is plasma made of?
- What is serum?

Formed Elements (Blood Corpuscles)

Types and Functions

- Formed elements: erythrocytes (RBCs), leucocytes (WBCs), platelets.
- They constitute about 45% of blood volume.

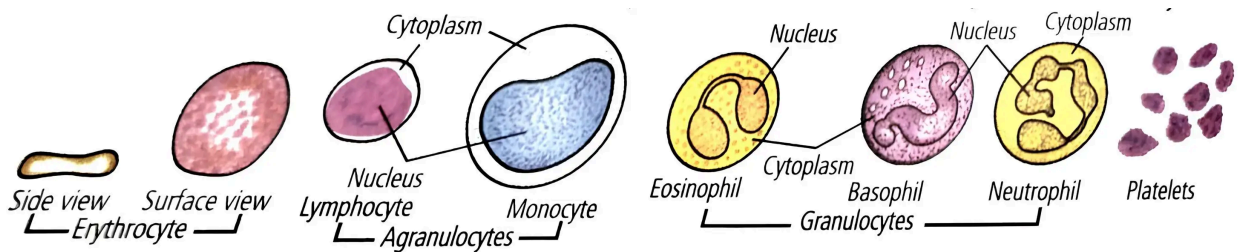


Fig.: Human blood corpuscles

- Erythrocytes carry oxygen; biconcave, enucleated, formed in red bone marrow.
- Haemoglobin gives red color; lifespan ~120 days; formation called erythropoiesis.
- Iron, proteins, vitamin B12, folic acid essential for RBC formation.
- Spleen destroys RBCs; called graveyard of RBCs.
- Polycythemia = high RBC count; erythrocytopenia = low RBC count causing oxygen shortage; anemia = low haemoglobin.
- People in hills have more RBCs to adapt to low oxygen.
- Leucocytes (WBCs) are nucleated, colorless, 6000-8000 per cubic mm, short-lived.
- Two types: granulocytes (neutrophils, eosinophils, basophils) and agranulocytes (lymphocytes, monocytes).

Table : Types of white blood cells

Character	Neutrophils	Basophils	Eosinophils	Lymphocytes	Monocytes
Number	60-65%	0-1 %	2-3%	20-25%	2-10%
Nucleus	Many lobed	3 lobed (S-shaped)	Bilobed	Large rounded	Bean shaped
Functions	Phagocytic, engulf harmful germs and foreign particles	Release heparin, serotonin and histamine involved in inflammatory reactions	Number increases in people with allergic reactions such as asthma or hay fever	Produce antibodies, two major types – B and T lymphocytes are responsible for immune responses of the body	Phagocytic in nature, engulf bacteria and cellular debris

- Neutrophils most numerous; monocytes largest.
- Leucocyte formation called leucopoiesis; decrease called leukopenia; increase in leukemia.
- Platelets (thrombocytes) are cell fragments from megakaryocytes; 1.5-3.5 lakh per cubic mm.
- Platelets aid blood clotting; lifespan ~1 week; low count causes clotting disorders.

Memory Aids

- RBCs = oxygen carriers, biconcave, no nucleus.
- WBCs = immune defense, nucleated.
- Platelets = clotting, cell fragments.

Quick Checkpoints

- What are the three formed elements of blood?
- Where are RBCs formed?
- What causes anemia?
- Types of leucocytes?
- Role of platelets?

Blood Groups

ABO Blood Grouping

- Discovered by Karl Landsteiner (1900); AB group by Dacastello and Sturli (1902).
- Controlled by gene I with alleles I^A , I^B , I^O .
- I^A and I^B produce A and B antigens on RBC surface; antibodies present in plasma.
- Donor and recipient blood groups must match to avoid RBC clumping.

Table : Human ABO blood groups and their compatibility

Blood group	Genotype	Antigens on red blood corpuscles	Antibodies in blood plasma	Can give blood to	Can get blood from
A	$I^A I^A$ or $I^A I^O$	A	B	A, AB	A, O
B	$I^B I^B$ or $I^B I^O$	B	A	B, AB	B, O
AB	$I^A I^B$	A, B	None	AB	A, B, AB, O
O	$I^O I^O$	None	A, B	A, B, AB, O	O

- Group O = universal donor; Group AB = universal recipient.

Rh Grouping

- Rh antigen discovered by Landsteiner and Wiener (1940) in Rhesus monkey.
- Present in ~80% humans; Rh+ve have antigen, Rh-ve lack it.
- Rh-ve exposed to Rh+ve blood form antibodies; matching needed before transfusion.
- Rh incompatibility in pregnancy causes erythroblastosis fetalis (fetal RBC destruction, anemia, jaundice).
- Prevented by anti-Rh antibodies given to mother after first delivery.

Memory Aids

- ABO: A and B antigens; O no antigen.
- Rh+: antigen present; Rh-: antigen absent.
- O = universal donor; AB = universal recipient.

Quick Checkpoints

- What alleles control ABO blood groups?
- Who is universal donor and recipient?
- What causes erythroblastosis fetalis?

Coagulation of Blood

Process and Importance

- Blood clotting stops bleeding after injury to blood vessels.
- Clot is a fibrin network trapping blood cells, forming a seal.

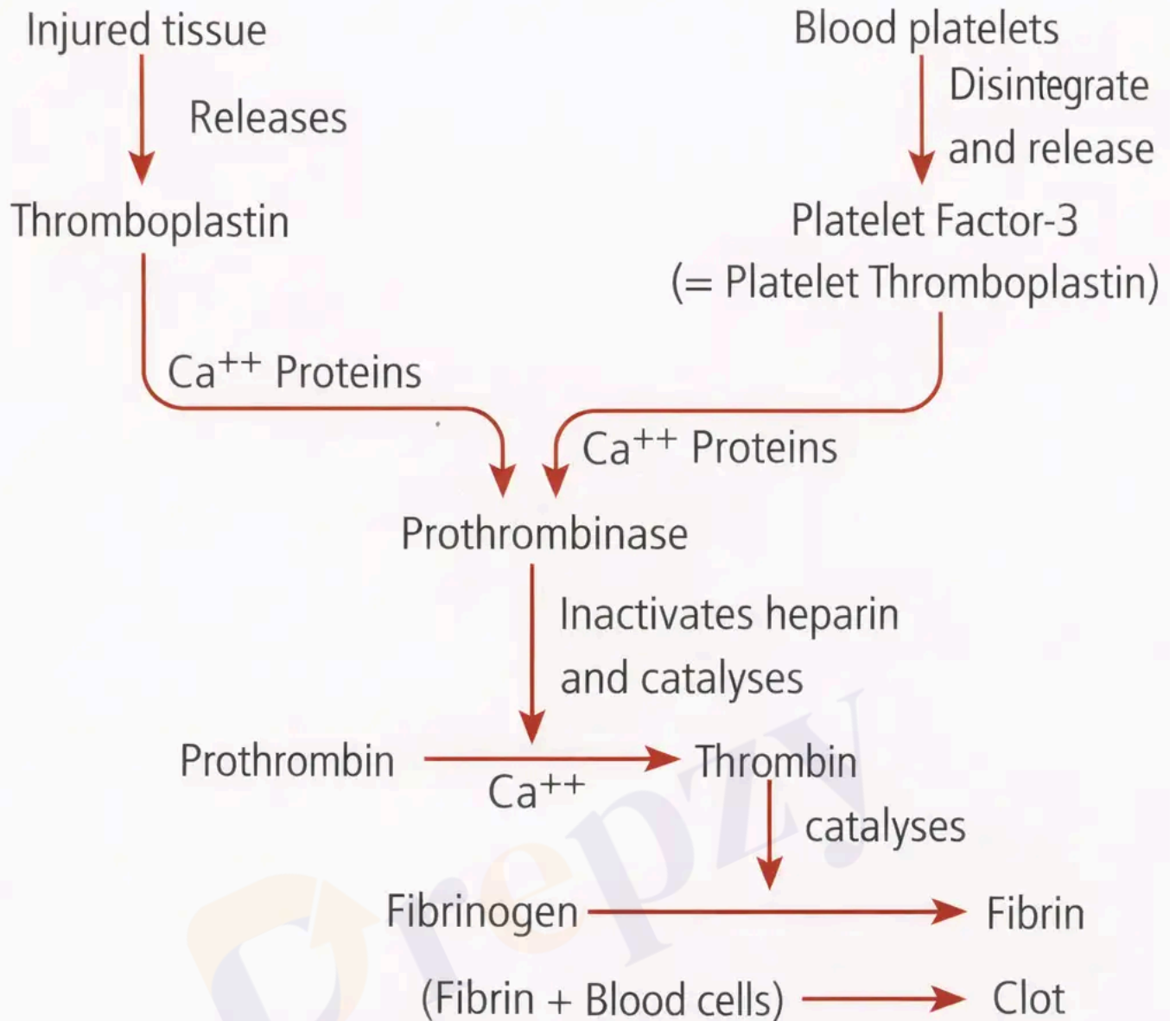


Fig.: The process of blood clotting

- Steps: injury releases thromboplastin; platelets release platelet factor 3.
- Thromboplastin + platelet factor 3 + Ca²⁺ form prothrombinase.
- Prothrombinase converts prothrombin to thrombin.
- Thrombin converts fibrinogen to fibrin, forming clot.
- Clotting time: 3-8 minutes.
- Vitamin K needed for prothrombin synthesis.
- Anticoagulants (heparin, oxalates) prevent clotting.

Memory Aids

- Clotting = thromboplastin → prothrombinase → thrombin → fibrin.

- Vitamin K essential for clotting.
- Heparin = anticoagulant.

Quick Checkpoints

- What triggers blood clotting?
- Role of thrombin?
- Why is vitamin K important?

Lymph (Tissue Fluid)

Composition and Characteristics

- Mobile connective tissue with lymph plasma and lymph corpuscles.
- **Lymph plasma:** Similar to blood plasma but with fewer proteins, less calcium and phosphorus, and higher glucose.
- Collected and drained by the lymphatic system into major veins.

Cellular Components and Functions

- **Lymph corpuscles:** Amoeboid leucocytes, mainly lymphocytes; no erythrocytes or platelets.
- Transports nutrients, hormones, and fats (absorbed via lacteals in intestinal villi).
- Acts as a transporter between body cells and blood, carrying wastes like carbon dioxide to blood.
- Destroys microorganisms and foreign particles in lymph nodes.

Memory Aids

- Lymph = Plasma + Corpuscles (mostly lymphocytes).
- Fats absorbed via lacteals → transported by lymph.
- Lymphatic system drains fluid back to veins.

Quick Checkpoints

- What are the main components of lymph?
- How does lymph plasma differ from blood plasma?
- Which cells are present and absent in lymph?
- What is the role of lymph in fat absorption?
- How does lymph contribute to immune defense?

Circular Pathways

Types of Circulatory Systems

- Open system: Blood leaves vessels, fills sinuses; found in arthropods, mollusks.
- Closed system: Blood stays in vessels, circulates continuously; found in annelids, chordates.
- Closed system allows precise regulation of fluid flow.
- Evolution of vertebrate hearts:
 - 2-chambered: 1 atrium, 1 ventricle; single circulation in fishes; pumps deoxygenated blood to gills.
 - 3-chambered: 2 atria, 1 ventricle; incomplete double circulation in amphibians, reptiles; mixed blood pumped.
 - 4-chambered: 2 atria, 2 ventricles; double circulation in crocodiles, birds, mammals; no blood mixing.

Memory Aids

- Open = blood leaves vessels; Closed = blood stays in vessels.
- 2-chambered = fish, single loop; 3-chambered = amphibians/reptiles, mixed blood; 4-chambered = birds/mammals, separate loops.

Quick Checkpoints

- What distinguishes open from closed circulatory systems?
- How does blood flow differ in 2, 3, and 4-chambered hearts?

- Why is closed circulation more efficient?

Human Circulatory System

Components and Heart Structure

- Also called blood vascular system: muscular heart, closed vessels (arteries, veins), blood.
- Heart: four-chambered, mesodermal, in thoracic cavity, left tilted, fist-sized.
- Enclosed in pericardium with pericardial cavity and fluid.
- Right and left atria separated by interatrial septum; ventricles by interventricular septum.
- Right atrium receives deoxygenated blood via superior and inferior vena cava.
- Left atrium receives oxygenated blood from lungs via pulmonary veins.
- Left ventricle thicker to pump blood at higher pressure.
- Atrioventricular septum separates atrium and ventricle on same side with valves:
 - Bicuspid (mitral) valve on left side.
 - Tricuspid valve on right side.
- Chordae tendineae connect valve flaps to papillary muscles.
- Semilunar valves at pulmonary artery and aorta openings prevent backflow.
- Heart muscle includes nodal tissue: sino-atrial node (SAN) as pacemaker, atrioventricular node (AVN) as pacesetter.
- AV bundle (bundle of His) and Purkinje fibers conduct impulses for rhythmic contraction.
- Heartbeat types:
 - Neurogenic: nerve impulse initiated (annelids, arthropods).
 - Myogenic: muscle initiated (molluscs, vertebrates including humans).

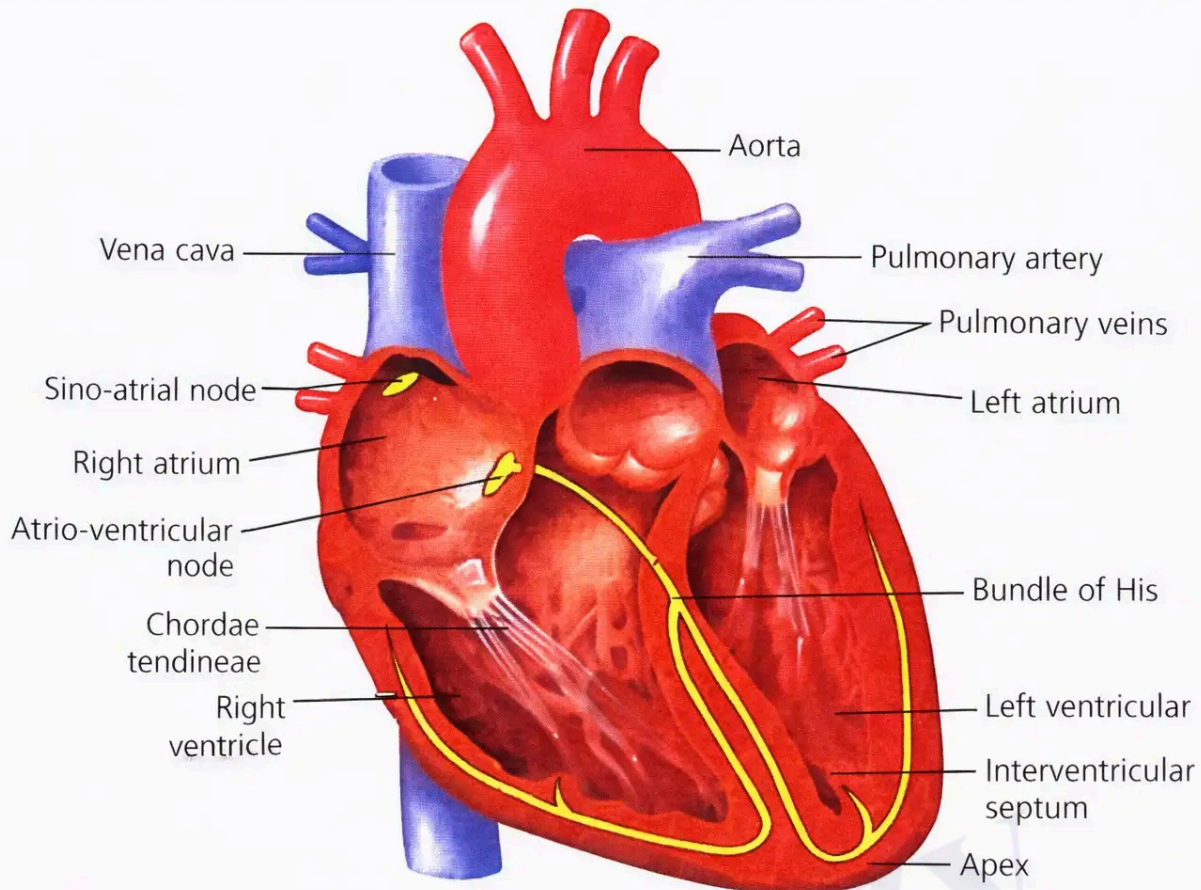


Fig.: Section of a human heart

Memory Aids

- SAN = pacemaker; AVN = pacesetter.
- Left ventricle thicker = higher pressure pump.
- Bicuspid = 2 cusps; Tricuspid = 3 cusps.

Quick Checkpoints

- What separates atria and ventricles?
- Which valves prevent backflow into atria?
- What is the role of nodal tissue?
- Difference between neurogenic and myogenic heartbeat?

Cardiac Cycle

Stages and Events

- Cardiac cycle = systole (contraction) + diastole (relaxation) of atria and ventricles.
- Stages:
 - Joint diastole: all chambers relaxed, AV valves open, semilunar valves closed, ventricles fill.
 - Atrial systole: atria contract, increase ventricular filling by 30%.
 - Ventricular systole: ventricles contract, AV valves close (first heart sound 'lub'), semilunar valves closed initially.
 - Ventricular diastole: semilunar valves open, blood ejected, ventricles relax, semilunar valves close (second heart sound 'dub').
 - Complete ventricular diastole: ventricles relax, AV valves open, cycle repeats.
- Cardiac output = heart rate $\times$ stroke volume (~ 5.5 L/min in humans).
- Duration of cardiac cycle = 0.8 seconds.
- Heart sounds: 'lub' (0.15 s, 25-45 Hz), 'dub' (0.12 s, 50 Hz).

Memory Aids

- Lub = AV valves closing; Dub = semilunar valves closing.
- Atrial systole = 0.1 s; Ventricular systole = 0.3 s; Joint diastole = 0.4 s.
- Cardiac output depends on heart rate and stroke volume.

Quick Checkpoints

- What happens during atrial systole?
- Which valves produce the first and second heart sounds?
- How is cardiac output calculated?
- Duration of one cardiac cycle?

Electrocardiogram (ECG)

Basics and Components

- ECG records electrical activity of cardiac muscles using electrocardiograph.
- Standard ECG uses three leads: two wrists, one left ankle.
- Normal ECG waves:
 - P wave: atrial depolarisation (contraction), caused by SA node.
 - QRS complex: ventricular depolarisation (contraction), starts with Q (down), R (up), S (down).
 - T wave: ventricular repolarisation (relaxation), dome-shaped.
- End of T wave marks end of systole.
- Heart rate can be determined by counting QRS complexes per time.
- Abnormal ECG shapes indicate heart diseases.

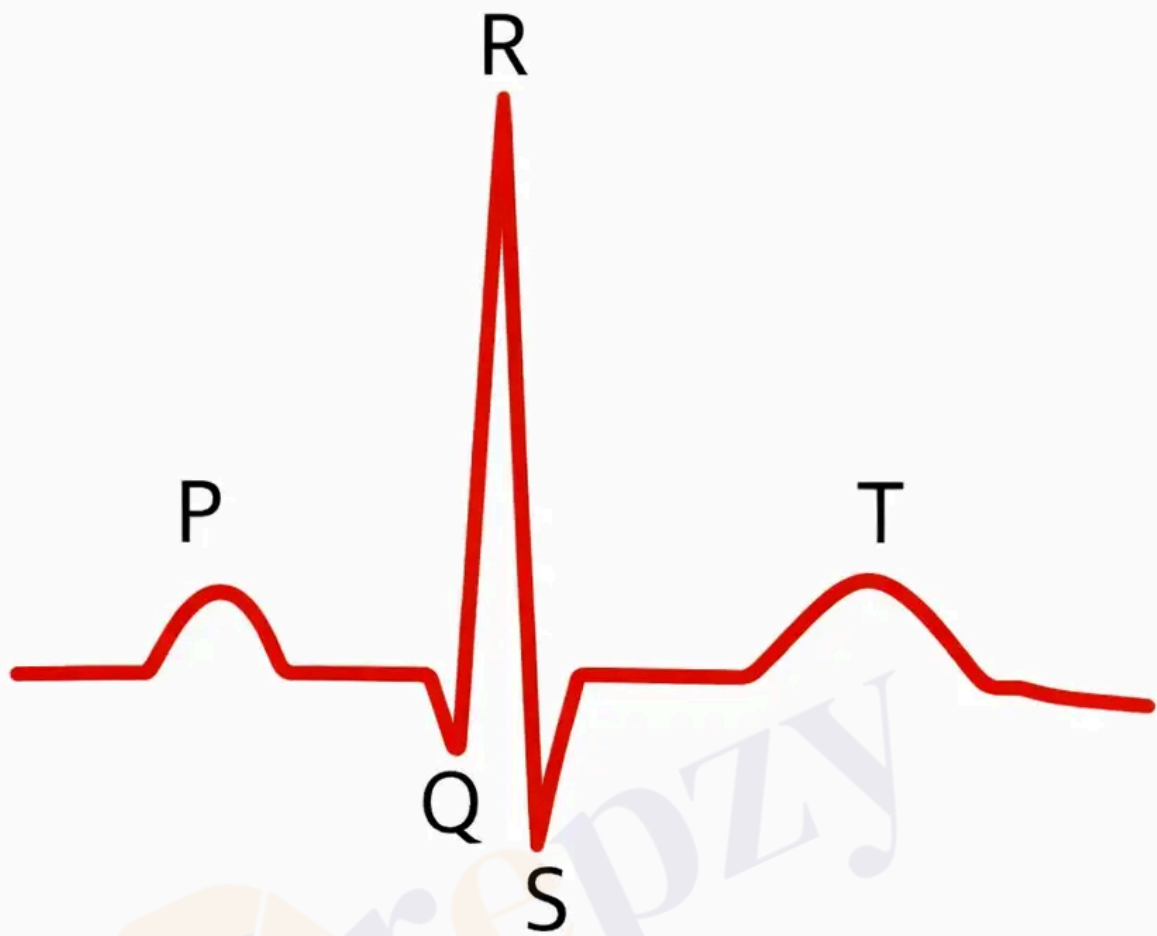


Fig.: Diagrammatic representation of a standard ECG

Memory Aids

- P wave = atrial contraction.
- QRS complex = ventricular contraction.
- T wave = ventricular relaxation.

Quick Checkpoints

- What does the P wave represent?
- Which wave indicates ventricular contraction?
- How is heart rate measured from ECG?
- What does an abnormal ECG indicate?

Double Circulation

Blood Vessels

- Three types: arteries, veins, capillaries.
- **Arteries:** Elastic vessels carrying oxygenated blood from heart to tissues; *pulmonary artery* carries deoxygenated blood.
- **Veins:** Carry deoxygenated blood to heart; *pulmonary vein* carries oxygenated blood from lungs to left atrium; veins have valves to prevent backflow.
- **Capillaries:** Connect arteries and veins in tissues.
- Walls of arteries and veins have three layers:
 - **Tunica intima:** Innermost, squamous endothelium + elastic membrane.
 - **Tunica media:** Middle, smooth muscle + elastic fibers; thinner in veins.
 - **Tunica externa:** Outer fibrous connective tissue with collagen.

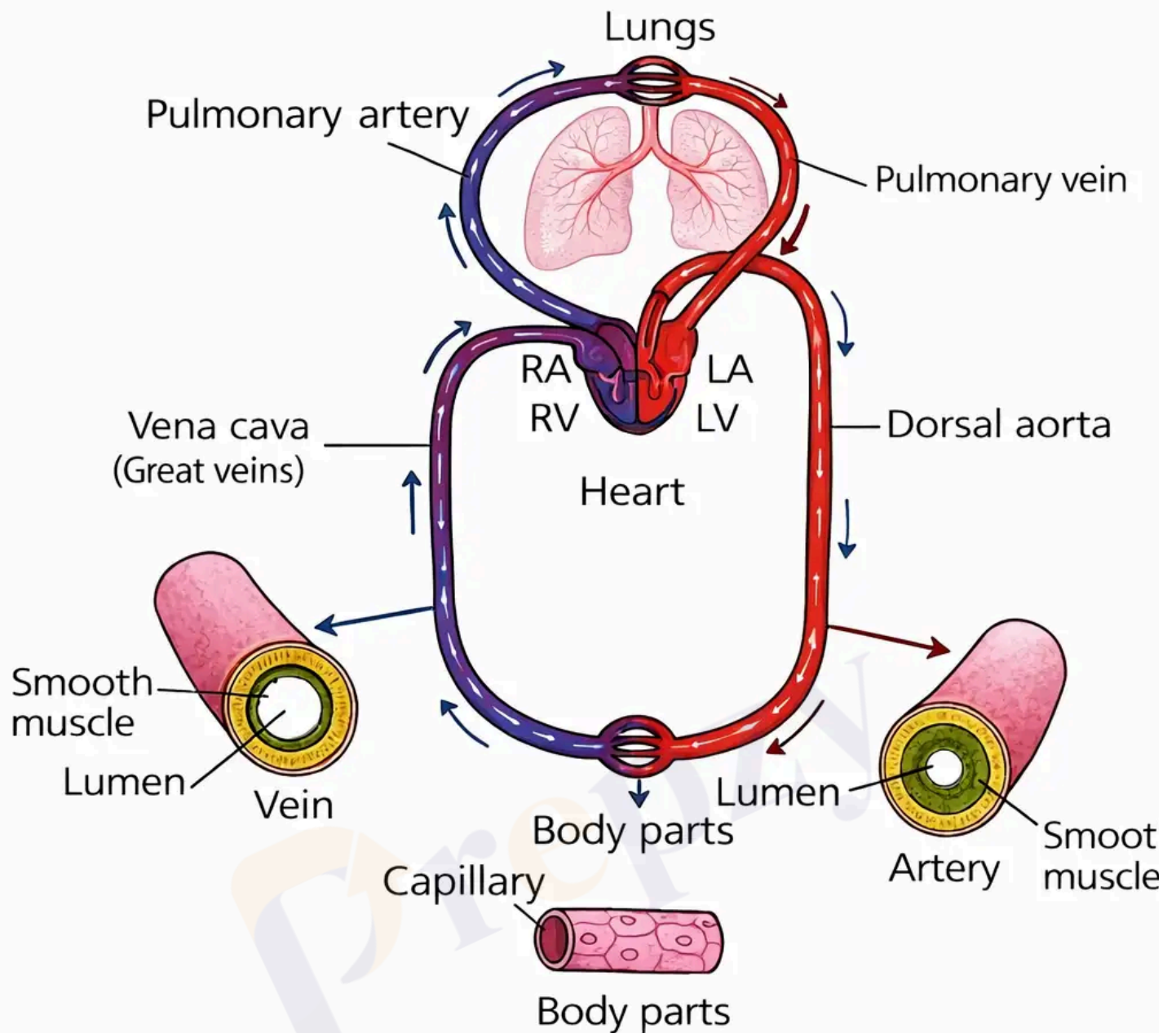


Fig.: Schematic plan of blood circulation in human

Double Circulation Pathways

- Blood passes twice through heart in separate routes per cycle.
- Consists of **pulmonary circulation** and **systemic circulation**.

Pulmonary Circulation

- Deoxygenated blood pumped from right ventricle to lungs via pulmonary trunk and arteries.
- Blood gets oxygenated in lungs.
- Oxygenated blood returns to left atrium via pulmonary veins.

Systemic Circulation

- Oxygenated blood pumped from left ventricle to body through arteries, arterioles, capillaries.
- Deoxygenated blood collected by venules, veins, vena cava, returns to right atrium.
- Delivers O₂, nutrients; removes CO₂, wastes.

Special Circulations

- **Hepatic portal system:** Connects digestive tract to liver.
- **Coronary circulation:** Supplies blood to cardiac muscle.

Memory Aids

- Arteries away, veins to heart (except pulmonary vessels).
- Pulmonary artery = deoxygenated; pulmonary vein = oxygenated.
- Double circulation = two heart passes per blood cycle.
- Hepatic portal = digestive tract to liver.
- Coronary = heart muscle blood supply.

Quick Checkpoints

- What are the three types of blood vessels and their functions?
- Which artery carries deoxygenated blood?
- Describe the layers of artery and vein walls.
- Explain pulmonary circulation steps.
- Explain systemic circulation steps.

- What is the hepatic portal system?
- What is coronary circulation?

Regulation of Cardiac Activity

Autoregulation by Nodal Tissue

- Heart's normal activity controlled by specialized muscles called nodal tissue.
- Heart is myogenic: it generates its own impulses without external stimuli.
- Medulla oblongata contains a neural center that modulates heart function via the autonomic nervous system (ANS).

Neural and Hormonal Control

- Sympathetic nerves (ANS) increase heart rate, ventricular contraction strength, and cardiac output.
- Parasympathetic nerves (ANS) decrease heart rate, slow action potential conduction, and reduce cardiac output.
- Adrenal medullary hormones also enhance cardiac output.

Memory Aids

- Myogenic = Heart beats by itself.
- Sympathetic = Speed up heart.
- Parasympathetic = Slow down heart.
- Medulla oblongata = Cardiac control center.

Quick Checkpoints

- What does myogenic mean in cardiac activity?
- How does the sympathetic nervous system affect the heart?
- Role of parasympathetic nerves in heart regulation?
- Which hormones increase cardiac output?

Disorders of Circulatory System

Hypertension and Blood Pressure

- **Hypertension** is high blood pressure above 140/90 mmHg, harming heart, brain, kidneys, and eyes.
- **Blood pressure** is the force exerted by blood on artery walls.
- **Systolic pressure** (120 mmHg) is pressure when left ventricle contracts.
- **Diastolic pressure** (80 mmHg) is pressure when heart rests during diastole.
- Blood pressure is expressed as **BP = 120/80 mmHg**.
- Difference between systolic and diastolic pressure is **pulse pressure**.
- Measured using a **sphygmomanometer**.

Memory Aids

- Normal BP: 120/80 (Systolic/Diastolic)
- Hypertension if BP > 140/90
- Pulse pressure = Systolic - Diastolic

Quick Checkpoints

- What defines hypertension?
- Difference between systolic and diastolic pressure?
- Device used to measure blood pressure?

Atherosclerosis and Coronary Artery Disease

Causes and Effects

- **Atherosclerosis/CAD** is lipid, fat, calcium, and fibrous tissue buildup forming *atheromatous* plaques in arteries.
- Plaques can block arteries, reducing blood supply to heart muscle, causing heart attack or stroke.

- **Arteriosclerosis** is hardening and thickening of arteries due to calcium and cholesterol deposits.
- Hardened arteries lose elasticity and may rupture, leading to heart attack or death.

Memory Aids

- Atherosclerosis = Plaque buildup in arteries
- Arteriosclerosis = Artery hardening
- CAD affects coronary arteries causing heart issues

Quick Checkpoints

- What forms atheromatous plaques?
- Difference between atherosclerosis and arteriosclerosis?
- Consequences of artery blockage?

Angina

Definition and Symptoms

- **Angina pectoris** is acute chest pain due to insufficient oxygen to heart muscle.
- Affects all ages, more common in middle-aged and elderly.
- Caused by reduced blood flow to heart.

Memory Aids

- Angina = Chest pain from low oxygen
- Occurs due to blood flow issues

Quick Checkpoints

- What causes angina?

- Who is commonly affected?

Heart Failure

Definition and Symptoms

- **Heart failure** or congestive heart failure is when heart pumps blood ineffectively.
- Leads to lung congestion as a main symptom.

Memory Aids

- Heart failure = weak heart pump
- Causes lung congestion

Quick Checkpoints

- What is congestive heart failure?
- Main symptom of heart failure?

Cardiac Arrest

Definition

- **Cardiac arrest** is the complete stop of heart beating.

Memory Aids

- Cardiac arrest = Heart stops beating

Quick Checkpoints

- What happens in cardiac arrest?

Heart Attack

Definition

- **Heart attack** occurs when heart muscle is damaged due to inadequate blood supply.

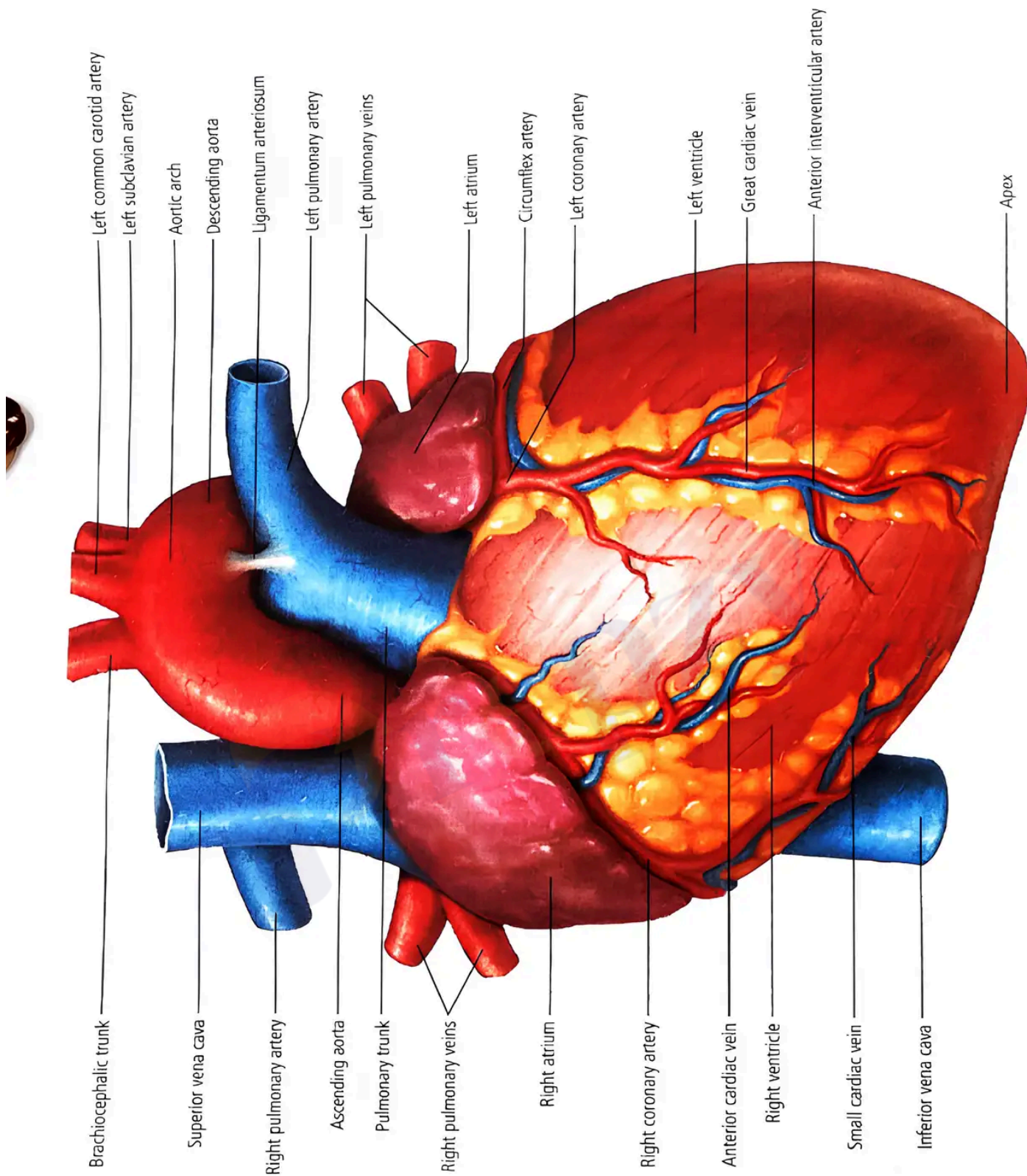
Memory Aids

- Heart attack = Sudden heart muscle damage

Quick Checkpoints

- Cause of heart attack?

Structure of Human Heart



Human Heart Structure

Key Features

- Four chambers: left atrium, left ventricle, right atrium, right ventricle.
- Blood enters via superior and inferior vena cava.
- Right atrium receives oxygen-poor blood, sends to right ventricle.
- Right ventricle pumps blood to lungs via pulmonary artery.
- Oxygen-rich blood returns to left atrium via pulmonary veins.
- Left ventricle pumps blood to body through aorta.
- Heart supplied by coronary arteries and veins on surface.
- Smaller vessels circulate blood within heart muscle.
- Apex is the pointed end directed downwards.

Memory Aids

- Right side: deoxygenated blood; Left side: oxygenated blood
- Coronary arteries supply heart muscle
- Apex points downwards

Quick Checkpoints

- Name the four chambers of the heart.
- Path of oxygen-poor blood through the heart?
- Function of coronary arteries?