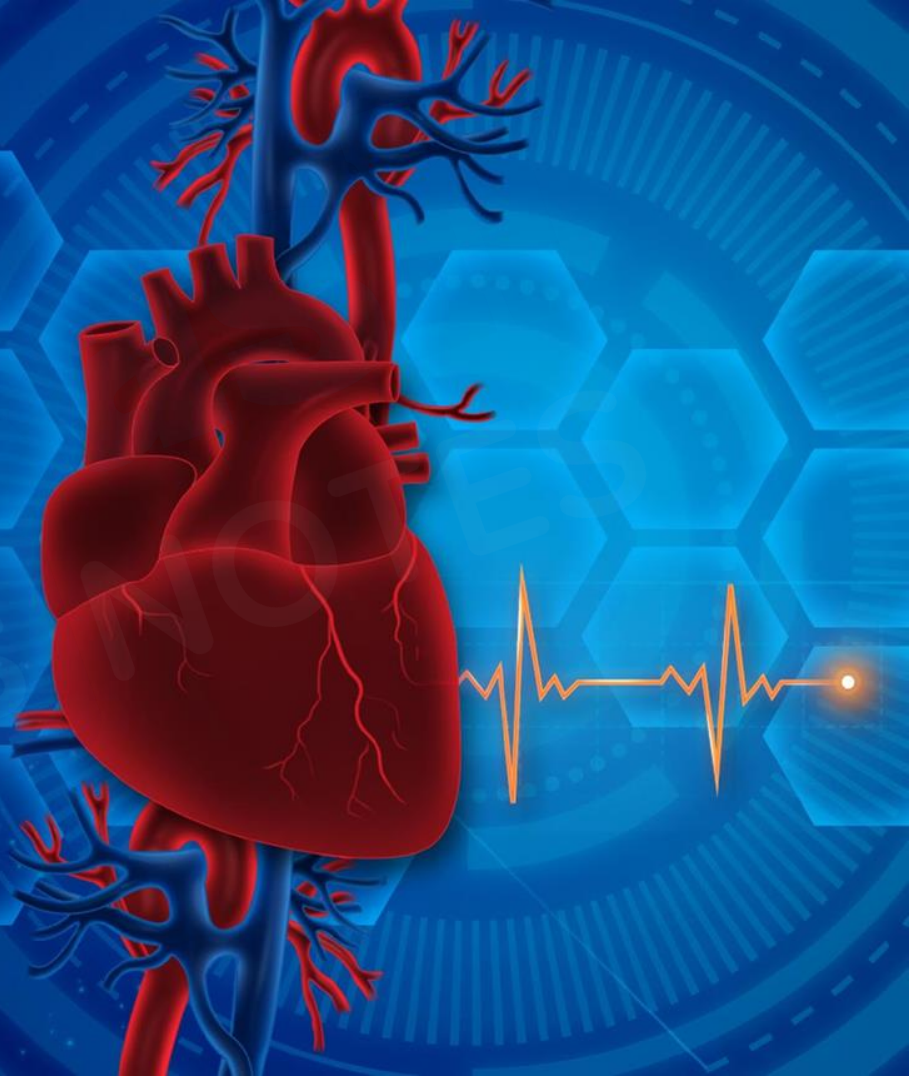
Aakash + BYJU'S NOTES

Body Fluids and Circulation



Key Takeaway

1. Circulatory system
2. Types of circulatory system
3. Human circulatory system
4. Circulation
5. Cardiac cycle
6. Stimulation of heart muscle contraction
7. Electrocardiogram: ECG
8. Heart diseases

8 Regulation of cardiac activity

Components of blood 9

10 Coagulation of blood

Functions of blood 11

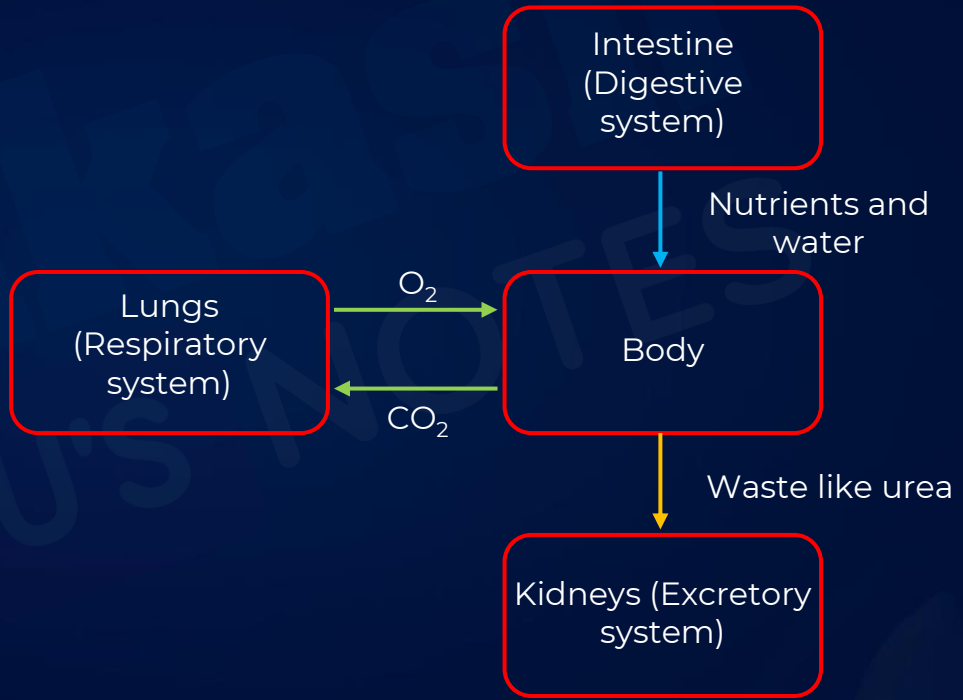
12 Blood grouping

Lymph 13

Summary

Circulatory System

- It is also known as the **cardiovascular system**.
- Its primary role is to provide **nutrients**, **gases**, and **hormones** to different parts of the body.
- It also transports **O_2** and **CO_2**.
- It collects all the **waste** from different parts of the body and delivers it to the excretory system.

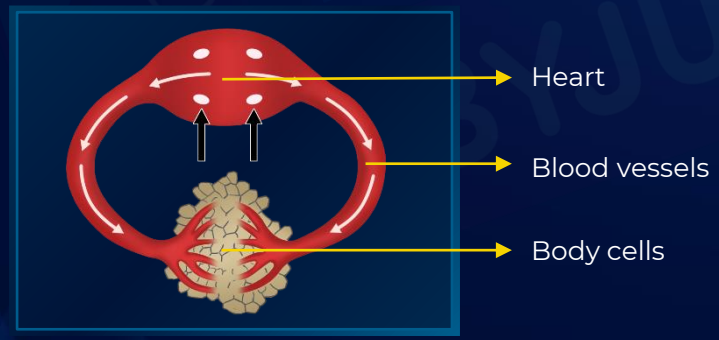


Types of Circulatory System

Types of circulatory systems in animals

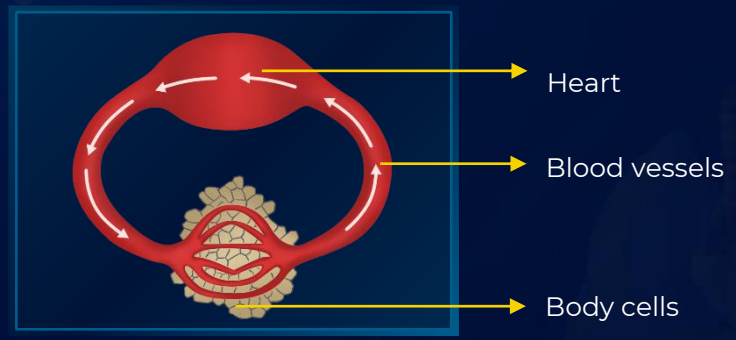
Open

- The heart pumps the circulatory fluid known as **hemolymph** through the vessels into open spaces or body cavities.
- The hemolymph returns to the heart via small pores known as **ostia**.



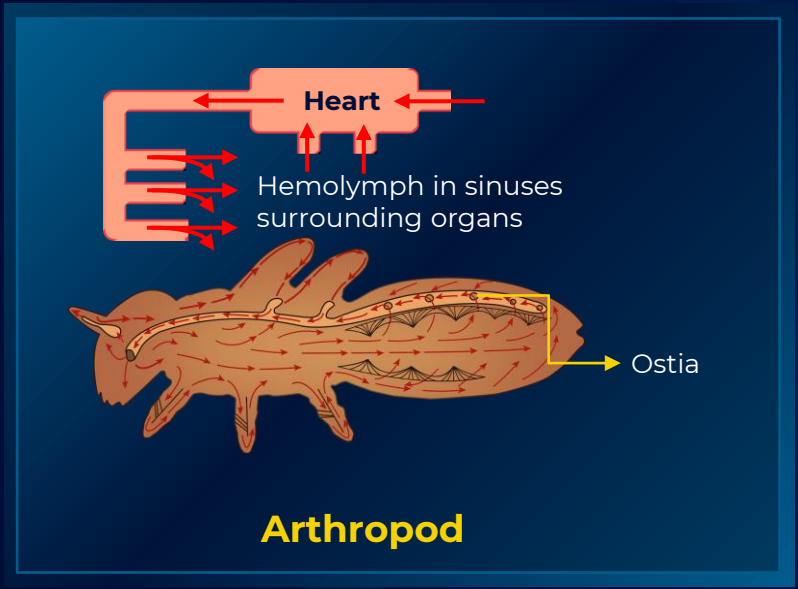
Closed

- The blood pumped by the heart is always circulated through a **closed network** of blood vessels.
- The flow of fluid through this system can be **regulated**.

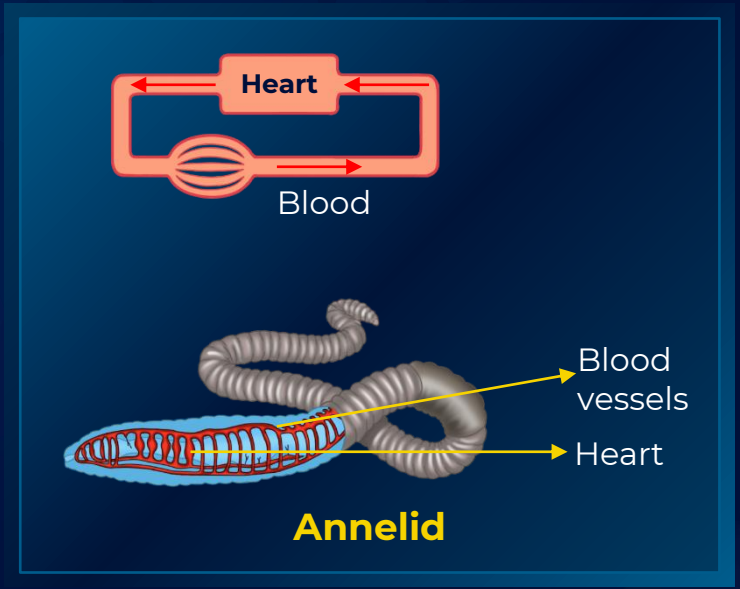


Types of Circulatory System

- Example: Arthropods, molluscs



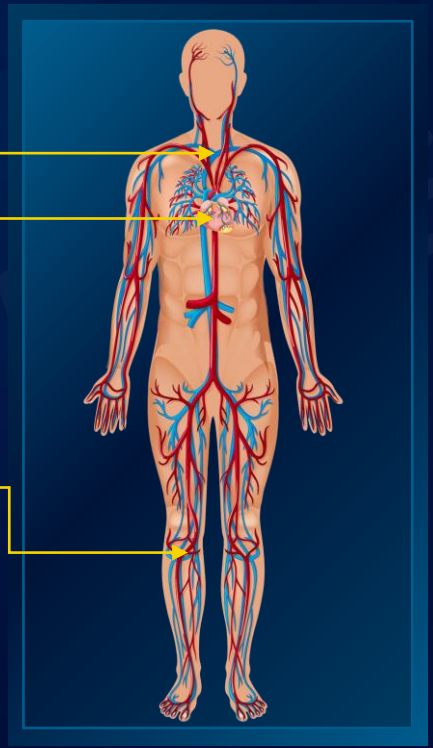
- Example: Annelids, chordates



Human Circulatory System

Human circulatory system

- Circulating fluid
- Heart
- Blood vessels



Human Circulatory System

Circulating fluids

Blood

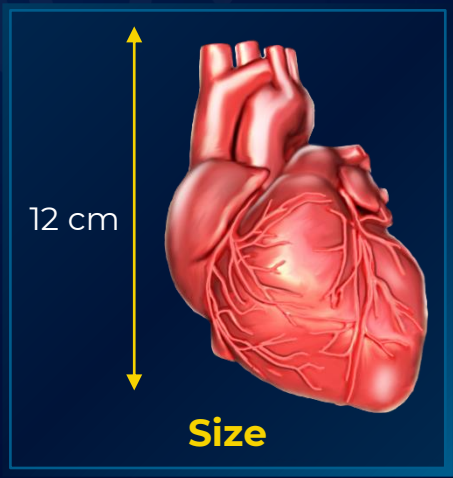
- It is a fluid connective tissue.
- It transports oxygen, nutrients, antibodies, etc.

Lymph

- It is a colourless fluid.
- It carries immune cells, nutrients, etc.

Human heart

- It is a **muscular organ**.
- It is derived from **mesodermal** tissue.
- It is located between the lungs in the thoracic cavity.
- It is roughly the size of a **clenched fist** and **12 cm long**.

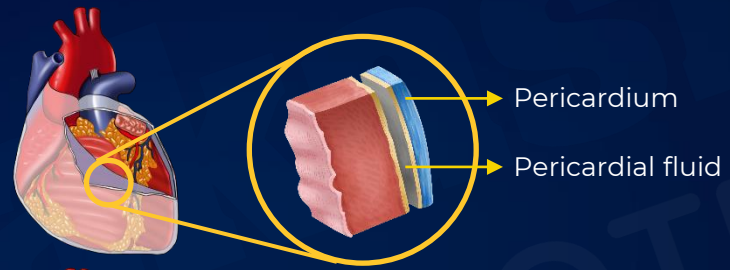


Human Circulatory System

Layers in the heart

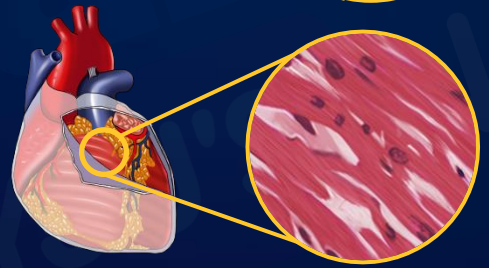
Pericardium
(Around heart)

It is a protective covering around the heart, and the space between pericardium is filled with pericardial fluid.



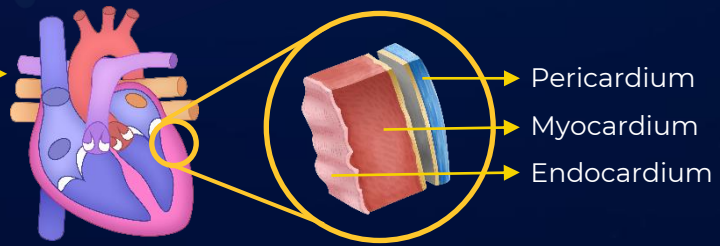
Myocardium
(Muscle heart)

It is a muscular wall of heart. It contracts to pump blood out of the heart and then relaxes as the heart refills with returning blood.



Endocardium
(Inner heart)

It remains in contact with blood.



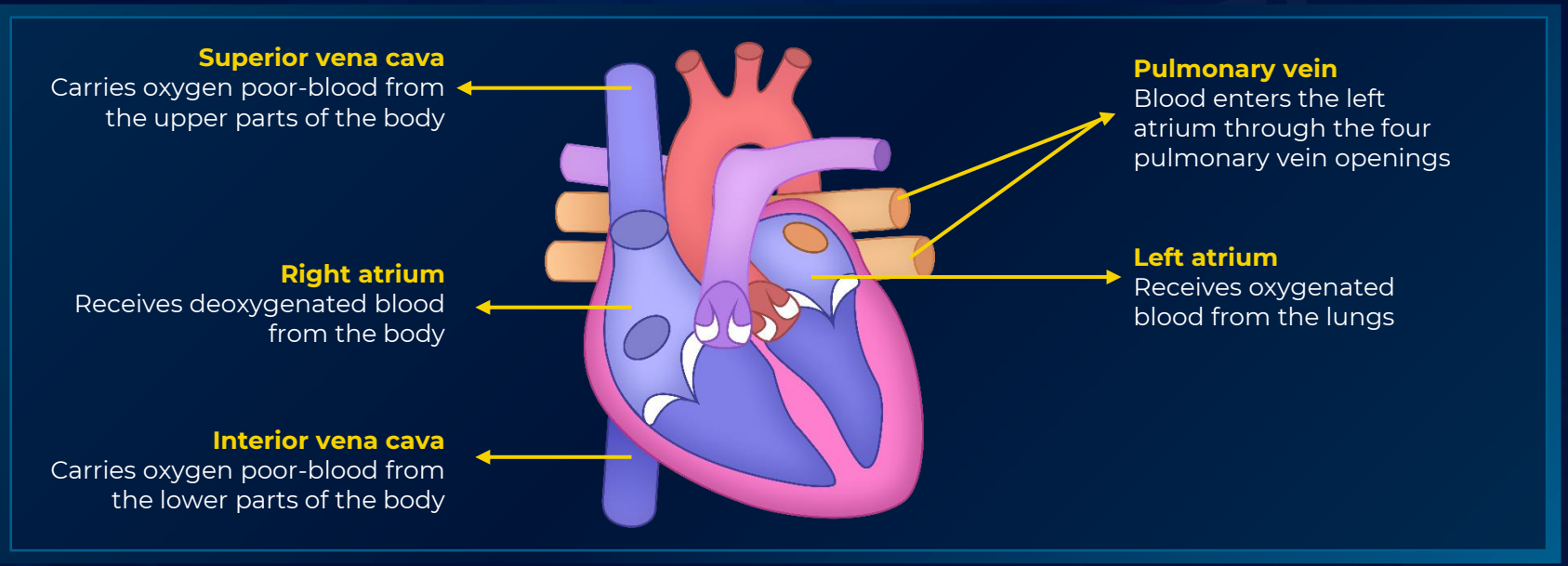
Human Circulatory System

Structure of a human heart

- Human heart consists of **four chambers**:
  - **Right and left atria**
  - **Right and left ventricles**

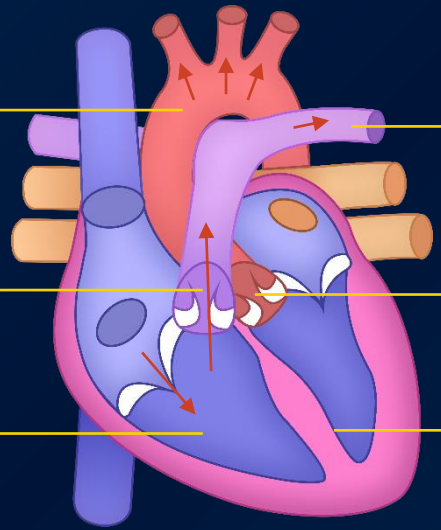
Atria

These are the small upper chambers.



Human Circulatory System

Ventricles These are the large lower chambers.



Aorta
Pumps oxygenated blood to the rest of the body

Pulmonary semilunar valve
Guards the opening of the right ventricle to the pulmonary artery

Right ventricle
Receives deoxygenated blood from the right atrium and then pumps blood into the pulmonary artery or pulmonary trunk

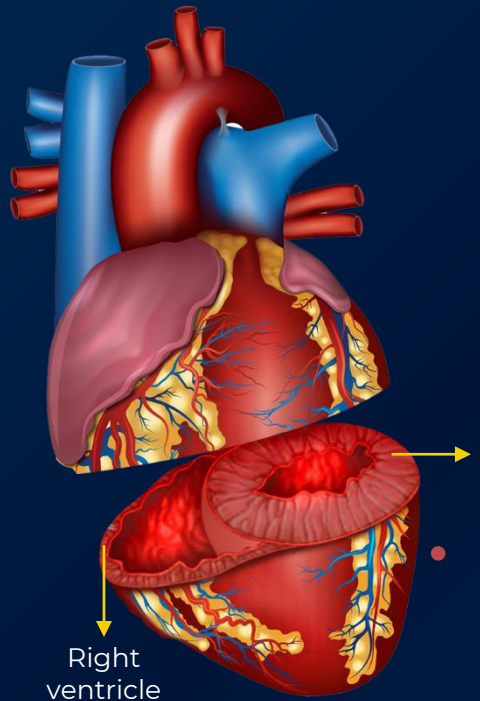
Pulmonary artery
Pumps deoxygenated blood to the lungs

Aortic semilunar valve
Guards the opening of the left ventricle to the aorta

Left ventricle
Receives oxygenated blood from the left atrium and then pumps blood into the aorta which then supplies to the whole body

Human Circulatory System

Right ventricle	Left ventricle
Comprises of thin wall	Comprises of thick wall
Receives deoxygenated blood from the right atrium	Receives oxygenated blood from the left atrium
Pumps blood to lungs through the pulmonary trunk	Pumps blood to the whole body through the aorta

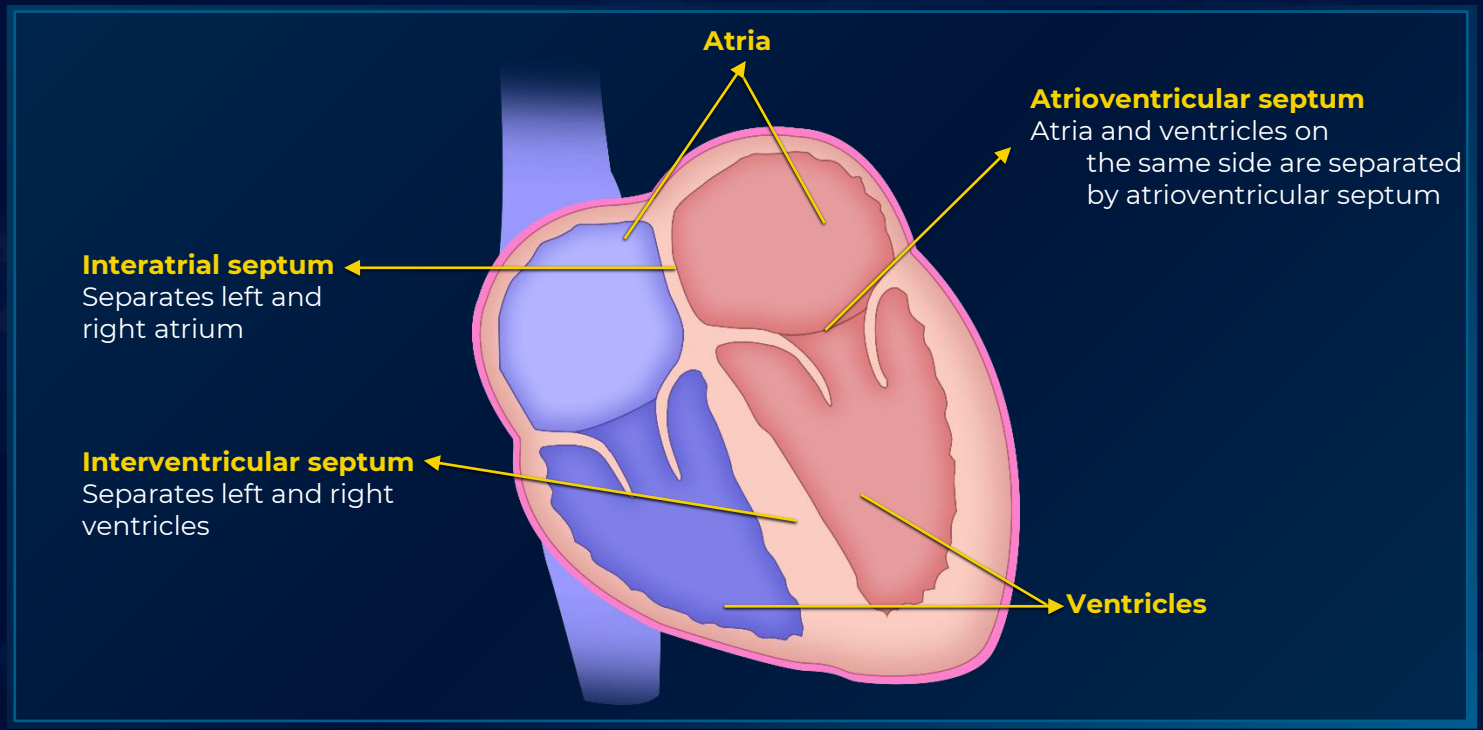


- The left ventricle is **larger** and **thicker** than the right ventricle
  - Because the left ventricle has to pump blood to the whole body through aorta.

Human Circulatory System

Septum

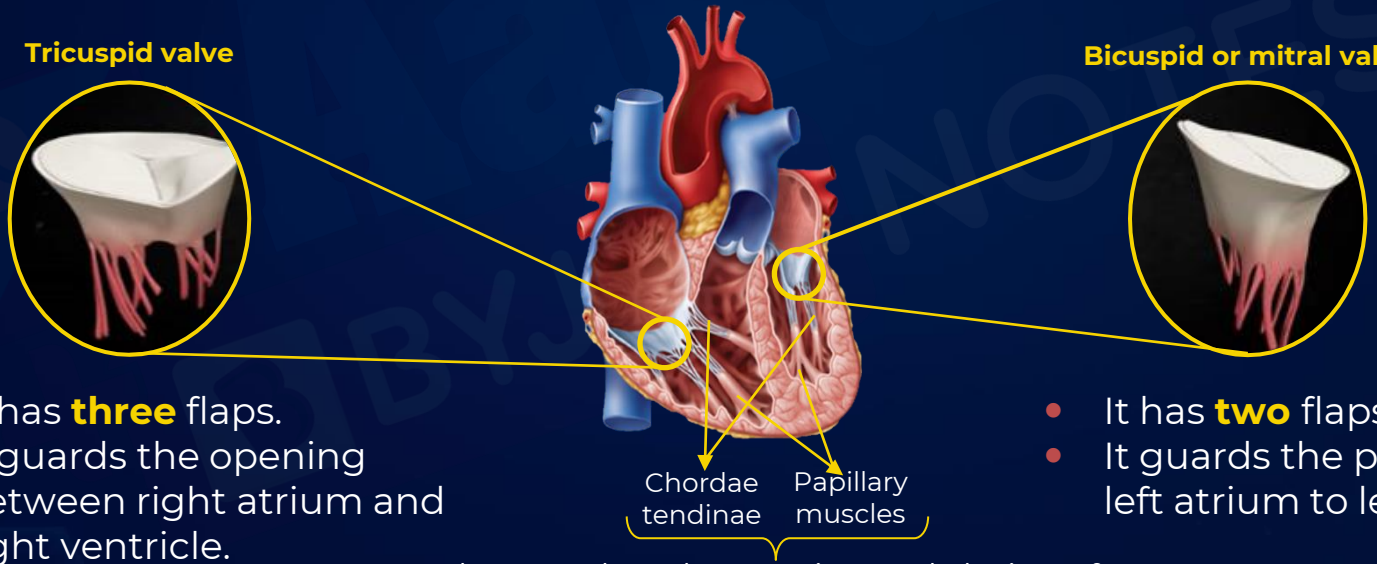
- The septum's primary function in the heart is to isolate the **two sides of the heart**.



Human Circulatory System

Valves

- Valves are flaps of fibrous tissues located in the cardiac chambers.
- They ensure that **blood flows in a single direction** (unidirectional).
- Flaps also prevent blood from flowing backwards.



- It has **three** flaps.
- It guards the opening between right atrium and right ventricle.

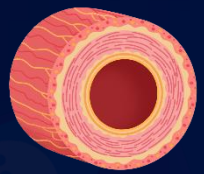
- It has **two** flaps.
- It guards the passage from left atrium to left ventricle.

They regulate the opening and closing of bicuspid and tricuspid valves.

Human Circulatory System

Blood vessels

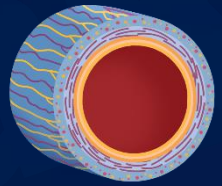
Arteries



Heart → Arteries (Carry blood) → Different parts of body

- Pinkish or bright red in colour as they carry **oxygenated** blood.
- Blood flows with a high pressure.

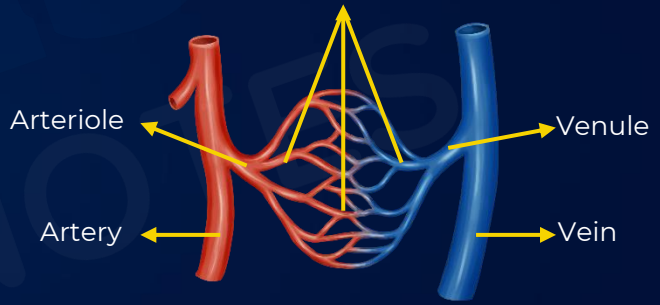
Veins



Different parts of body → Veins (Carry blood) → Heart

- Bluish or deep red in colour as they carry **deoxygenated** blood.

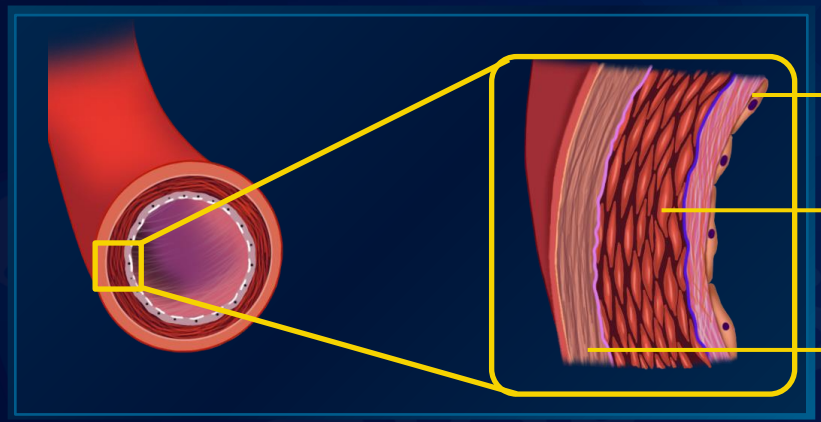
Capillaries



- Arteries branch out into arterioles and veins into venules.
- These arterioles and venules branch out into smaller, thinner blood vessels known as **capillaries.**
- They allow exchange of gases and other materials.
- They act as a connection between arteries and veins.

Human Circulatory System

Layers of arteries and veins



Tunica intima	Squamous endothelium
Tunica media	Smooth muscle and elastic fibres
Tunica externa	Fibrous connective tissue with collagen fibres

Human Circulatory System

Types of blood circulation

Single circulation

- Seen in **2-chambered** heart
- Contains **one atrium** and **one ventricle**
- Example: Fish
- The deoxygenated blood is pumped from heart to gills.

Incomplete double circulation

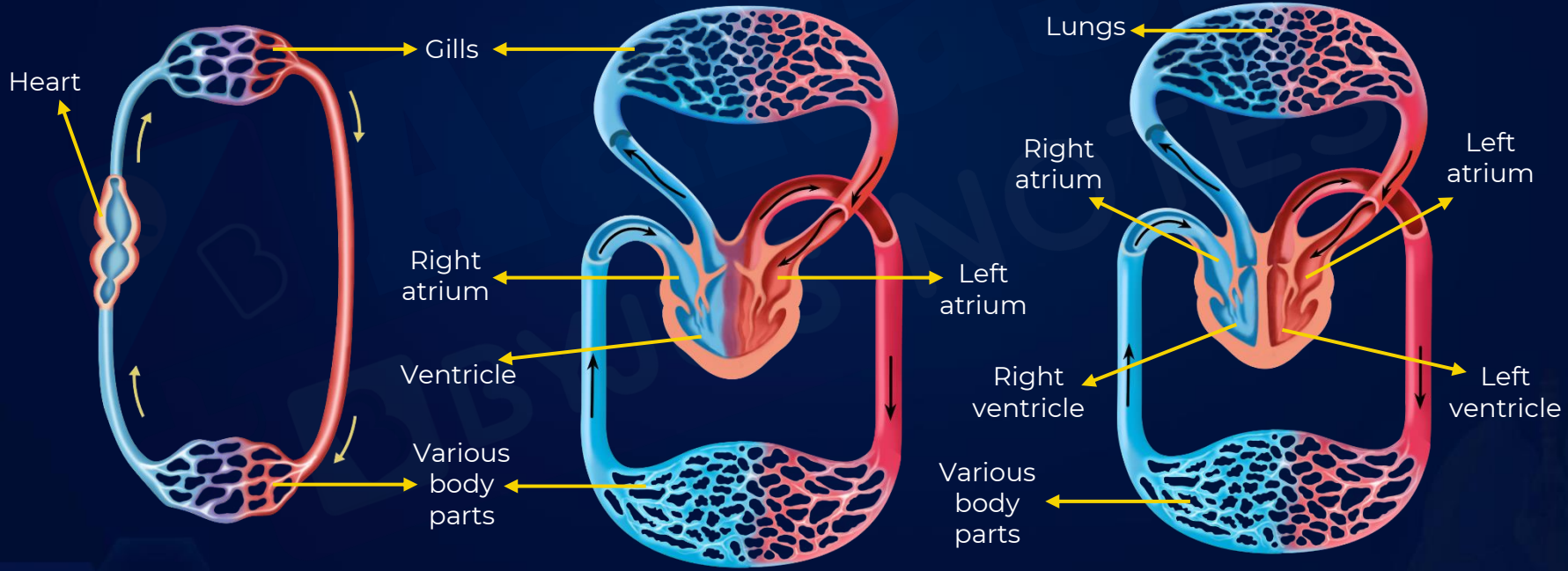
- Seen in **3-chambered** heart
- Contains **two atria** and **one ventricle**
- Examples: Amphibians and reptiles (except crocodile)
- The left atrium receives oxygenated blood from gills/skin/lungs and the right atrium receives deoxygenated blood from the body.
- They inter-mix in a single ventricle, which pumps it out to gills/skin/lungs and to different parts of body, thus it is known as incomplete circulation.
- **Blood passes through the heart twice,** hence known as double circulation.
- It is **inefficient** when compared to complete double circulation.

Complete double circulation

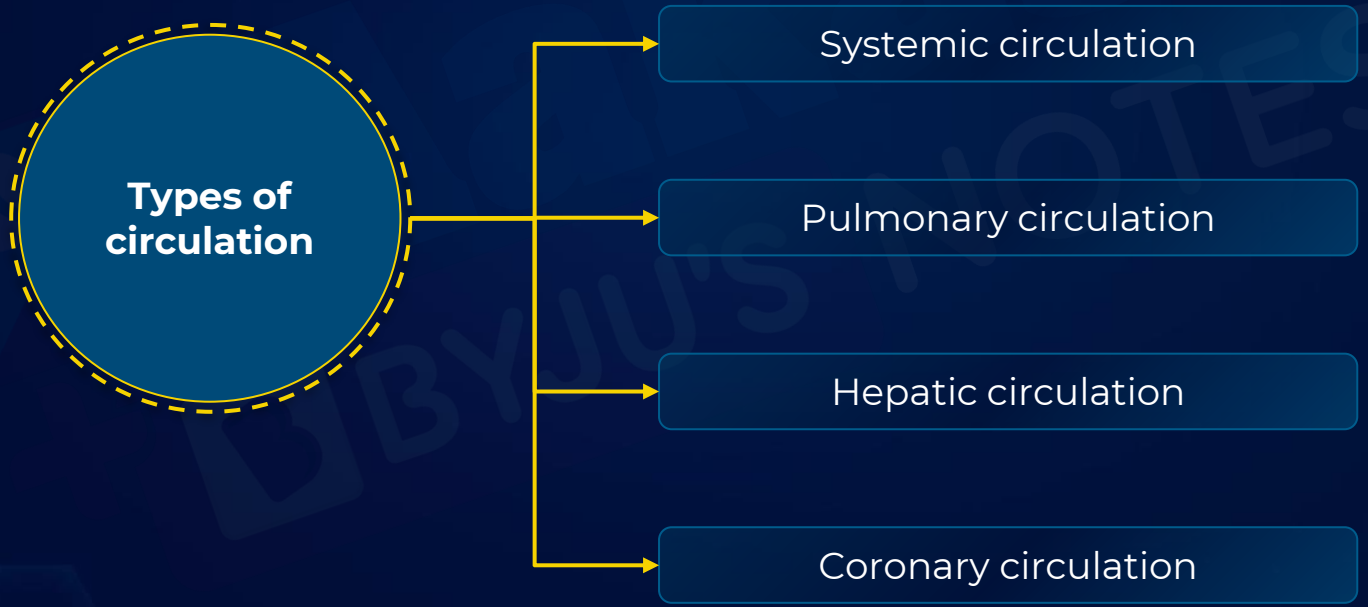
- Seen in **4-chambered** heart
- Contains **two atria** and **two ventricles**
- Examples: Birds and mammals
- The left atrium receives oxygenated blood from lungs and passes it to the left ventricle.
- The right atrium receives deoxygenated blood from the body and passes it to the right ventricle.
- Ventricles pump out the blood **without mixing up**.
- **Two separate circulatory pathways** are present, hence known as complete double circulation.

Human Circulatory System

Single circulation | Incomplete double circulation | Complete double circulation

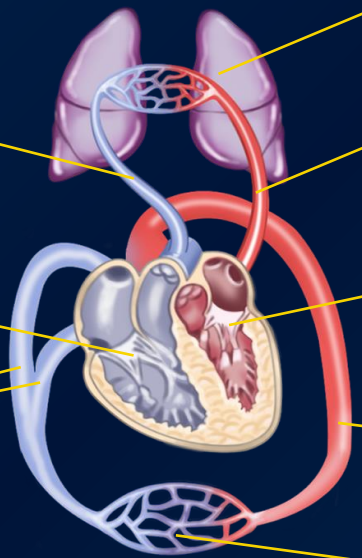


Circulation



Double Circulation

- It is known as double circulation because the **blood passes through the heart twice**.
- The separation of oxygenated and deoxygenated blood allows for a more efficient supply of oxygen to the body.



Pulmonary artery
- Right ventricle to lungs
- Carries **deoxygenated** blood

Tricuspid valve
- Right atrium to right ventricle

Vena cava
- Tissues to right atrium
- Carries **deoxygenated** blood

Lungs
- Deoxygenated blood gets converted to oxygenated blood

Pulmonary veins
- Lungs to left atrium
- Carry **oxygenated** blood

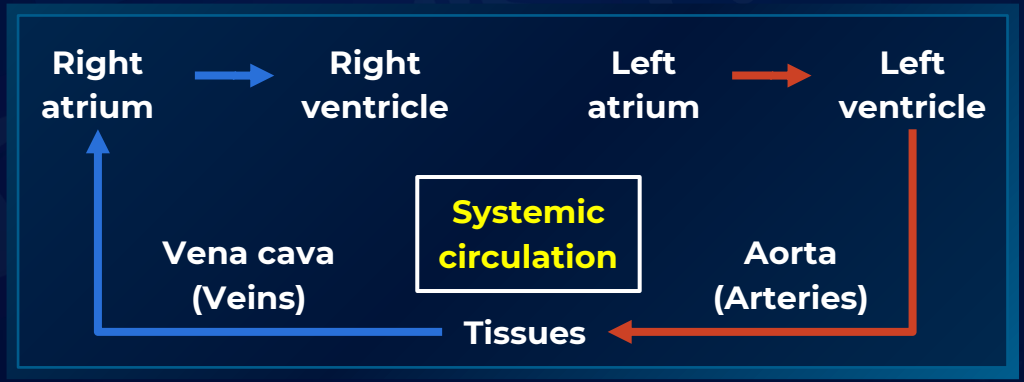
Bicuspid valve
- Left atrium to left ventricle

Aorta
- Left ventricle to tissues
- Carries **oxygenated** blood

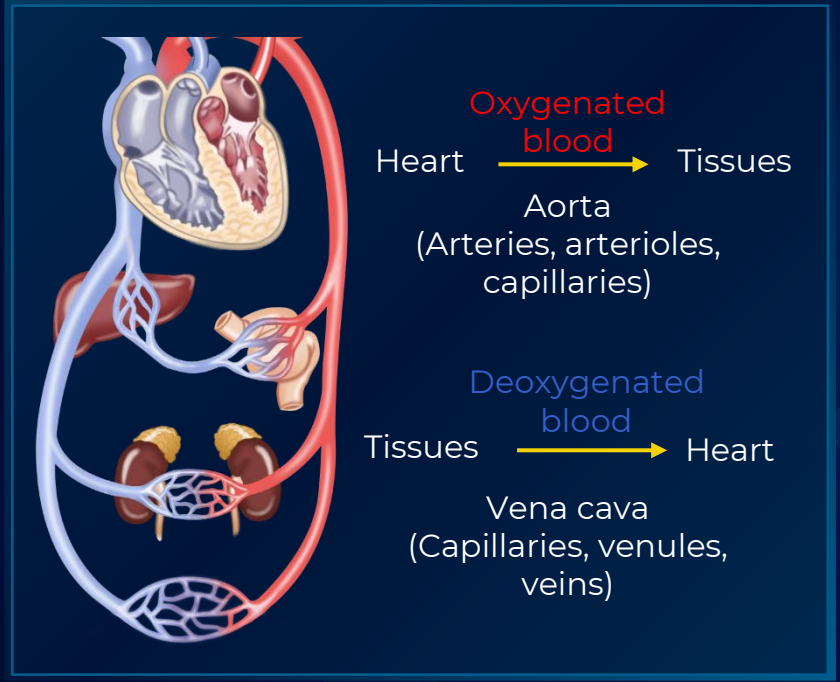
Tissues
- Oxygenated blood gets converted to deoxygenated blood

Systemic Circulation

- The upper and the lower body have different supplies.
  - At every organ and tissue, oxygenated blood is converted to deoxygenated blood.
  - All deoxygenated blood returns to the heart.
  - The **oxygenated blood** entering the aorta is carried by a network of arteries, arterioles, and capillaries to the tissues.
  - From the tissues, the **deoxygenated blood** is collected by a system of venules, veins, and vena cava and emptied into the right atrium.
  - This is systemic circulation.
  - The **lungs are not involved** in this process.



Systemic Circulation

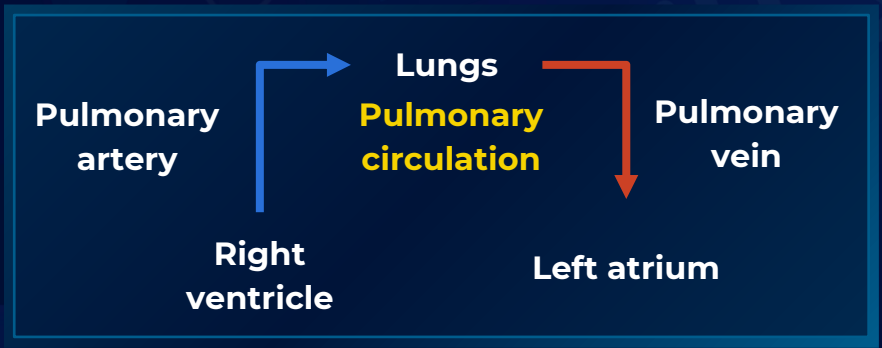


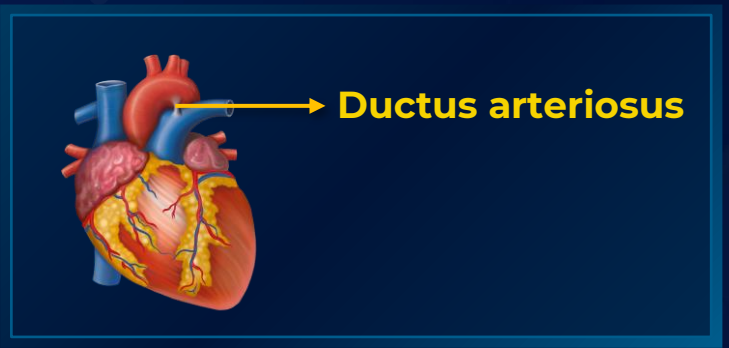
Functions of systemic circulation

- Provides:
  - Nutrients
  - Oxygen
  - Other essential substances to the tissues
- Removes:
  - Carbon dioxide
  - Other harmful substances from the tissues

Pulmonary Circulation

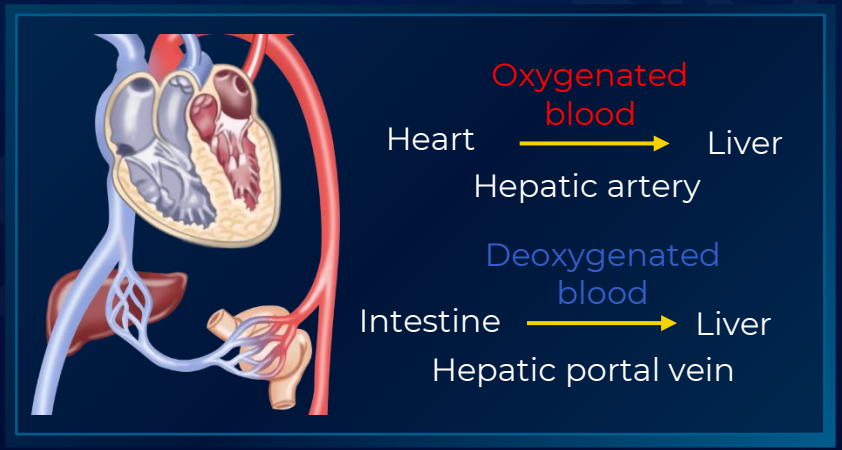
- Deoxygenated blood is pumped by the right ventricle into the **pulmonary artery**.
- The deoxygenated blood pumped into the pulmonary artery is passed on to the lungs and from there, the oxygenated blood is carried by the pulmonary veins into the left atrium.
- This pathway constitutes the pulmonary circulation.
- Before birth, the major portion of blood from the right side bypasses the pulmonary circulation (no air in lungs) via **foramen ovale** (between right and left auricle) and **ductus arteriosus**.
- This bypass becomes non-functional after the birth. If the hole fails to seal, then it is said that there is a hole in the heart.





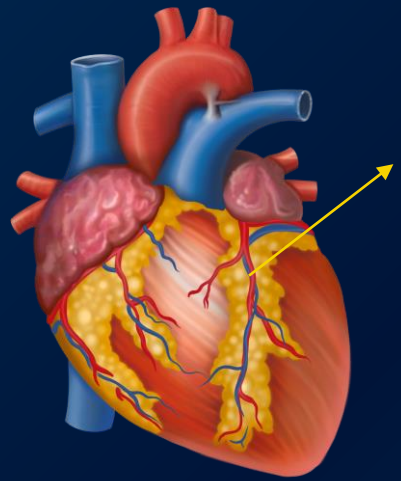
Hepatic Circulation

- A unique vascular (circulatory) connection between the digestive tract and the liver is known as the hepatic portal system.
- The liver receives **oxygenated blood** from the **hepatic artery**.
- It also receives **blood** from the **hepatic portal vein**.
- The hepatic portal vein carries blood from the intestine and parts of the digestive system to the liver before it is delivered to the systemic circulation.
- This blood contains nutrients and toxins extracted from digested contents, which the liver stores and detoxifies respectively.



Coronary Circulation

- **Coronary arteries** supply oxygenated blood to the heart muscle.
- **Cardiac veins** drain the deoxygenated blood from the heart muscle.
- The heart muscle, like all the tissues in our body, requires energy and it takes energy from the oxygen and nutrients from the coronary artery.

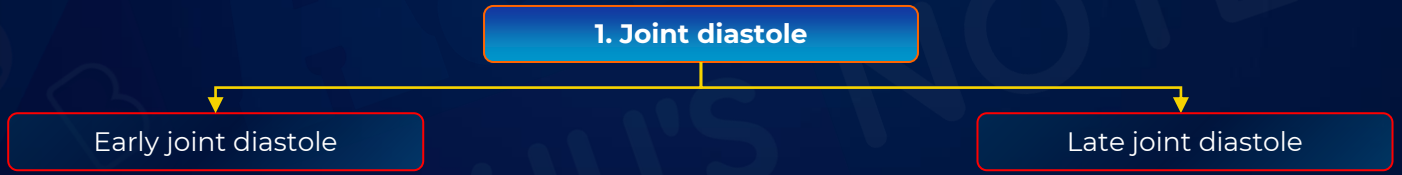


Coronary circulation

Cardiac Cycle

- It comprises the complete **relaxation and contraction** of both the atria and ventricles.
- It consists of **three stages**:
  - Joint diastole
  - Atrial systole
  - Ventricular systole

Duration of one cardiac cycle is **0.8 seconds**.

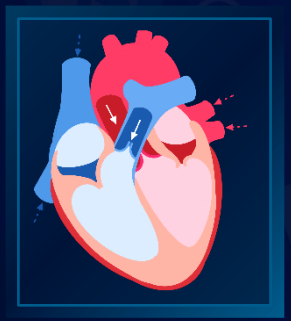


Cardiac Cycle

1. Joint diastole

Early joint diastole

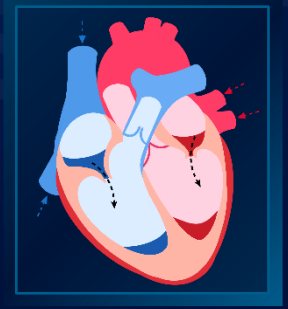
Ventricles	Atria
Diastole (Relaxed)	Diastole (Relaxed)
Atrioventricular valves- (Closed)	Semilunar valves- (Closed)



- All the chambers of the heart are relaxed and the blood enters the heart chambers through the veins.
- The oxygenated blood flows through the pulmonary veins and the deoxygenated blood flows through the superior and inferior vena cava into the left and the right atria, respectively.

Late joint diastole

Ventricles	Atria
Diastole (Relaxed)	Diastole (Relaxed)
Atrioventricular valves– (Open)	Semilunar valves- (Closed)



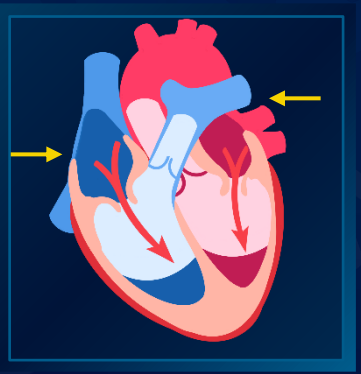
- The tricuspid and bicuspid valves are pushed open by the pressure in the atria exerted by the blood that was being emptied into them by the veins.
- The blood moves from the atria to the ventricles.

Cardiac Cycle

2. Atrial systole

Ventricles
Diastole (Relaxed)

Atrioventricular valves– (Open)



Atria
Systole (Contract)

Semilunar valves- (Closed)

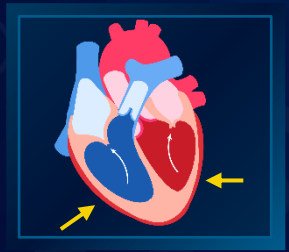
As the atria contract, the rest of the blood is pumped from the atria to the ventricles.

Cardiac Cycle

3. Ventricular systole

Early ventricular systole

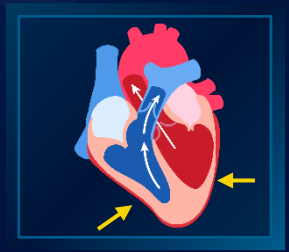
Ventricles systole (Contract)	Atria diastole (Relaxed)
Atrioventricular valves- (Closed)	Semilunar valves- (Closed)



Ventricular systole increases the ventricular pressure, causing the closure of the tricuspid and bicuspid valves due to the attempted backflow of blood into the atria.

Late ventricular systole

Ventricle systole (Contract)	Atria diastole (Relaxed)
Atrioventricular valves- (Closed)	Semilunar valves (Open)



As the ventricular pressure increases, the semilunar valves guarding the pulmonary artery (right side) and the aorta (left side) are forced open, allowing the blood in the ventricles to flow through these vessels into the circulatory pathways.

Cardiac Cycle

Joint diastole

- **Early**: Blood enters the atria through the veins.
- **Late**: The AV valves are open.
  Some blood enters the ventricles.

Atrial systole

The rest of blood is pumped from the atria to the ventricles.

Ventricular systole

- **Early**: Ventricular contraction causes the AV valves to close.
- **Late**: Ventricular contraction causes the semilunar valves to open.
  The blood is pumped into the arteries.

Heartbeat, Heart Sounds and Stroke Volume

Heartbeat

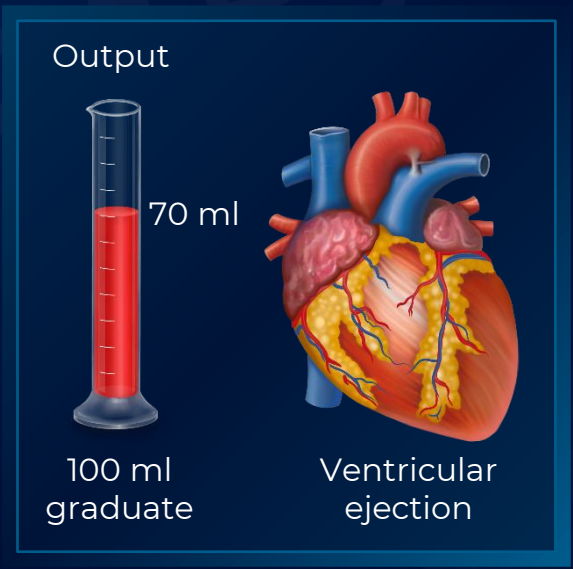
- A heartbeat is the rhythmic contraction and relaxation of the heart chambers.
- Our heart normally beats 70-75 times in a minute (average 72 beats per min). This is called **heart rate**.
- The contraction of the heart chambers is known as **systole.**
- The relaxation of the heart chambers is known as **diastole.**

Heart sound

- Due to the closure of the valves in the heart, we hear heart sounds.
- During each cardiac cycle, two sounds are produced.
- The closing of atrioventricular valves causes the first sound, which is **lub**.
- The closing of semilunar valves causes the second sound, which is **dub**.

Stroke volume

- Each ventricle pumps out approximately 70 mL of blood, which is the **stroke volume.**

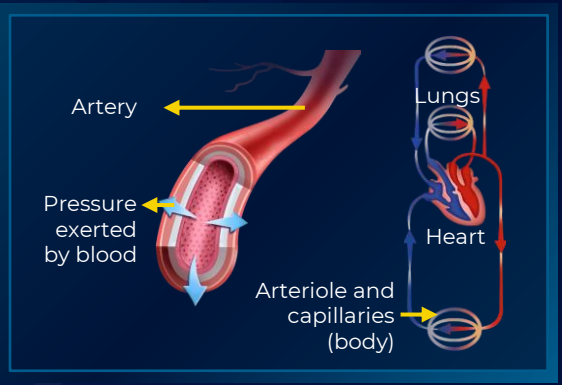


Cardiac Output

- It can be defined as the volume of blood pumped out by each ventricle **per minute**.
- Heart rate is the rhythmic contraction and relaxation of the heart chambers.
- Cardiac output = Heart rate x Stroke volume
  72 × 70 = 5,040
- Approximately, **5,000 ml** or 5 liters of blood is pumped every minute.

Blood Pressure

- Blood pressure is the force that blood exerts against the walls of the blood vessels.
- Blood pressure drives the flow of blood from the heart through the arteries and arterioles to the capillary beds due to the pumping of the heart.
- It is only calculated in arteries because the blood pressure in the arteries is much higher than in the veins.
- It is due to receiving blood from the heart after contraction and also due to their contractile capacity.
- **Systolic pressure** refers to the maximum pressure within the large arteries when the heart muscle contracts to propel blood through the body.
- **Diastolic pressure** describes the lowest pressure within the large arteries when the heart muscles relax between two beats.



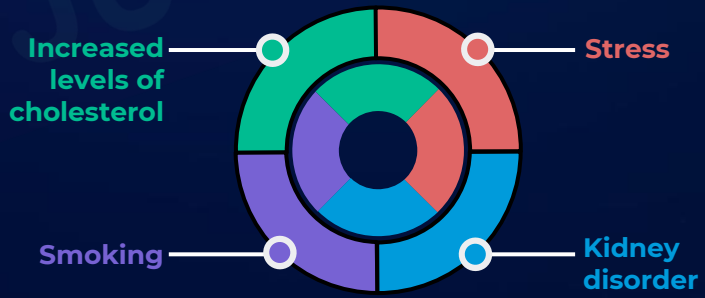
How is blood pressure measured?

- **Sphygmomanometer**: Also known as the blood pressure monitor
- It is a device for measuring blood pressure.
- In this measurement, **120 mm Hg** (millimetres of mercury pressure) is the systolic pressure or pumping pressure, and **80 mm Hg** is the diastolic pressure or resting pressure.

Hypertension

- The levels of arterial pressure put mechanical stress on the arterial walls.
- Higher pressures increase heart workload and the progression of unhealthy tissue growth that develops within the walls of the arteries.
- **Higher the pressure, more is the stress on the heart**. The heart muscle tends to thicken, enlarge, and become weaker over time.
- If repeated checks of an individual's blood pressure has a reading of **140/90** or **higher,** it indicates **hypertension**.
- High blood pressure leads to heart diseases and also affects vital organs like the brain and the kidneys.
- It can harm the heart, the brain, the kidneys, and the eyes.

Causes of hypertension

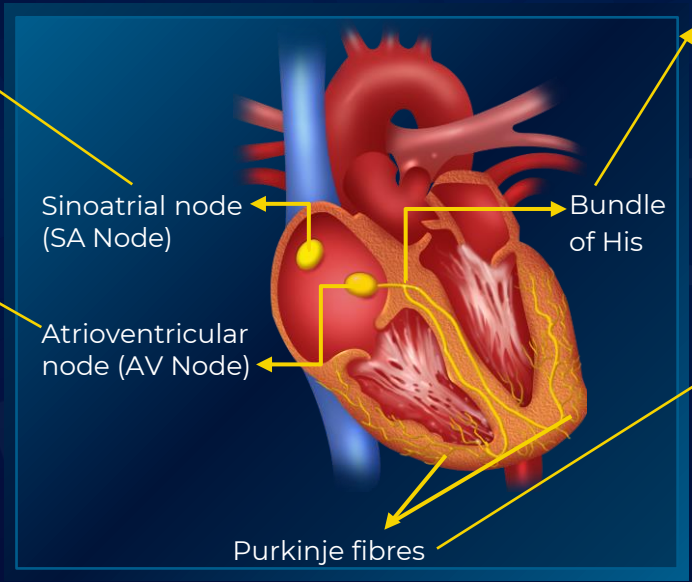


Stimulation of Heart Muscle Contraction

Nodal tissue
Regulates the heartbeat intrinsically

Sinoatrial node
- SA Node present at the upper right corner of right atrium is called as **pacemaker**, a contracting wave originates from SAN and spreads to other parts of the heart.

Atrioventricular node
- AV node present at the lower left corner of the right atrium transfers the contraction wave via atrio-ventricular septa to come out at interventricular septum as **bundle of His** and immediately divides into a right and left bundle.



Bundle of His
- It conducts action potential.
- It helps in contraction of ventricles.

Purkinje fibres
- A bundle of nodal fibres that help in ventricular contraction

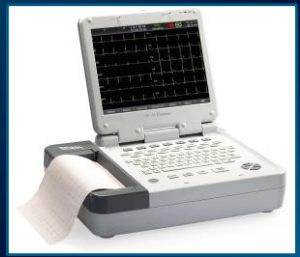
Stimulation of Heart Muscle Contraction

- The nodal musculature has the ability to generate action potentials without any external stimuli. i.e., it is **auto excitable**.
- **Action potential** is a short-lasting event in which the electrical membrane potential of a cell rapidly rises and falls.
- The SAN initiates conduction because it generates the maximum number of action potentials, i.e., 70-75 min^{-1}, and is responsible for initiating the contractile activity of the heart. Therefore, it is called the **pacemaker** of the heart.
- **Myogenic heart** is capable of generating a cardiac contraction independent of the nervous input.

Myogenic heart

Electrocardiogram: ECG

- It is used to measure the **electrical activity** of the heart.
- An **electrocardiograph** is used to obtain an **electrocardiogram** (ECG).
- An electrocardiograph is an instrument, and an electrocardiogram is the reading.



Electrocardiograph

Gel applied on the chest

Electrodes connected

Electrocardiogram: ECG

- A normal ECG is composed of the following:
  - P wave
  - QRS wave
  - T wave

- It is a small upward wave that represents **atrial depolarisation**, which represents electrical excitation or atrial contraction.
- Depolarisation causes contraction.

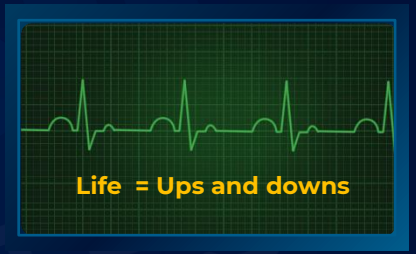
Normal healthy person's ECG

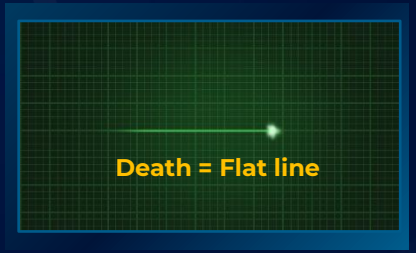
- It is a small upward dome-shaped wave that represents **ventricular repolarisation** or relaxation.
- It represents the return of the ventricles from the excited to the normal state (repolarisation).

- It begins with a downward deflection wave Q and continues as a large upright wave R.
- It ends into a downward wave S at the base of R.
- The contraction starts shortly after Q and marks the beginning of the **systole**.

Significance of ECG

- Any deviation in the ECG indicates a possible abnormality or disease.
- For example:
  - **Enlargement of P wave** indicates enlargement of the atria.
  - **Myocardial infarction (MI)** is shown by **enlarged Q and R waves**.





Heart Diseases

Coronary artery disease (CAD)

- It affects the supply of blood to the heart muscle.
- It is caused by the build up of plaque of the following:
  - Calcium
  - Fat
  - Cholesterol
  - Fibrous tissues
- It makes the lumen of arteries narrower.

Plaque formation in the artery hindering the blood flow

Heart Diseases

Angina

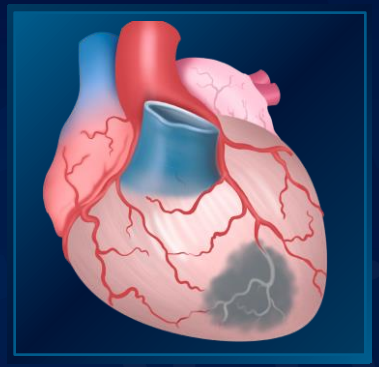
- It is also known as **angina pectoris**.
- A symptom of **acute chest pain** appears when enough oxygen is not reaching the heart muscle.
- It can occur in men and women in any age.
- It is more common among the middle-aged and elderly.
- It occurs due to the conditions that affect the blood flow.

Enough oxygen does not reach the heart muscle due to narrowing of arteries

Heart Diseases

Heart attack

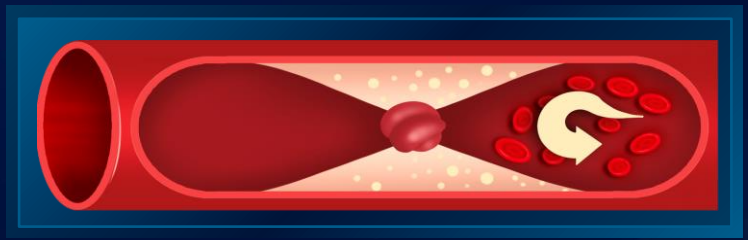
- Heart attack occurs when the heart muscle is damaged by inadequate blood supply.



Heart having a portion of dead muscle tissue.

Heart failure

- Heart does not pump blood effectively enough to meet the needs of the body.
- It is also known as **congestive heart failure** because congestion of lungs is a main symptom.



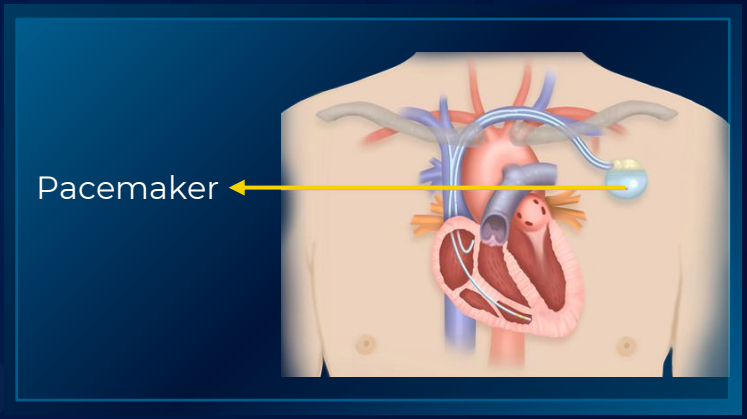
A clot blocking the blood flow.

Heart Diseases

Cardiac arrest

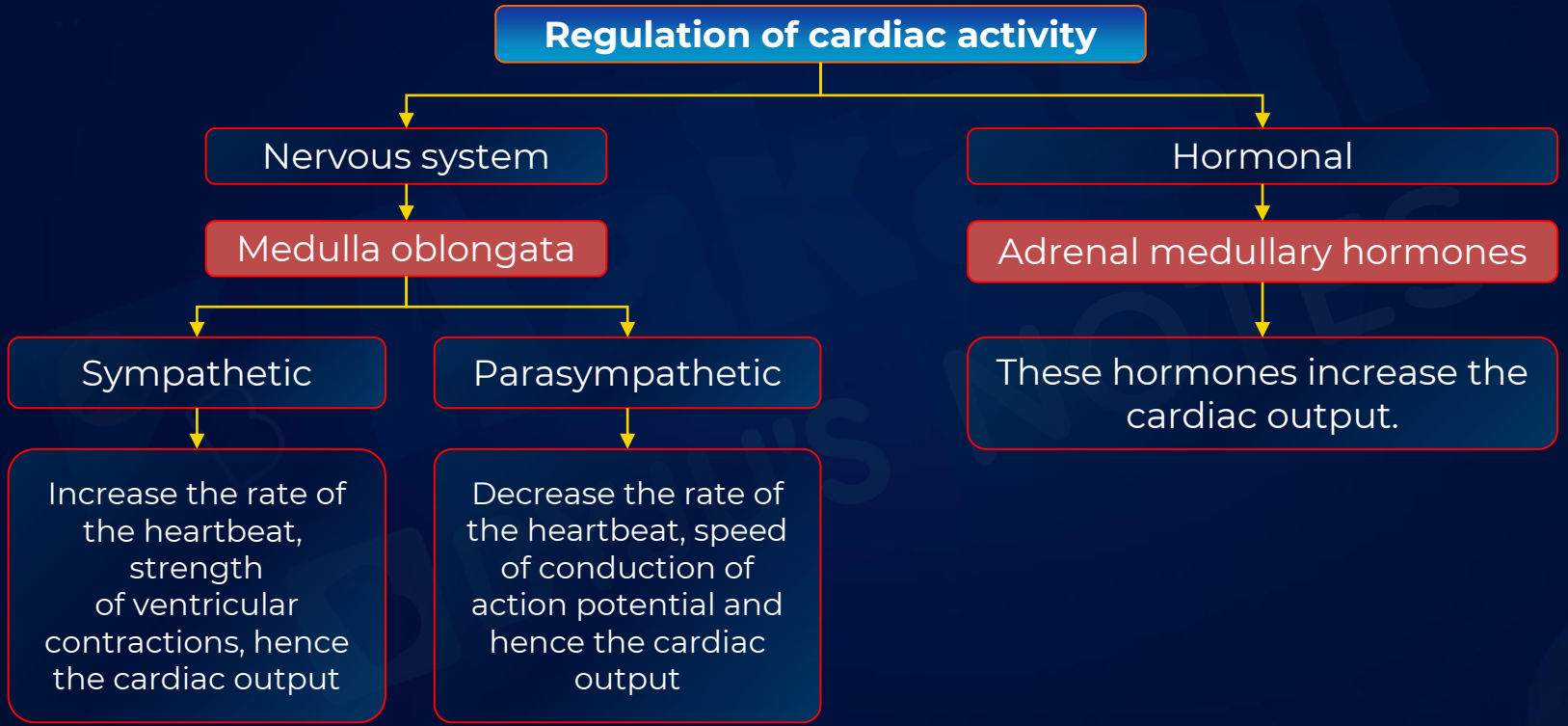
- The **heart stops beating**.
- The blood stops flowing to the vital organs.

Artificial pacemaker

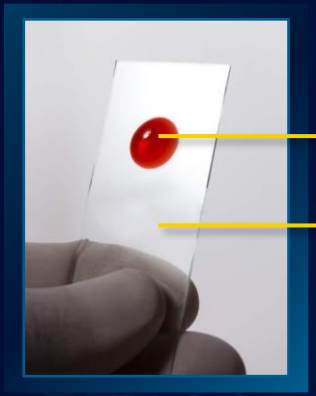


- **Restores** and **maintains** the normal heartbeat.
- Used in the case of a blockage or a dysfunctional SA node.

Regulation of Cardiac Activity



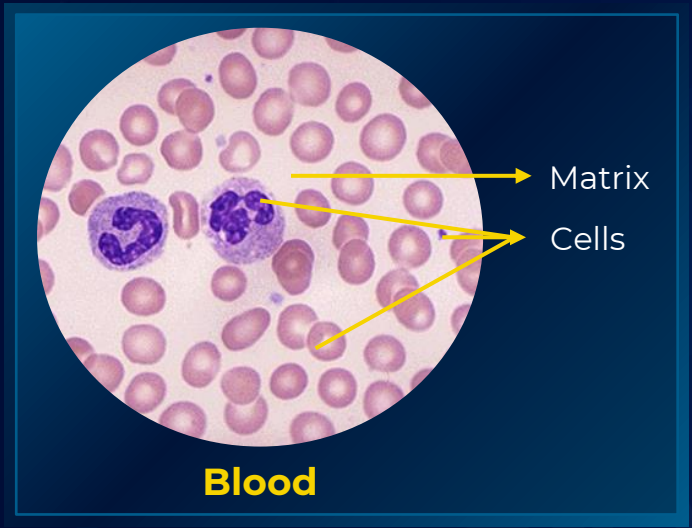
Components of Blood



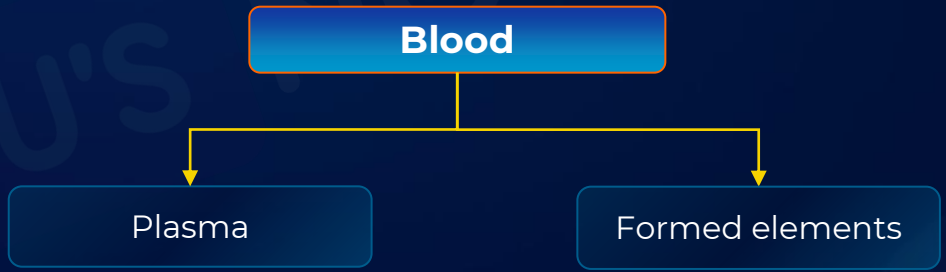
- It is a specialised **fluid connective tissue** that is responsible for the transport of oxygen and nutrients throughout the body. It carries away carbon dioxide and waste products from body cells.

- If you observe blood under a microscope, it appears like the given image.
- Blood is not just a thick and homogeneous liquid but comprises **cells** suspended in it.

Components of Blood

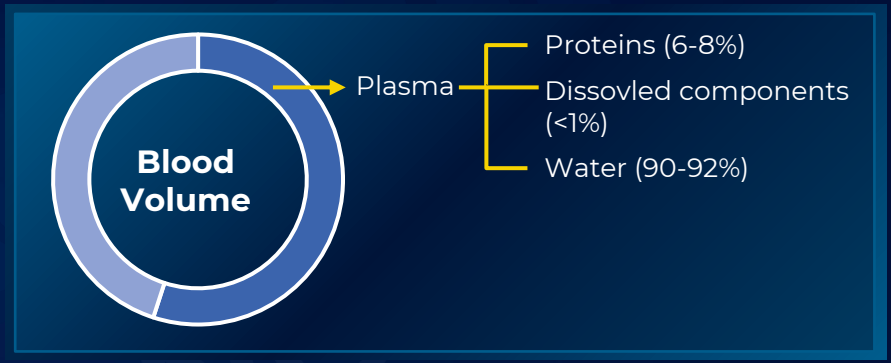


- The fluid matrix of blood is known as **plasma**.
- The cells of the blood are known as **formed elements**.



Plasma

- Plasma is a straw-coloured, viscous fluid constituting nearly **55%** of the blood volume.
- Plasma also contains small amounts of different kinds of molecules such as ions (Na^+, Ca^{++}, Mg^{++}, $HCO3^-$, Cl^-), simple sugars, amino acids, lipids, urea, ammonia, carbon dioxide, oxygen, hormones, vitamins, etc.
- Around **6-8%** of plasma is made of **proteins**.



Plasma proteins

Albumin	Globulins	Fibrinogen
Helps in maintaining the osmotic balance of blood	Involved in the defense mechanisms of the body	One of the main proteins required for clotting of blood

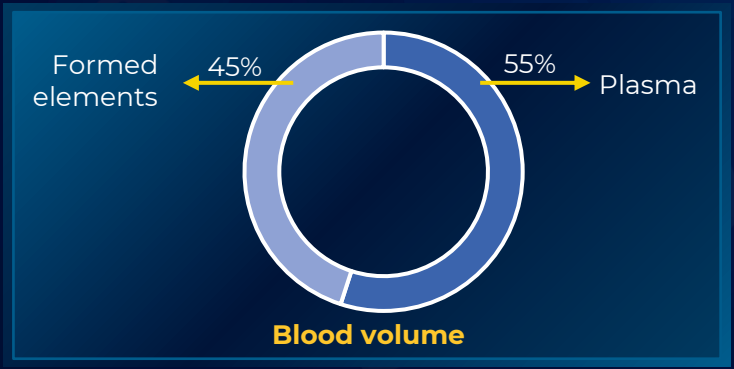
Serum and Formed Elements

Serum

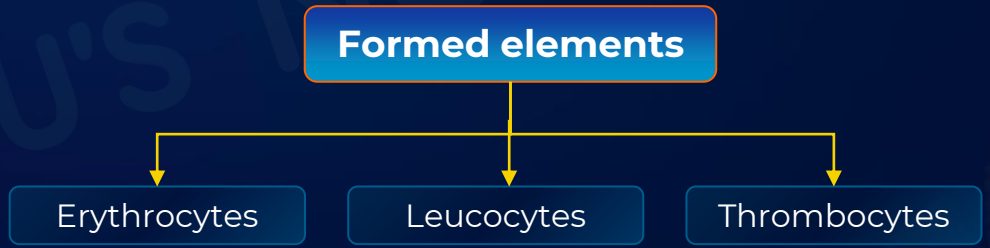
Plasma − Clotting factors = Serum

- Serum is a **plasma without clotting factors**.
- It includes all proteins, all electrolytes, antibodies, antigens, and hormones except for clotting factors.

Formed elements



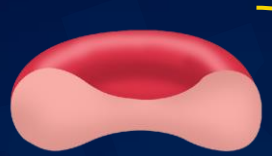
The formed elements or the blood cells constitute nearly 45% of the blood volume.



Erythrocytes

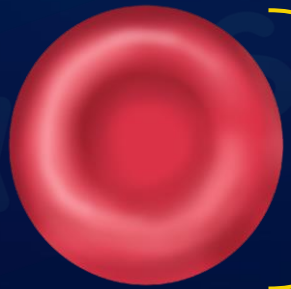
Have presence of haemoglobin

- Biconcave shape
- Most abundant cells of the body
- 5-5.5 million RBCs/ml of blood in healthy human
- Lifespan = 120 days



2.5 µm

Cross section



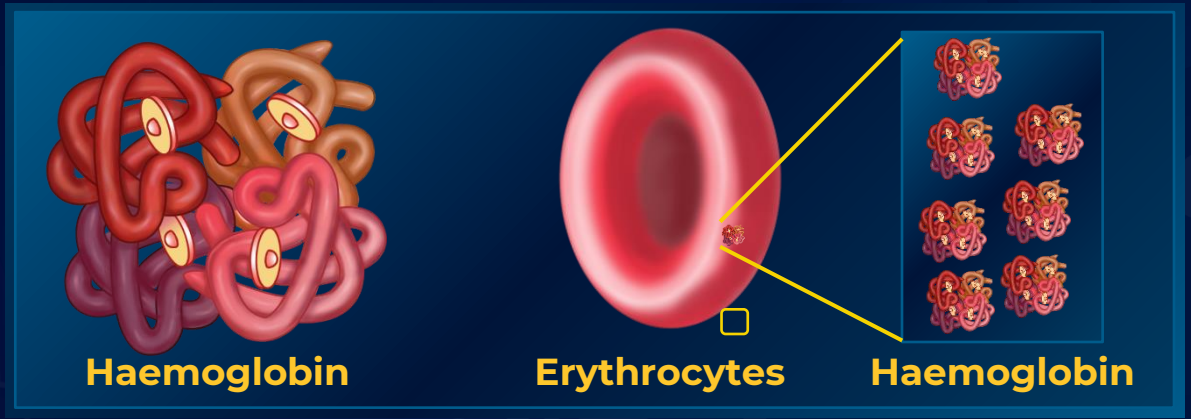
7 µm

Top view

- RBCs are destroyed in spleen
- Graveyard of RBCs = Spleen
- Corpuscles: No organelles
- Mature mammalian RBCs are enucleated (No nucleus)

Structure of RBC/Erythrocyte

Erythrocytes



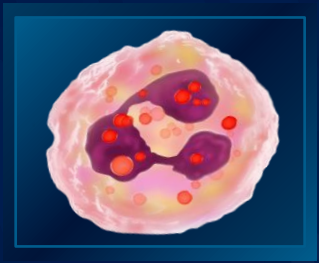
Haemoglobin

- Haemoglobin plays a significant role in the **transport of respiratory gases** (oxygen and carbon dioxide).
- A healthy individual has **12-16 gms** of haemoglobin in every 100 ml of blood.
- Each human red blood cell contains approximately **270 million haemoglobin** molecules.

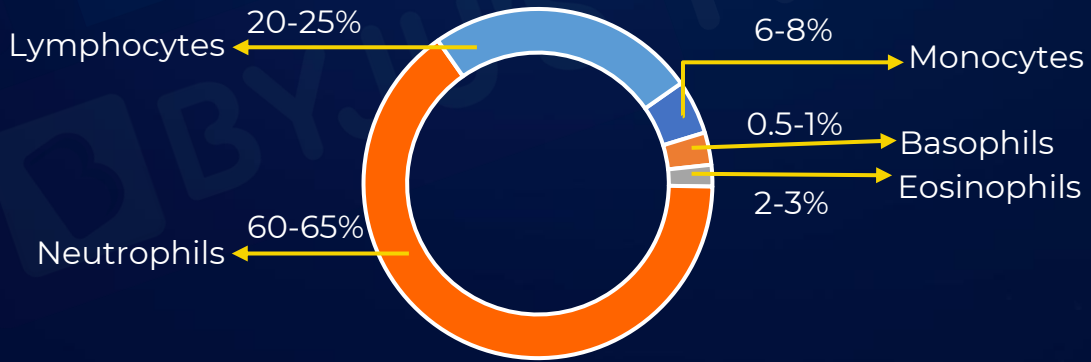
Leucocytes

Constitute a mobile army that protect the body from infectious microbes such as bacteria, virus, and parasites

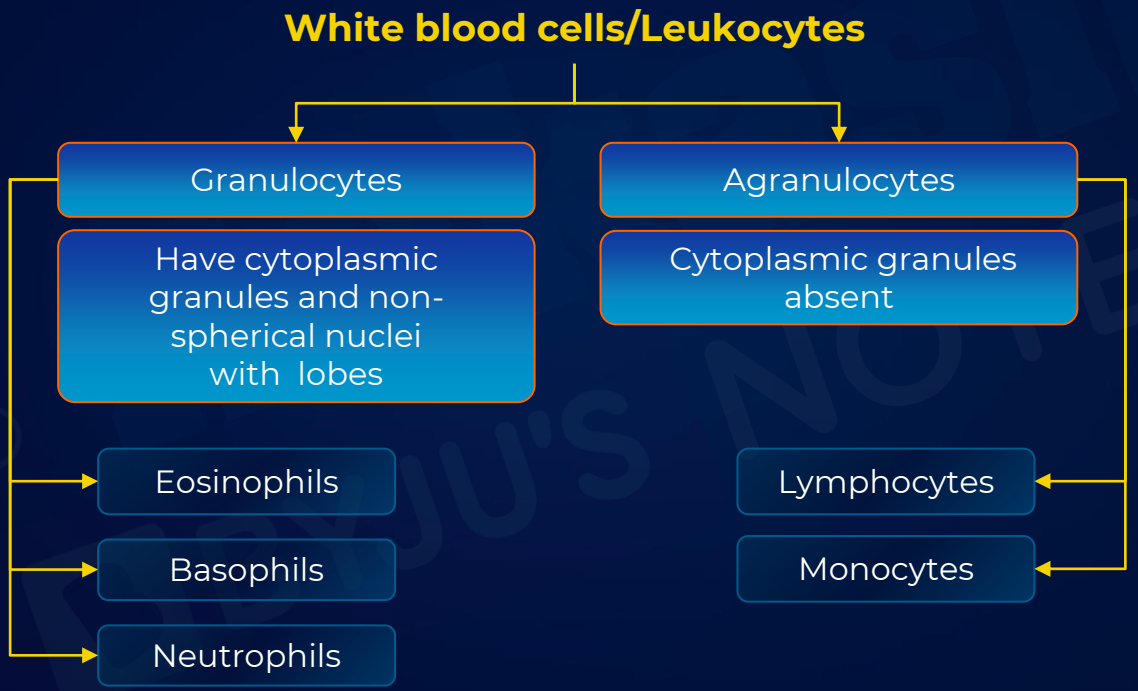
- Colourless; Hence, known as white blood cells
- 6,000-8,000 WBCs/ml of blood
- Less in number than RBCs



- Haemoglobin absent
- Short-lived
- Multiple types



Leucocytes



Granulocytes

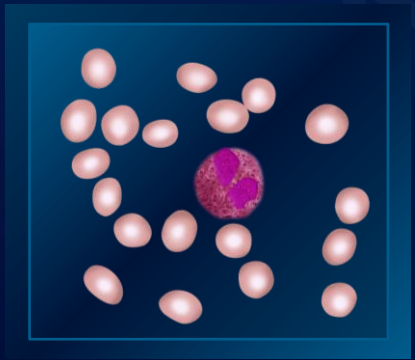
- Granulocytes can be further divided into neutrophils, eosinophils, and basophils.

Eosinophils

'Eosinophil' stands for ‘eosine loving’ or ‘acid loving’. This is because granules in eosinophils take up acidic red stains. Hence, they appear red in colour when observed under a microscope.

Less abundant as compared to other WBCs

2-3% of total WBCs



Play a role in allergic reactions

Fight against parasites

Eosinophils

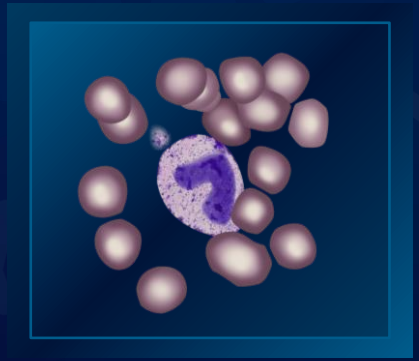
Granulocytes

Basophils

'Basophil' stands for ‘base loving’. This is because these cells take up basic blue stains. Hence, they appear blue in colour when observed under a microscope.

Rarest of all WBCs

0.5-1% of total WBCs



Secrete chemicals like histamines, heparin, and serotonin

Histamines mediate inflammation during allergy and parasitic infections

Heparin is a natural anticoagulant

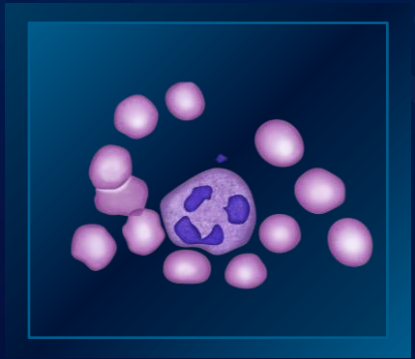
Granulocytes

Neutrophils

'Neutrophil' stands for ‘neutral loving’. This is because these cells take up neutral stains.

Most abundant of all WBCs

60-65% of total WBCs



Neutrophils

Phagocytic cells

Engulf foreign organisms and neutralise them

Agranulocytes

- Agranulocytes are WBCs that lack cytoplasmic granules.
- Agranulocytes are of two types: **lymphocytes** and **monocytes**.

Lymphocytes

- Lymphocytes comprise 20-25% of WBCs.
- Lymphocytes can be of two types: B-lymphocytes and T-lymphocytes.

T lymphocytes

- Though T-lymphocytes originate in bone marrow, they travel and undergo maturation in the thymus gland.
- Here, T stands for thymus. It is the site of maturation for T lymphocytes.
- T lymphocytes **recognise infected cells** and **alert defense system** to kill them.

B lymphocytes

- B-cells or B-lymphocytes originate and mature inside the bone marrow. Hence, the name B-lymphocytes.
- B-cells release antibodies that **recognise pathogenic microorganisms**.

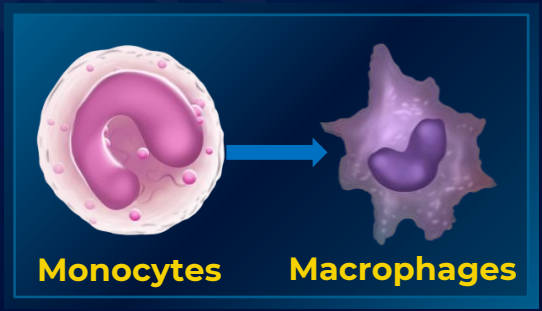
Agranulocytes

Monocytes

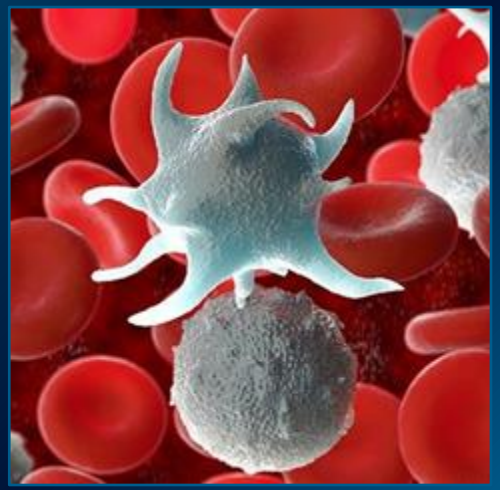
- Monocytes are the second type of agranulocytes. They are about **6-8%** of the total WBCs.
- Monocytes are large cells. The notable feature of monocytes is that the shape of its nucleus resembles a horseshoe.

Macrophages

- Macrophages are phagocytic cells. They **ingest** and **neutralise pathogens** such as bacteria, viruses, parasites, etc. Thereby, they defend our body against these pathogens.
- Monocytes transform into macrophages.



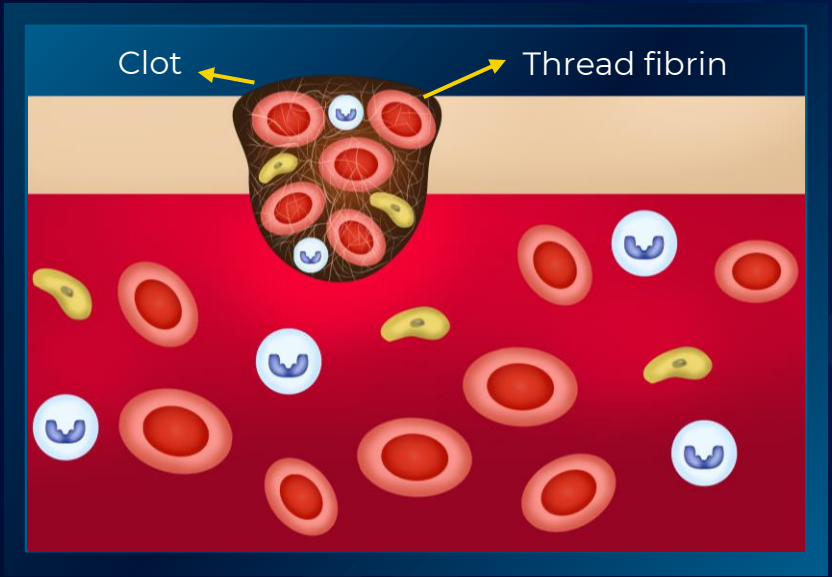
Thrombocytes



- Thrombocytes are cells that help in clotting. They are also known as **platelets.**
- There are around **1,50,000-3,50,000** platelets per microlitre of blood.
- Platelets release a molecule known as **thromboplastin**. When there is damage in the blood vessel, it initiates the clotting process.
- Fibrin, platelets, and other blood cells together form a clot that seals the damaged blood vessel.
- Reduction in the platelets can lead to clotting disorders. It can further lead to excessive loss of blood from the body.

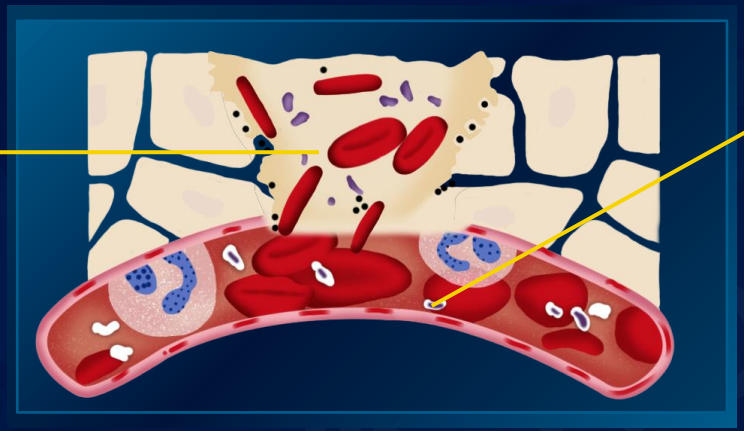
Coagulation of Blood

- The mechanism that the body employs to reduce/stop the flow of blood is known as coagulation of blood or blood clotting.



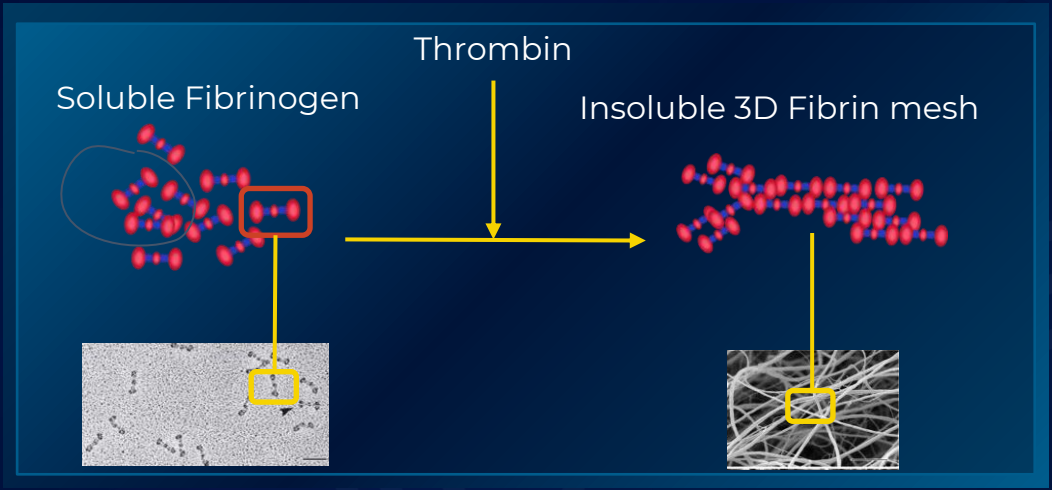
- The blood clot formed at the wound is essentially like a **net** that catches fish.
- It is a meshwork of **protein fibres** that catches the blood cells so that they do not escape when there is a cut.
- The protein that makes up this meshwork is known as **fibrin**.

Coagulation of Blood



- Prothrombin activator catalyses the formation of thrombin.
- **Prothrombin** is the inactive form of thrombin that is always present in the plasma.
- The conversion of prothrombin to thrombin was believed to be catalysed by an enzyme known as **thrombokinase**.

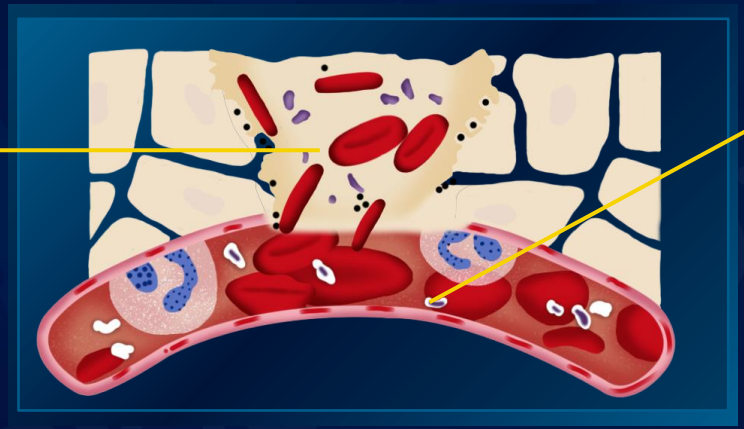
Coagulation of Blood



- **Fibrinogen**, like prothrombin, is another protein that circulates in the plasma. It is water-soluble.
- **Thrombin** catalyses the polymerisation of fibrinogen into long chains known as fibrin.
- **Fibrin** is insoluble water and forms a mesh.
- The images in black and white are real electron microscope images.
- It is in this mesh of fibrin that the blood cells are trapped and cannot escape. Thus, it stops the blood flow.

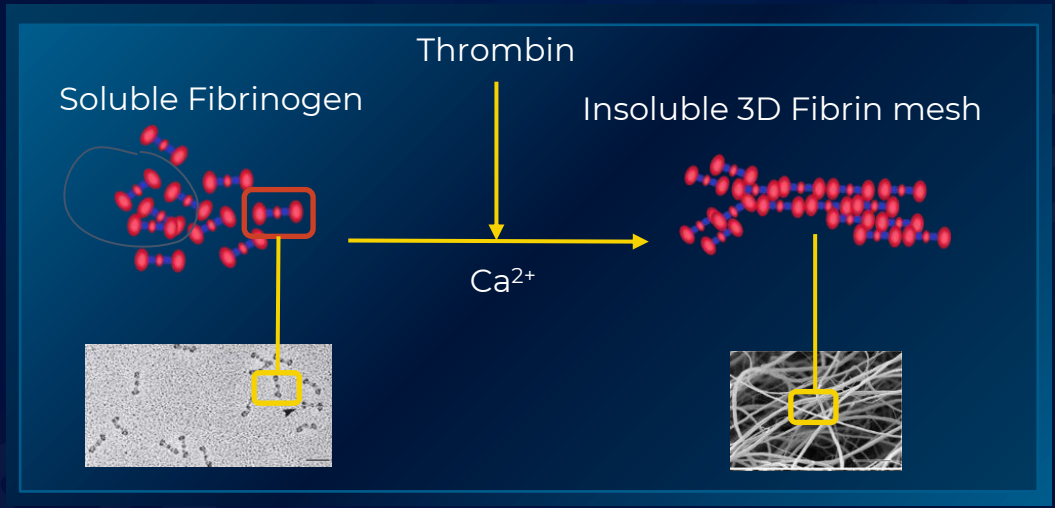
Role of Ca^{2+} ions

- Calcium ions are required for most steps of coagulation.



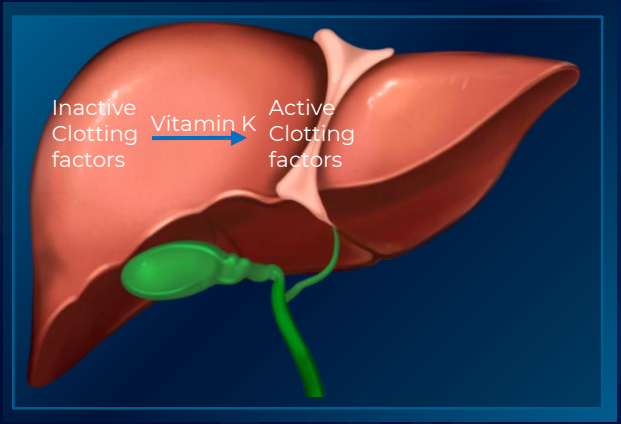
Role of Ca^{2+} ions

- So, without enough calcium the blood will not clot properly.



Role of Vitamin K

- The liver activates a lot of the cofactors. It can do so only in the presence of vitamin K.
- So, a lack of vitamin K can cause **bleeding disorders**.



Mast cells

- Mast cells are present in areolar tissue.

- If we do not check for blood clotting, it can happen inside undamaged vessels.
- It can even lead to life-threatening conditions like **heart attack** and **stroke**.

Heparin

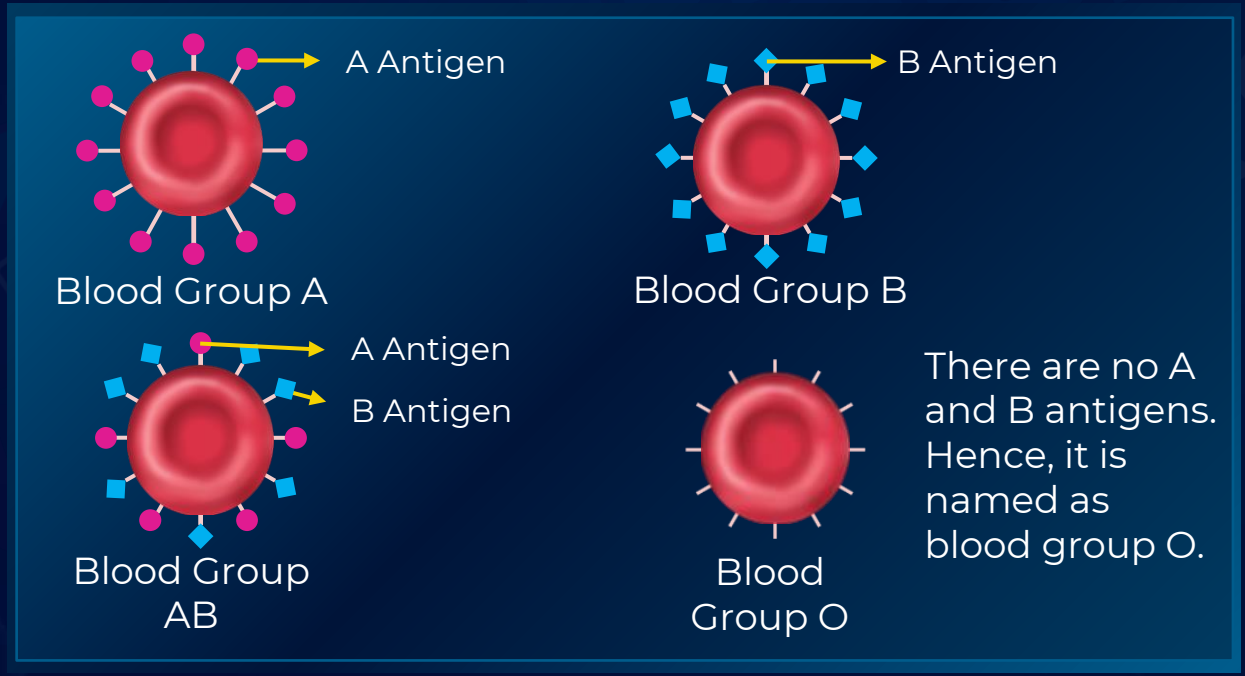
- Heparin is a **natural anticoagulant** that is secreted by mast cells and basophils.
- It prevents unnecessary blood coagulation.

Functions of Blood

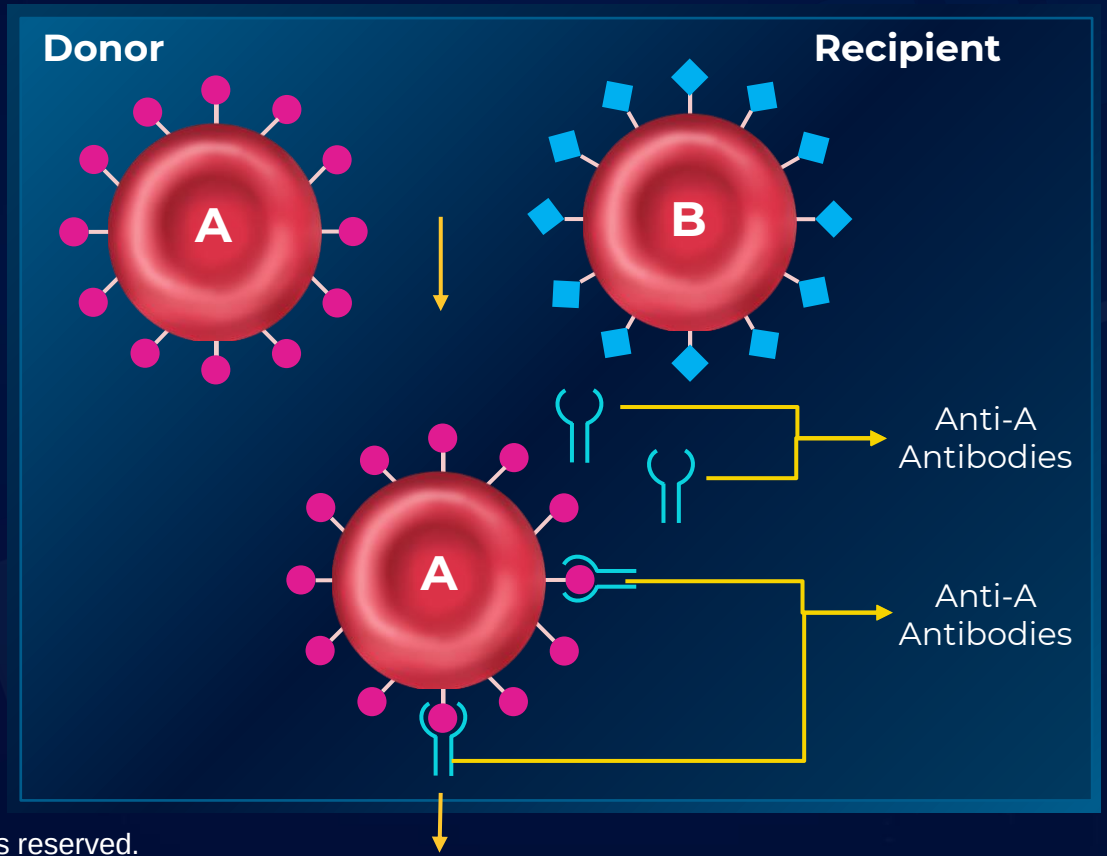
- Blood delivers oxygen from the lungs to the cells of the body and moves carbon dioxide from the cells to the lungs. This happens with the help of the haemoglobin present in RBCs.
- Blood carries nutrients, waste products, and hormones to various destinations.
- Blood helps to **maintain a steady pH** of body fluids. It also distributes heat and adjusts body temperature.
- Blood forms seals or **clots** in response to injury, prevents blood loss, and maintains cardiovascular function.
- Blood helps in defending our body against pathogens by exhibiting an **immune response**.
- White blood cells protect against disease by **ingesting invading pathogens** and **producing antibodies**.

Antigens on RBCs

- The two antigens present in human RBCs are carbohydrate antigens. They are known as **antigens A** and **B**.
- Based on these two antigens, the blood group is divided into **four types**.



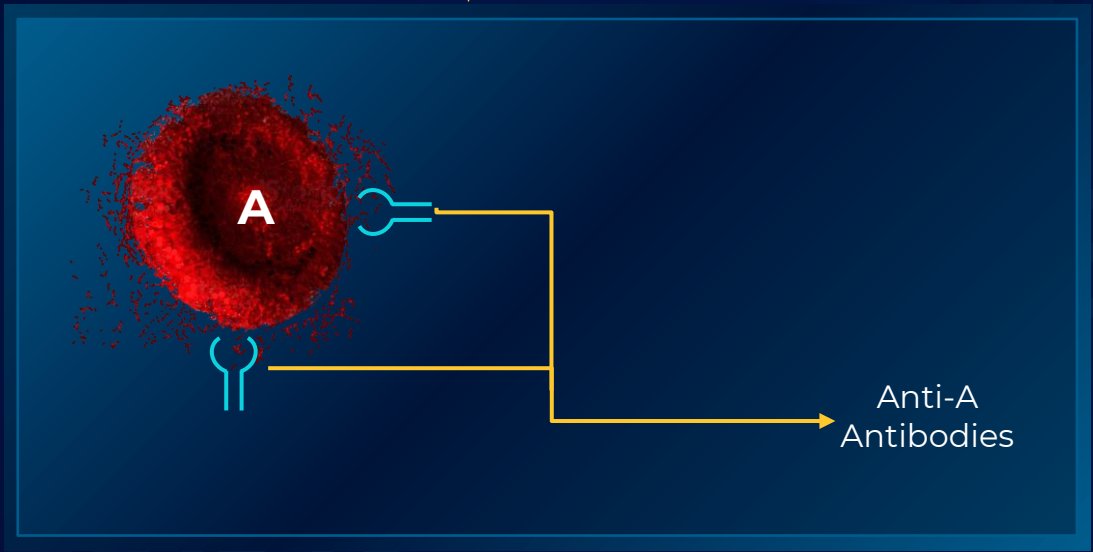
Antigens on RBCs



Antigen A is foreign to the recipient. As the donor's blood enters the recipient's body, anti-A antibodies attack donor's cells.

Once the anti-A antibodies bind to antigen A on the donor RBCs, the immune cells of the recipients attack the foreign RBCs and they are destroyed.

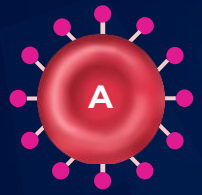
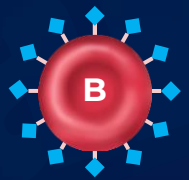
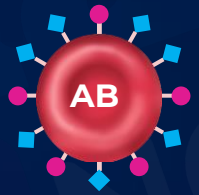
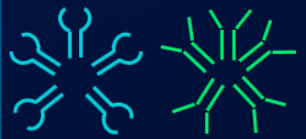
Antigens on RBCs



The destruction of RBCs leads to blood clotting in the vessels, which can even cause death.

Antigens on RBCs

Antigens and antibodies present in different blood groups

	A	B	AB	O
RBC type				
Antigens on red blood cell	 A antigen	 B antigen	 A and B antigens	None
Antibodies in plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B

Antigens on RBCs

Blood transfusion

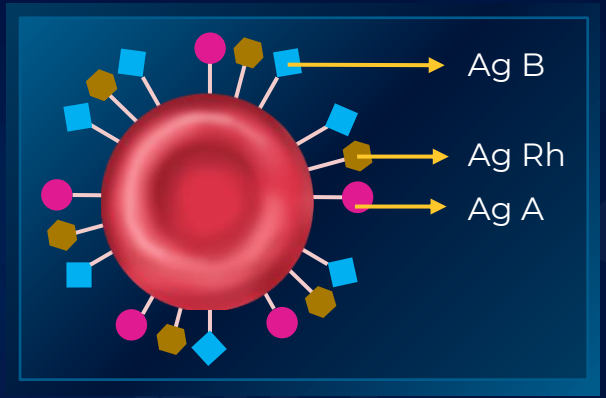
Recipient		Donor			
		O	A	B	AB
		-	Ag A	Ag B	Ag A Ag B
O	Anti A Anti B	YES	NO	NO	NO
A	Anti B	YES	YES	NO	NO
B	Anti A	YES	NO	YES	NO
AB	-	YES	YES	YES	YES

The blood **group O** is known as universal donor. It can donate blood to all the blood groups.

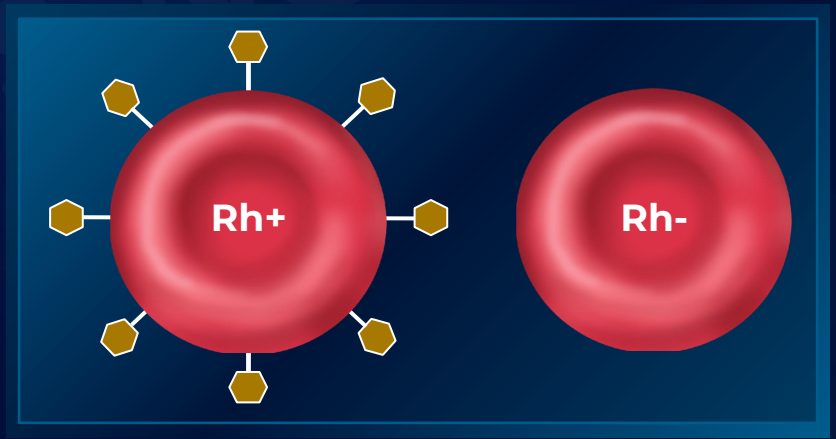
The blood **group AB** is known as the universal recipient. It can receive blood from all blood groups.

Rh grouping

- Rh factor is a **protein.** It is a type of **antigen** present on the surface of RBCs.

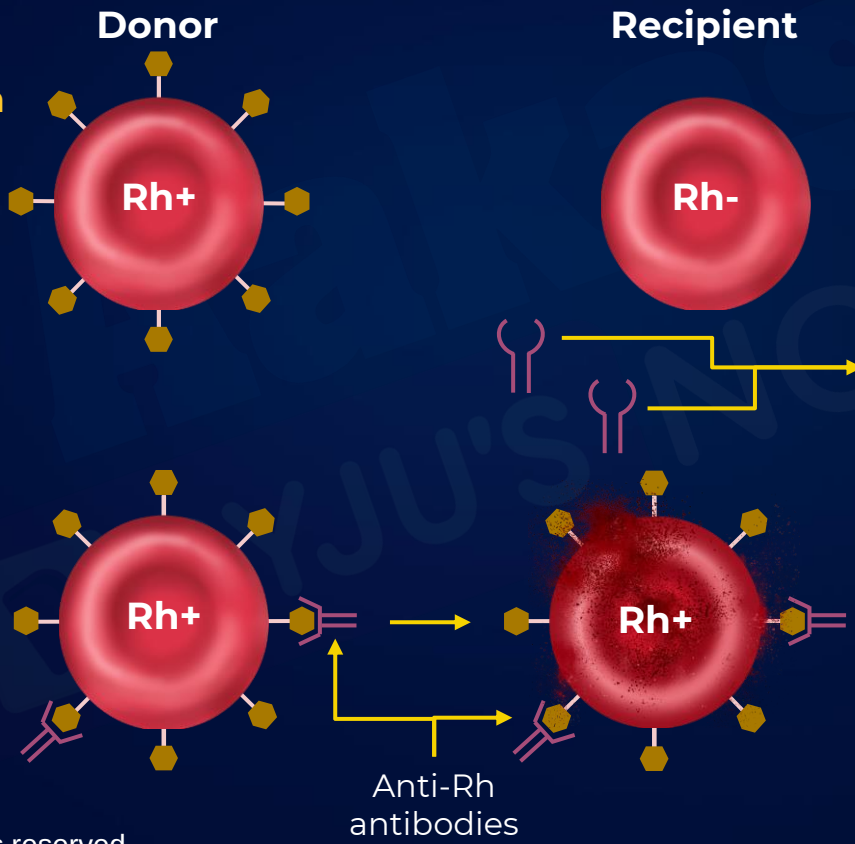


- It is considered that **80%** of the people in the world have Rh antigen on the surface of RBCs.
  - People who have this antigen in their RBCs are termed to have **positive blood groups.** People who do not have this antigen are termed to have **negative blood groups**.



Rh grouping

What happens when a donor is Rh positive and a recipient is Rh negative?



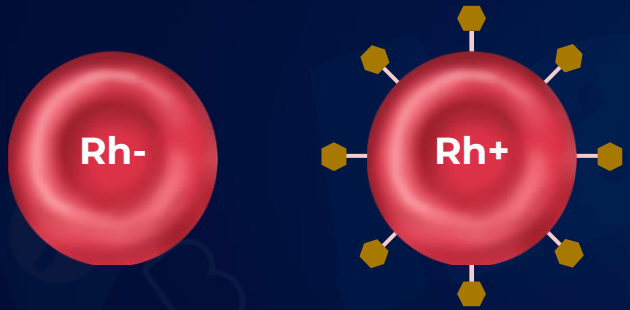
Antigen Rh is foreign to the recipient. As the donor's blood enters the recipients body, it generates specific antibodies known as anti-Rh antibodies.

Once the anti-Rh antibodies bind to antigen Rh on the donor RBCs, the immune cells of the recipients attack the foreign RBCs and they are destroyed.

Rh grouping

What happens when a donor is Rh negative and a recipient is Rh positive?

Donor **Recipient**



As there is no Rh antigen on the donor, the antibodies will not be generated in the recipient. Hence, a blood transfusion will be allowed as there will be no reaction.

- The blood groups that we hear in our daily life are the combinations of ABO and Rh grouping.

ABO Factor	Rh Group	Blood Group
A	+	A +
A	-	A -
B	+	B +
B	-	B -
AB	+	AB +
AB	-	AB -
O	+	O +
O	-	O -

Erythroblastosis Fetalis

- It is a special case of Rh incompatibility that happens without blood transfusion.
- How does it occur?

It starts when a Rh negative mother has a Rh positive baby.

↓

As long as the baby is not delivered, there is no mixing of blood and nothing bad happens.

↓

However, **during delivery**, some blood cells of the baby enter the mother's bloodstream.

↓

The mother's blood starts producing antibodies against Rh antigens.

↓

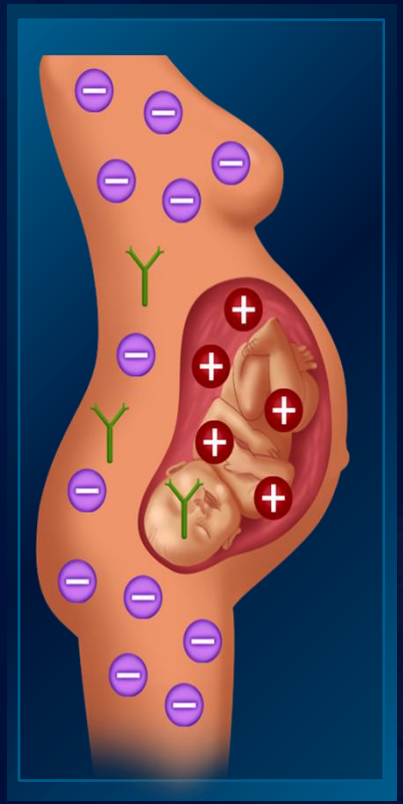
The antibodies against the Rh antigens remain in the mother's blood.

↓

During **next pregnancy**, the mother's antibodies start attacking fetal RBCs having the Rh antigen.

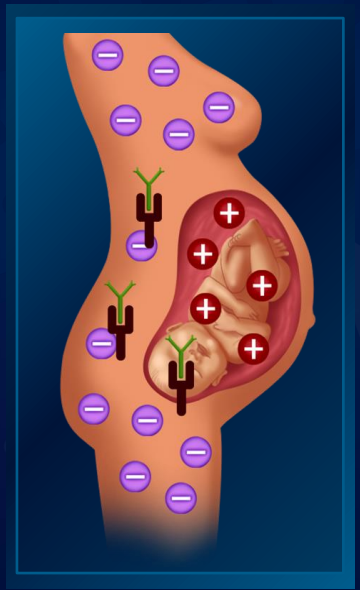
↓

It leads to anaemia and jaundice in the baby and can be fatal for fetus.



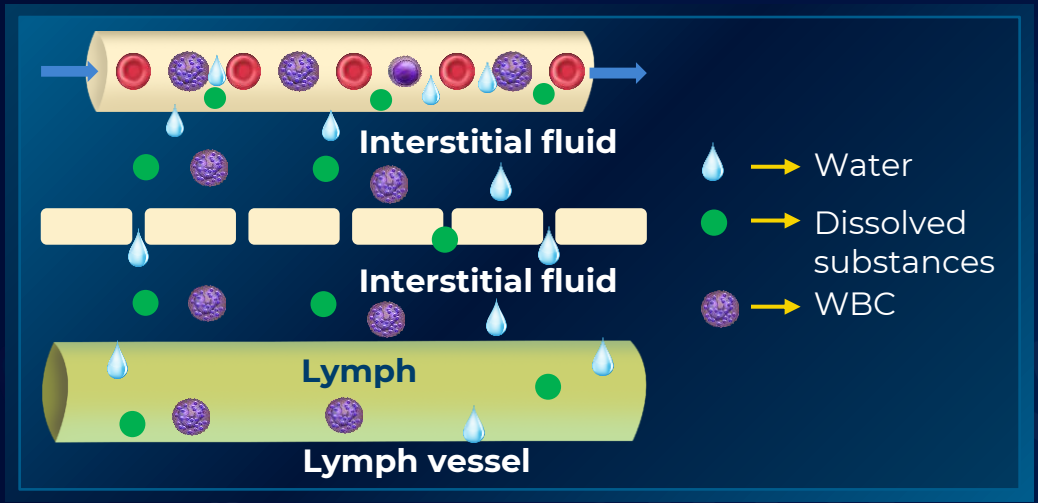
Erythroblastosis Fetalis

- Administering the **artificial antibodies (anti-D immunoglobulins)** to the mother immediately after delivery of the first Rh+ child saves the next Rh+ child.



Artificial antibodies within the mother's bloodstream

Lymph



- **Lymph**:
  - **It is a colourless fluid.**
  - It contains **ions, nutrients, hormones, proteins, and WBCs.**
  - It is present in **the lymphatic system.**
    - The lymphatic system is a **network of lymph vessels** that **collects lymph** from all over the body and **drains it into major veins**.
  - It is rich in **lymphocytes** (a type of WBCs).

- **Lymphatic capillaries** are the smallest vessels of the lymphatic system.
- Once the tissue fluids enters the lymphatic capillaries, it is known as **lymph**.
- Lymph nodes are located at the regular intervals along the course of lymphatic vessels, they contain phagocytic cells that help in removal of pathogens and help in proliferation of lymphocytes.

Summary

Types of circulatory systems seen in animals

Open

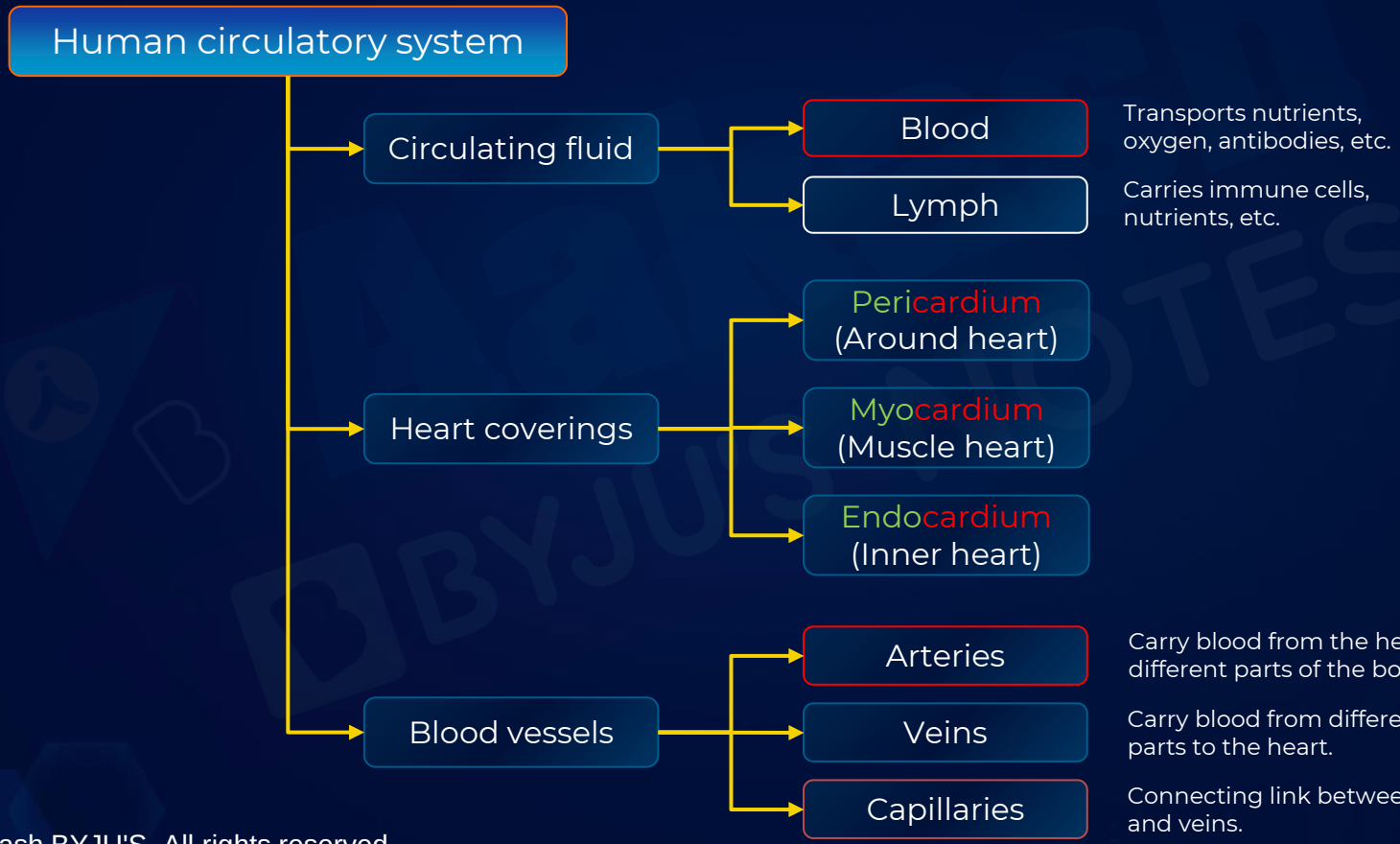
- The heart pumps the circulatory fluid called **hemolymph** through the vessels into open spaces or body cavities.

Closed

- The blood pumped by the heart is always circulated through a **closed network** of blood vessels.

Arteries	Veins
Involved in carrying **oxygenated blood**	Involved in carrying **deoxygenated blood**
Carry blood **away from the heart** to various parts of the body	Carry blood **towards the heart** from various parts of the body
Valves are absent	Valves are present

Summary



Summary

Atria	Ventricles
Smaller chambers	Larger chambers
Form the upper chambers of the heart	Form the lower chambers of the heart
Divided into right and left atria	Divided into left and right ventricles
Collect blood from the body/lungs and supply to ventricles	Supply blood to lungs/different parts of the body

Types of blood circulation

Single circulation

- Seen in **2-chambered heart** containing one atrium and one ventricle
- Example: Fish

Incomplete double circulation

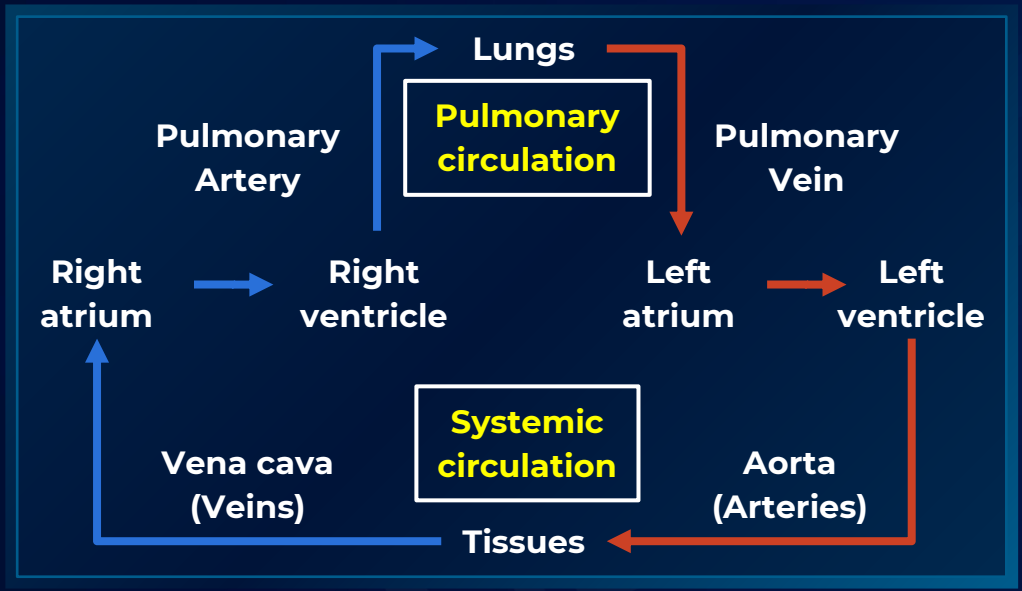
- **3-chambered heart**
- Contains two atria and one ventricle
- Examples: Amphibians and reptiles except crocodile
- Mixing of blood occurs
- Inefficient

Complete double circulation

- **4-chambered heart**
- Contains two atria and two ventricles
- Examples: Birds and mammals
- No mixing of blood
- Two separate circulatory pathways present

Summary

Double Circulation



Hepatic circulation

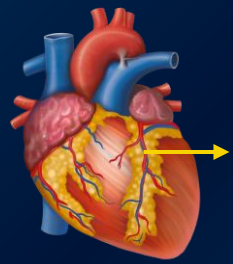
Heart → (Oxygenated blood) → Liver

Hepatic artery

Intestine → (Deoxygenated blood) → Liver

Hepatic portal vein

Coronary circulation



Coronary arteries and veins

Summary

Cardiac cycle

Cardiac cycle comprises the complete relaxation and contraction of both the atria and ventricles.

3 stages

Joint diastole

- **Early** — Blood enters the atria through the veins.
- **Late** — The AV valves open. Some blood enters the ventricles.

Atrial systole — The rest of blood is pumped from the atria to the ventricles.

Ventricular systole

- **Early** — Ventricular contraction causes the AV valves to close.
- **Late** — Ventricular contraction causes the semilunar valves to open. The blood is pumped into the arteries.

Summary

Heartbeat

- Heart chambers contract and relax rhythmically.
- The contraction of the heart chambers is known as **systole.**
- The relaxation of the heart chambers is known as **diastole.**

Hypertension

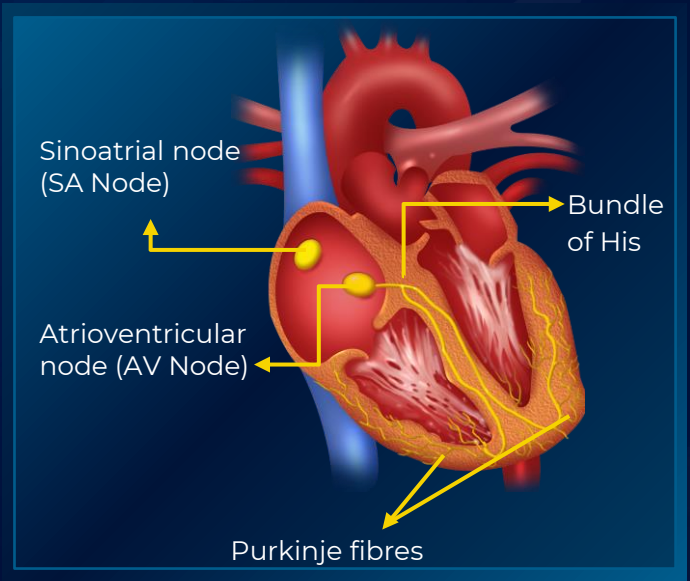
- If repeated checks of an individual's blood pressure has a reading of **140/90 mm Hg or higher**, it indicates hypertension.

Stimulation of heart muscle contraction

Nodal tissue
Regulates the heartbeat intrinsically

Generates action potential and conducts to AV node

Conducts action potential to bundle of His



Conducts action potential

Propagation of impulse to the ventricular muscles

Summary

Electrocardiogram (ECG)

It is used to measure the electrical activity of the heart.

- It is a small upward wave that represents **atrial depolarisation,** which represents electrical excitation or atrial contraction.

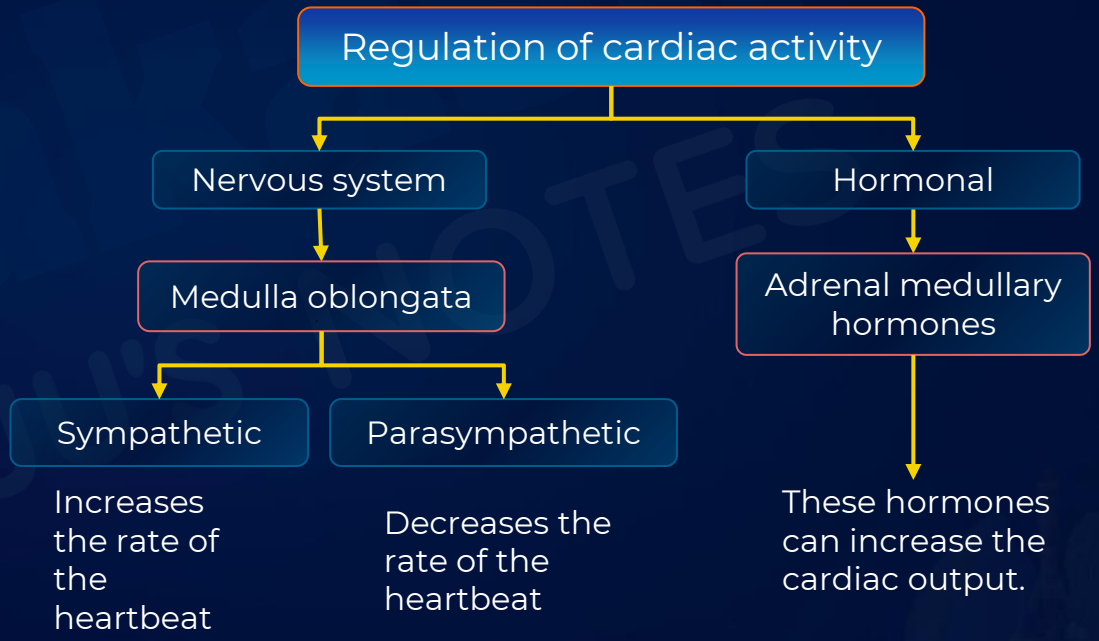
- It is a small upward dome-shaped wave that represents **ventricular repolarisation** or relaxation.
- It represents the return of the ventricles from the excited to the normal state (repolarisation).

- It begins with a downward deflection wave Q and continues as large upright wave R.
- It ends into a downward wave S at the base of R.
- The Q marks the beginning of the systole.

Summary

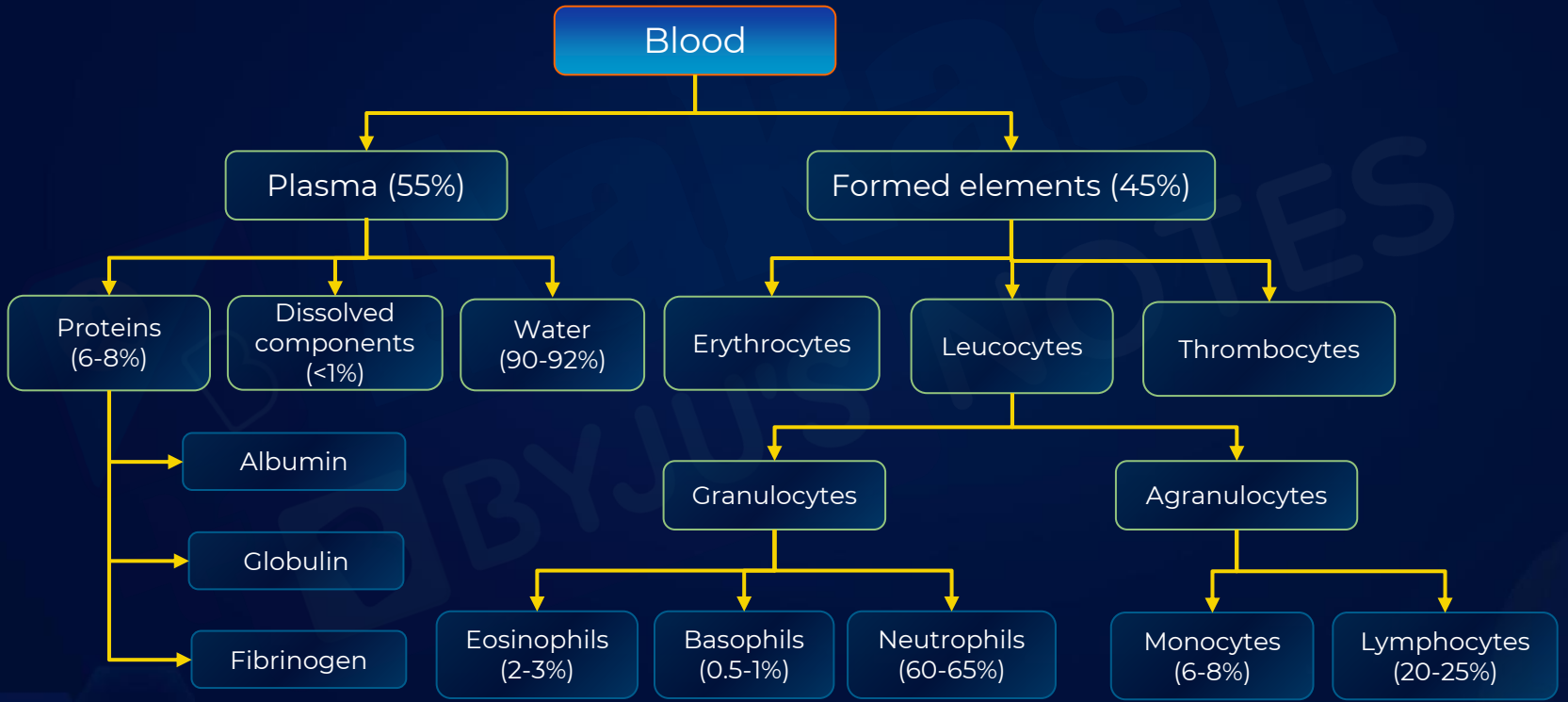
Heart diseases

- Coronary artery disease (CAD)
- Angina
- Heart attack
- Heart failure
- Cardiac arrest
- Arteriosclerosis
- Congenital heart disease

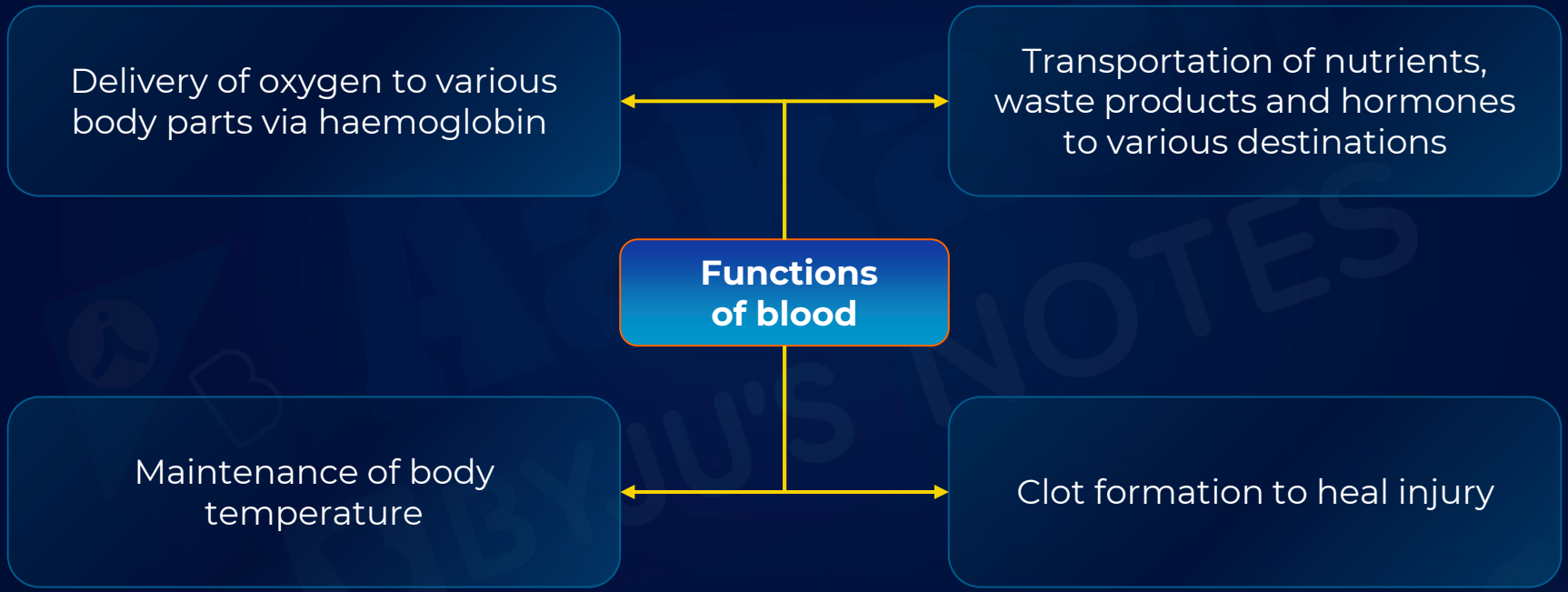


Summary

Components of blood

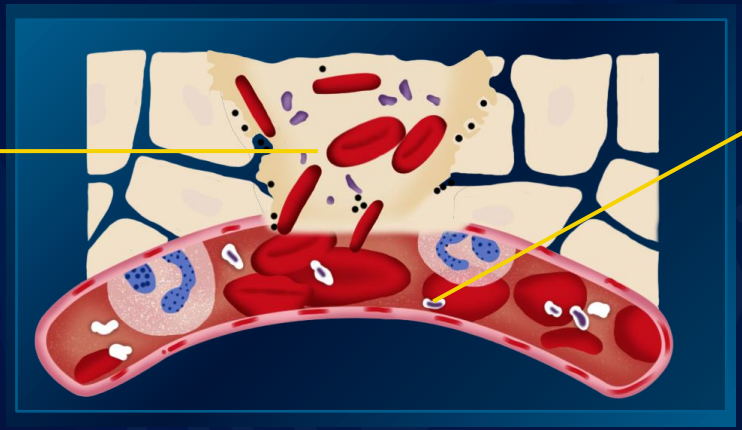


Summary

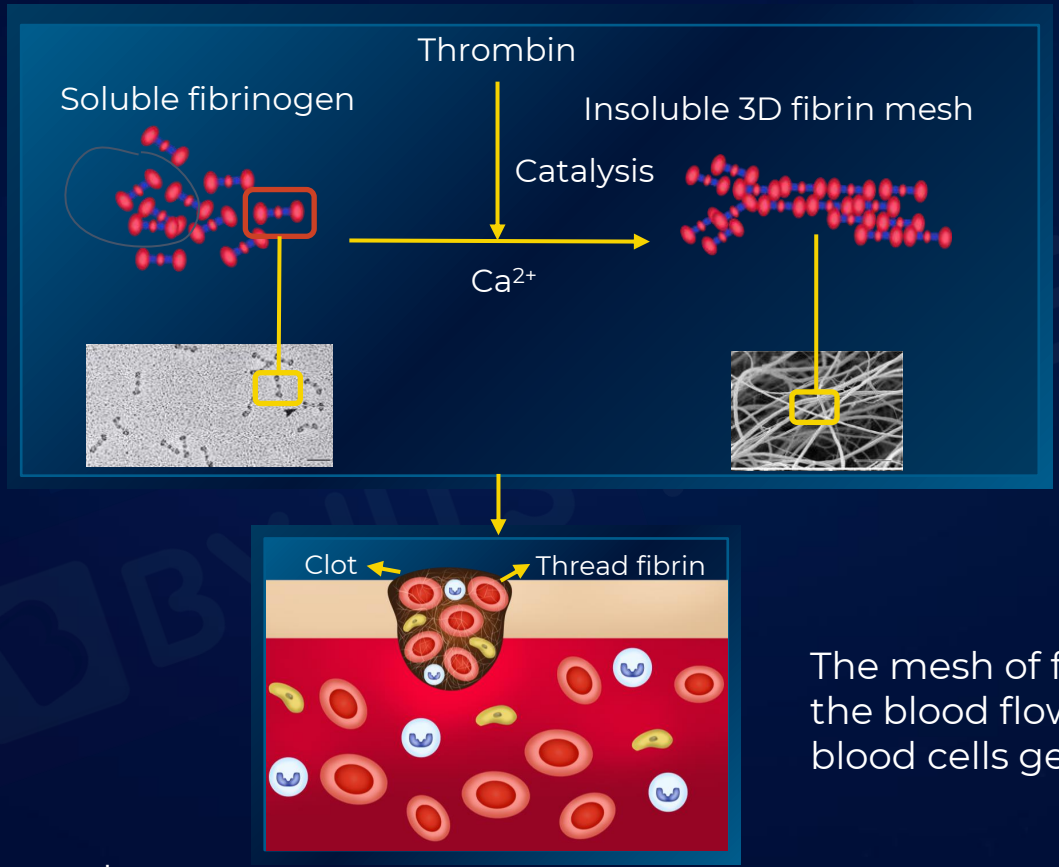


Summary

Coagulation of blood



Summary

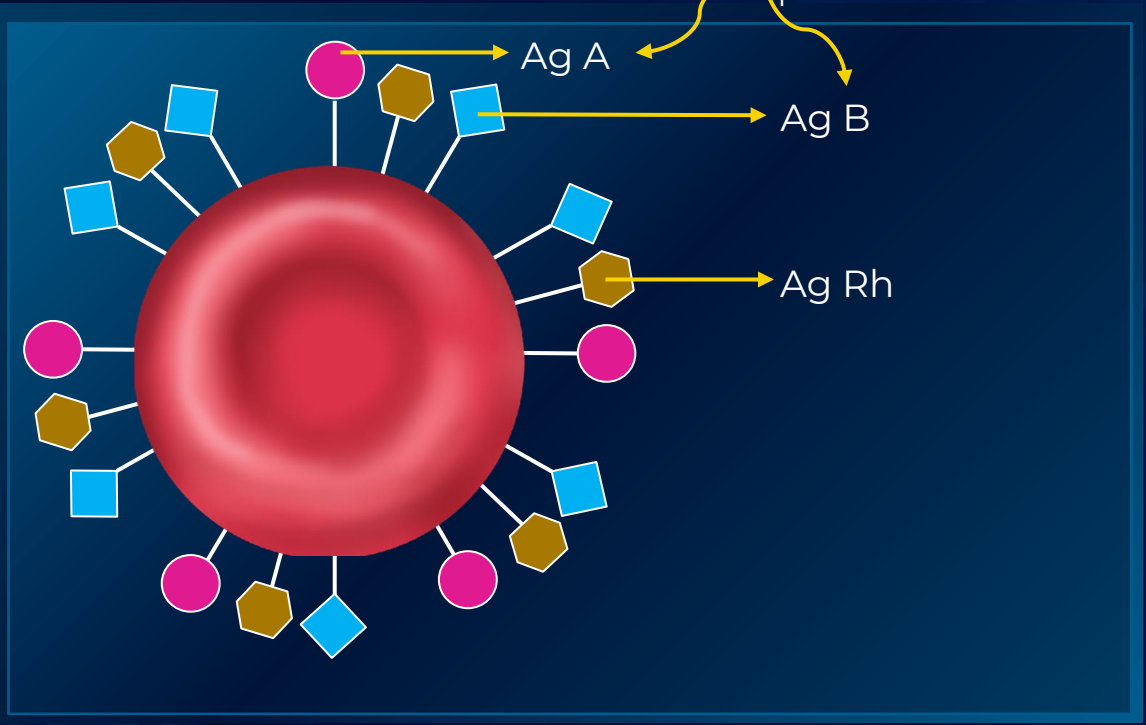


The mesh of fibrin (clot) stops the blood flow because the blood cells get trapped in it.

Summary

Antigens on RBCs

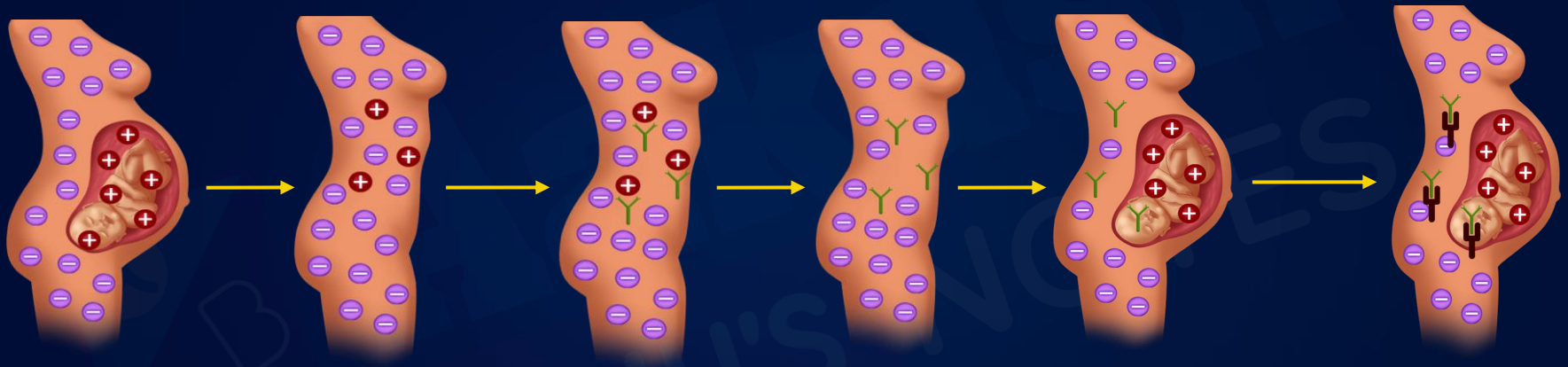
Two most common antigens present in human RBCs



ABO Factor	Rh Group	Blood Group
A	+	A +
A	-	A -
B	+	B +
B	-	B -
AB	+	AB +
AB	-	AB -
O	+	O +
O	-	O -

Summary

Erythroblastosis fetalis



During pregnancy
Rh -ve mother and **Rh +ve baby**

During delivery
Baby's Rh+ blood cells enter mother's bloodstream

After delivery
Mother's blood produces antibodies against Rh antigens

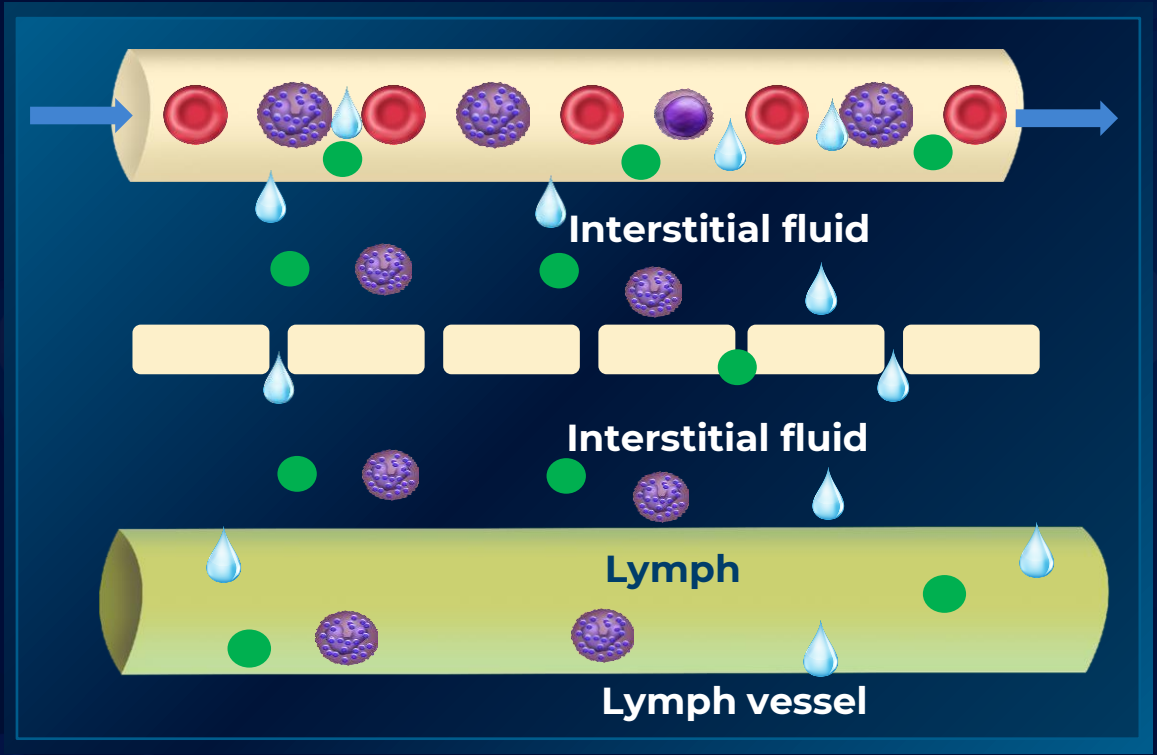
Months after delivery
Antibodies against Rh antigens remain in mother's blood

Next pregnancy
Mother's antibodies attack fetal RBCs, having the Rh factor

Thus, to avoid erythroblastosis fetalis, the artificial antibodies are administered to the mother

Summary

Interstitial fluid and lymph



Water

Dissolved substances

WBC

The leaked substances constitute **interstitial fluid**.

The excess interstitial fluid which enters the **lymph vessels** and is known as **lymph**.