

CHAPTER 10.1 – TYPES OF CIRCULATORY SYSTEM

The necessity for transport systems in complex multicellular organisms

→ Each living cell **requires** essential substances such as oxygen and nutrients, and **expels** cellular waste products such as carbon dioxide and nitrogenous wastes

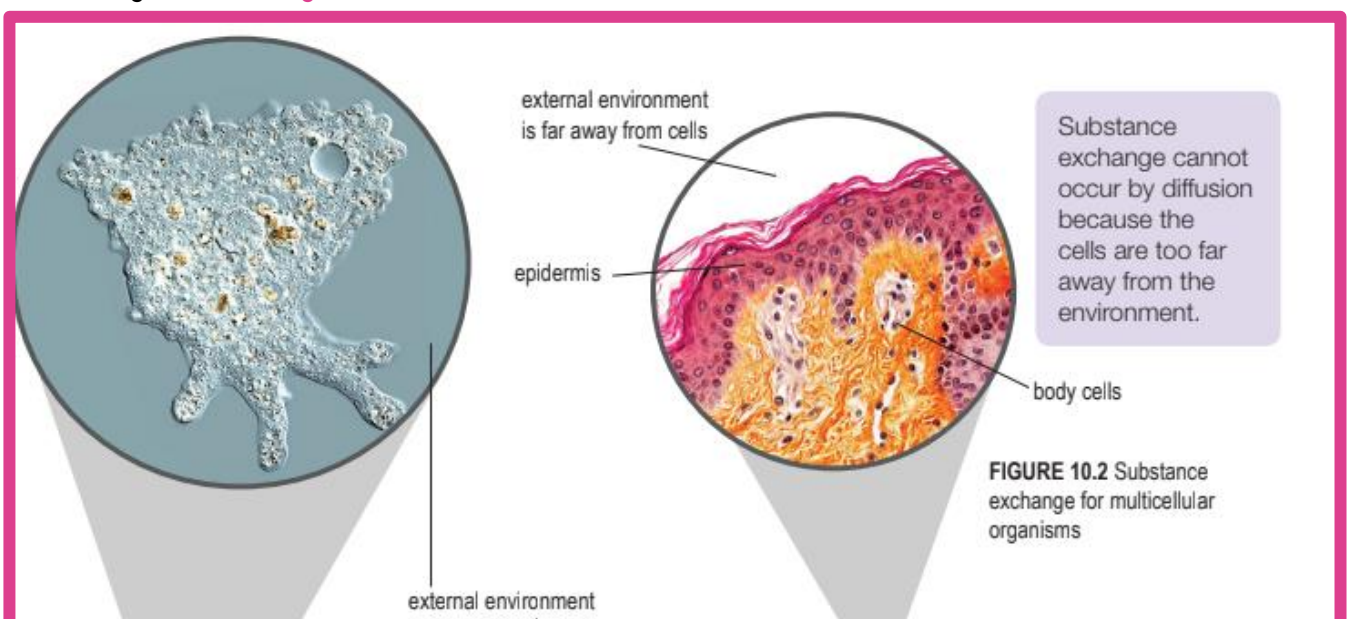
UNICELLULAR ORGANISMS

- Unicellular organisms (Amoeba sp.) **get** their essentials and **expel** wastes by **diffusion** from and to its external surroundings
- Unicellular organisms have a **small body mass**
- Therefore, **the total surface area to volume ratio (TSA/V)** of the organism is **large**

- As such, Amoeba sp. **does not require** a specialised transport system to **transport** substances in and out of the cell

MULTICELLULAR ORGANISMS

- ❖ Large complex multicellular organisms **cannot obtain** essential substances and **expel** wastes by **diffusion** because their **TSA/V** is **small**
- ❖ The **distance** between the external environment and the cell is **too far** for **direct** substance exchange
- ❖ Hence, multicellular have an **internal transportation system**
- ❖ In vertebrates, **transportation system** is called the **blood circulatory system**



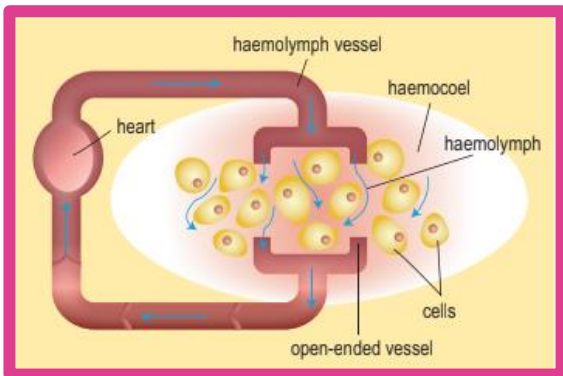
Types of circulatory systems in multicellular organisms

The circulatory system in multicellular organisms is divided into **two**

- I. Open circulatory system
- II. Closed circulatory system

Open circulatory system

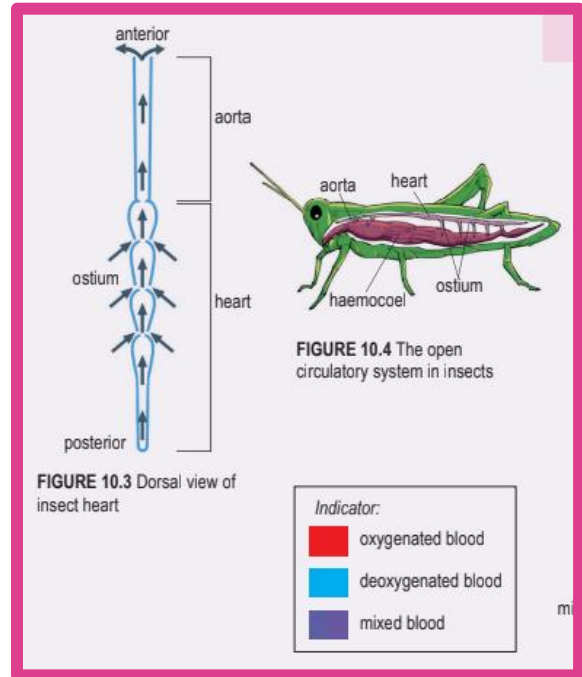
- ❖ In an open circulatory system, haemolymph **flows directly** into the body cavity (**haemocoel**) and **bathes the cells**
- ❖ **Haemolymph** is a **blood-like nutritious liquid** found in most invertebrates (insects, molluscs)



CIRCULATORY SYSTEM OF INSECTS

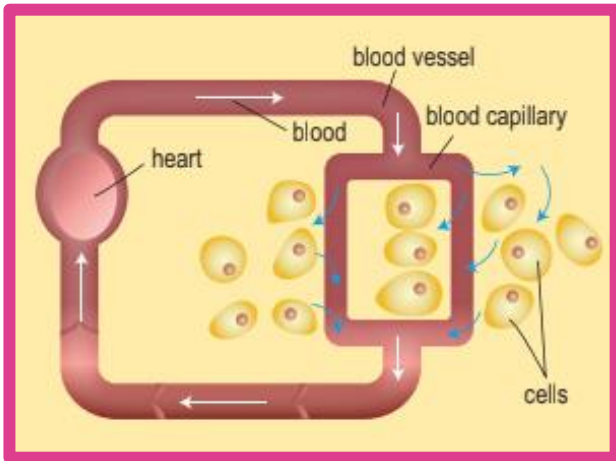
- ✚ The **circulatory system** of insects is an **open circulatory system**
- ✚ This means that **one or more hearts pump haemolymph** through the **blood vessels** into the **haemocoel**
- ✚ Haemolymph **flows out** from the heart into the **haemocoel** when the **heart contracts**

- ✚ In the **haemocoel**, substances **exchange** between **haemolymph** and body cells **occurs** through **diffusion**
- ✚ When the **heart relaxes**, haemolymph **flows back** into the heart through **tiny openings** called **ostium**



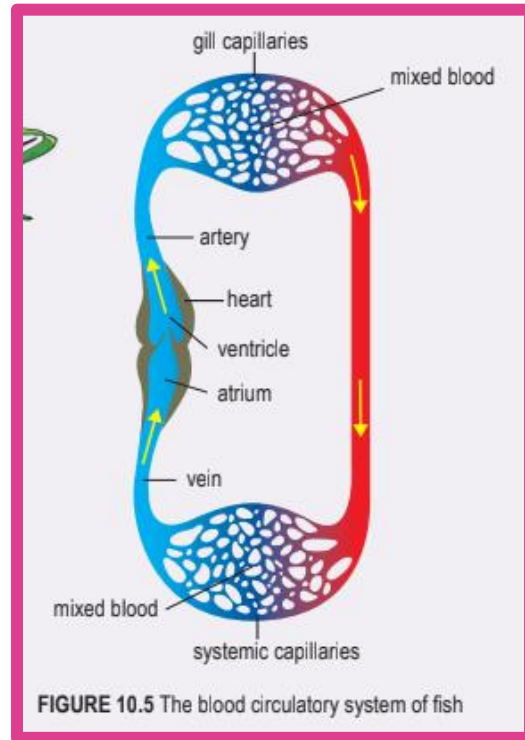
Closed circulatory system

- ◇ In a **closed circulatory system**, **blood** is always **contained** in a **continuous closed blood vessel** and is **distributed** to the whole body
- ◇ The **exchange** of substances that are **essential** to cells such as oxygen and nutrients **occurs across** the **walls** of **blood capillaries**
- ◇ There **three types** of circulatory system
 - 1 Circulatory system of fish
 - 2 Circulatory system of amphibians
 - 3 Circulatory system of humans



CIRCULATORY SYSTEM OF FISH

- ❑ The heart of the fish has **two chambers**
 1. An atrium (plural: atria)
 2. A ventricle
- ❑ Blood that **leaves** the ventricle is **pumped** to the gill capillaries to **enable** gaseous exchange
- ❑ The gill capillaries **carry** blood to the blood vessels that **transport** oxygenated blood to systemic capillaries
- ❑ In the **systemic capillaries**, oxygen **diffuses into** the tissues while carbon dioxide **diffuses from** the tissue into the capillaries
- ❑ The deoxygenated blood is then **returned** to the heart **atrium** through the **veins**
- ❑ As the blood flows in **one** direction, the fish circulatory system is known as a **single circulatory system**

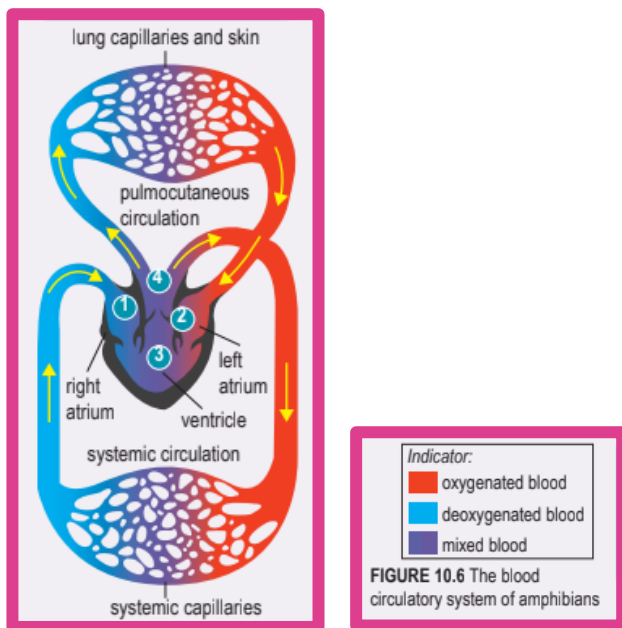


CIRCULATORY SYSTEM OF AMPHIBIANS

- » The heart of an amphibians has **three chambers**
 - 1) Two atria
 - 2) A ventricle
- » The blood flows in **two directions**
 - A Pulmocutaneous circulation
 - B Systemic circulation
- » This system is known as a **double circulatory system**
- » Amphibians are said to have an **incomplete double circulatory system** because the deoxygenated blood and the oxygenated blood are **mixed**
- » **Pulmocutaneous circulation** transports blood to the **lungs and skin**, and the exchange gases takes place here
- » **Systemic circulation** transports oxygenated blood to the body tissues and **returns** the deoxygenated blood to the **right atrium** through the **veins**

THE MOVEMENT OF BLOOD IN CIRCULTORY SYSTEM OF AMPHIBIANS

- 1 Deoxygenated blood from body is transported to the right atrium
- 2 Oxygenated blood from lungs and skin is transported by the pulmonary vein to the left atrium
- 3 Blood from both atria enters one ventricle. Although there is some mixing of oxygenated and deoxygenated blood in the ventricle, most of the oxygenated blood remains on the left side of the ventricle while the deoxygenated blood remains on the right side of the ventricle.
- 4 The ventricle then pumps the blood through the pulmocutaneous (lungs and skin) and systemic circulations



CIRCULATORY SYSTEM OF HUMANS

- Δ The human heart consists of four chambers that are separated completely
 - I Two atria
 - II Two ventricles

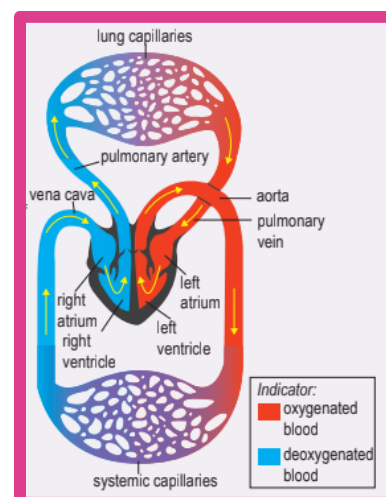
- Δ Human have a double circulatory system
- Δ This means that in one complete circulatory cycle, blood flows in the blood vessels through the heart twice
- Δ As there are two different circulations, humans are said to have a complete double circulatory system because the deoxygenated blood and the oxygenated blood do not mix
- Δ There two types of circulation
 - I. Pulmonary circulation
 - II. Systemic circulation

PULMONARY CIRCULATION

- ⊕ Deoxygenated blood is transported through the pulmonary artery to the lungs for gaseous exchange
- ⊕ Oxygenated blood from the lungs is returned to the left atrium and flows into the left ventricle

SYSTEMIC CIRCULATION

- ⊕ Blood is pumped from the heart to all the body tissues through the aorta
- ⊕ Then the deoxygenated blood returns to the right atrium through vena cava



Compare and contrast the circulatory systems in complex multicellular organisms

SIMILARITIES

SIMILARITIES	
	<ul style="list-style-type: none"> Found in all multicellular organisms Consists of a heart to pump blood or haemolymph (in insects) Functions to transport nutrients and wastes The heart has valves that ensure blood flows in one direction

DIFFERENCES

DIFFERENCES				
organism	Insects	Fish	Amphibians	Humans
Types of circulatory system	Open blood circulatory system	Closed blood circulatory system	Closed blood circulatory system	Closed blood circulatory system
Number of circulations		Single (Blood flows in the blood vessel and through the heart once in a complete circulation)	Double (Blood flows in the blood vessel and through the heart twice in one complete circulation)	Double (Blood flows in the blood vessel and through the heart twice in one complete circulation)
Number of heart cavities	The heart is made up of many cavity segments	Two (One atrium, one ventricle)	Three (Two atria, one ventricle)	Four (Two atria, two ventricles)
Separation of oxygenated blood and deoxygenated blood			Incomplete (Some oxygenated blood is mixed with the deoxygenated blood in the ventricle)	Complete (Oxygenated blood does not mix with the deoxygenated blood in the ventricle)

CHAPTER 10.2 – CIRCULATORY SYSTEM OF HUMANS

Circulatory system of humans

There are **three main** components in the circulatory system of humans

- Blood
- Heart
- Blood vessels

BLOOD

- ↳ A type of **connective tissue** that is made up of
 - a) Blood plasma
 - b) Blood cells
 - c) Platelets
- ↳ Blood acts as a **medium** of **transportation**

HEART

- Functions as a **muscular pump** that **circulates** blood to the whole body

BLOOD VESSELS

- Consists of
 - A. Arteries
 - B. Capillaries
 - C. Veins
- **Connected** to the heart
- **Transport** blood to all the body tissues

Structure of the heart

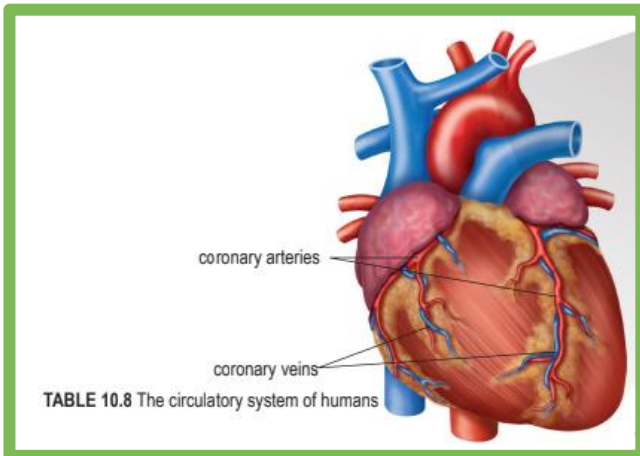
- » The heart is **located** between the lungs in the thorax cavity
- » Contains **four** chambers
 - I Left atrium
 - II Right atrium
 - III Left ventricle
 - IV Right ventricle
- » The left chamber is **separated** from the right chamber by a **muscular wall** called **septum**
- » Atrium **receives** blood that **returns** to the heart
- » Ventricle **pumps blood** out of the heart
- » The ventricle has **thicker walls** and **contract stronger** than the atrium
- » The muscular wall of the left ventricle is **much thicker** than the muscular wall of the right ventricle
- » This is because the left ventricle has to **generate greater pressure** to **pump blood** out of the aorta to the whole body while the right ventricle only has to pump blood to the lungs

CORONARY ARTERIES

- **Transport oxygenated blood** for heart tissues

CORONARY VEINS

- **Transport deoxygenated blood**



AORTA

- ✚ Aorta is the main blood artery that transports oxygenated blood to the whole body

VENA CAVA

- ⊕ Vena cava is the main vein that transports deoxygenated blood back to the heart

PULMONARY ARTERY

- ⊕ Transports deoxygenated blood from the heart to the lungs

PULMONARY VEINS

- ◇ Transports oxygenated blood from the lungs to the heart

SEMILUNAR VALVES

- ☐ Located at the base of the pulmonary artery and the base of the aorta
- ☐ Ensures the blood to not flow back into the ventricle when the ventricle relaxes

BICUSPID VALVE

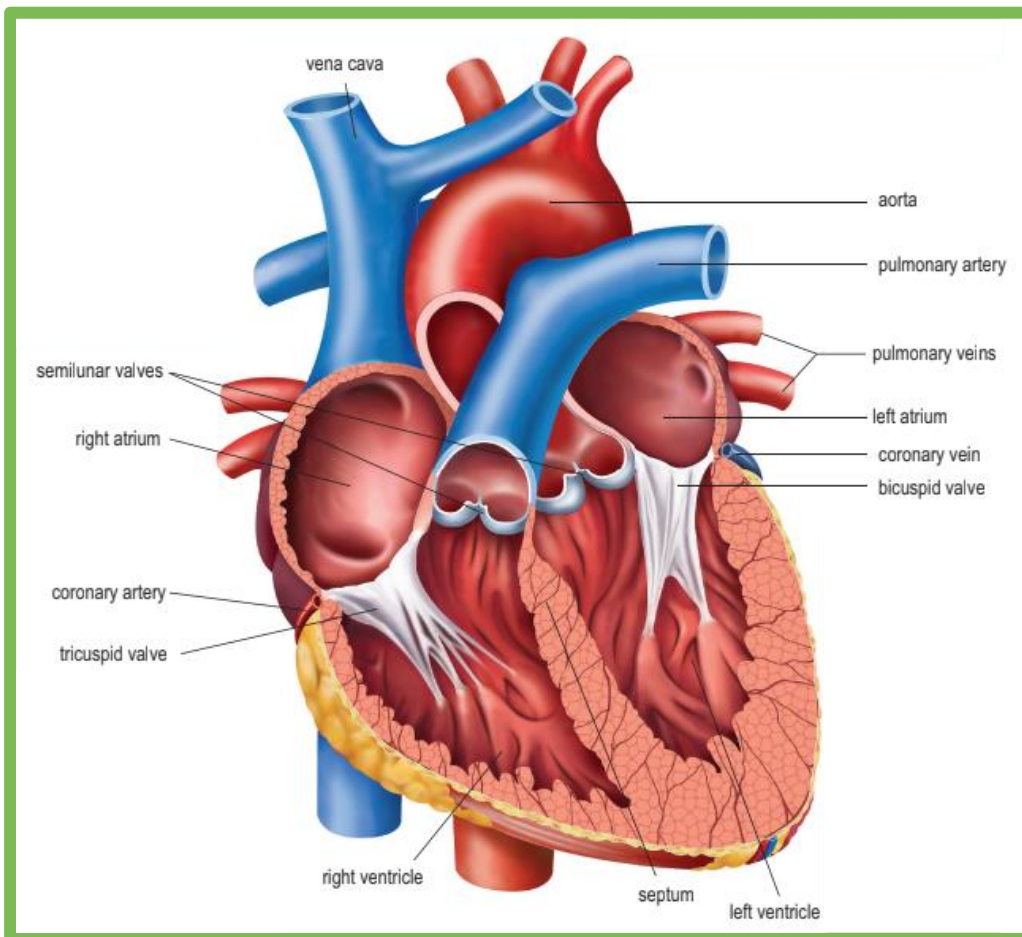
- ∨ Located between the left atrium and the left ventricle
- ∨ Ensures the blood that flows into the left ventricle does not flow back into the left atrium
- ∨ Consists of two leaflets
- ∨ Bi = two

TRICUSPID VALVE

- ✚ Located between the right atrium and the right ventricle
- ✚ Ensures the blood that flows into the right ventricle does not flow back into the right atrium
- ✚ Consists of three leaflets
- ✚ Tri = three

SEPTUM

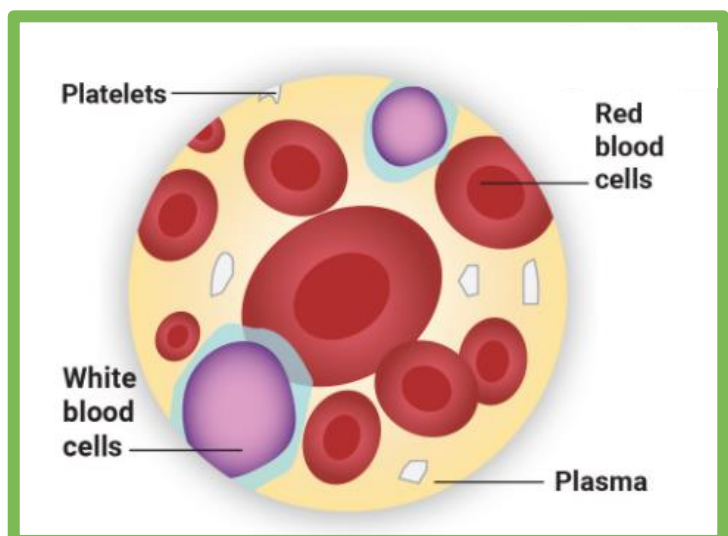
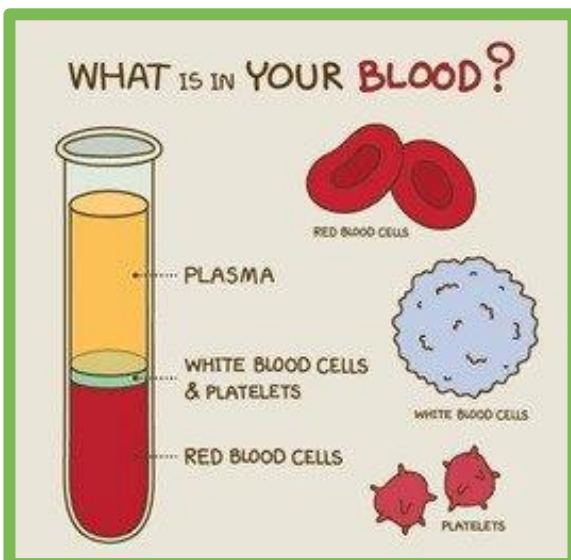
- ◇ Separates the left part of the heart from the right part of the heart
- ◇ Ensures the deoxygenated blood to not mix with the oxygenated blood



Composition of human blood

- The human blood consists of
- 1) 55% plasma
 - 2) 45% cell components

- Plasma is the **medium of transportation** in the body
- The components of blood cells consist of
- a) Red blood cells (erythrocytes)
 - b) Platelets
 - c) White blood cells (leucocytes)



Blood plasma components and the main function of each component

WATER

- ⊕ Blood plasma consists of 90% of water
- ⊕ Water is a medium of transportation
- ⊕ A solvent for
 - I. Respiratory gas
 - II. Ions
 - III. Digestive products
 - IV. Excretory substances

PLASMA PROTEINS

- Δ Fibrinogen plays a role in blood clotting
- Δ Albumin controls blood osmotic pressure
- Δ Globulin is a type of antibody that is involved in the body's defence

SOLUTES

- ↳ Consist of
 - A. Nutrients (glucose)
 - B. Excretory substance (urea, respiratory gas)
- ↳ Nutrients are important for energy, growth and maintenance of health
- ↳ Excretory substances are toxic substances that need to be disposed of from the body
- ↳ Oxygen is required in the respiration of cells

HORMONES AND ENZYMES

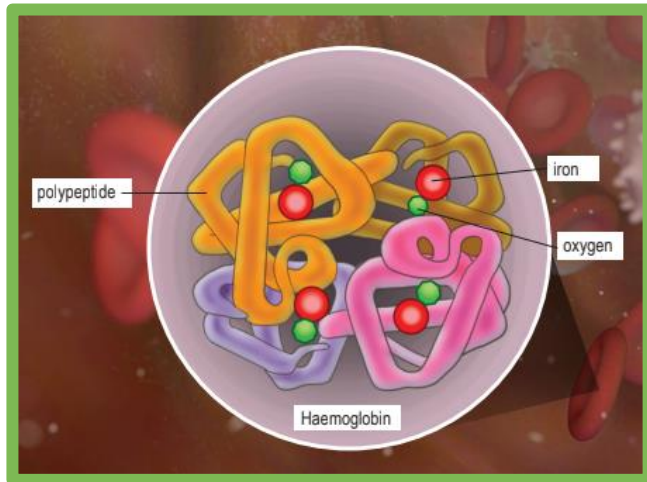
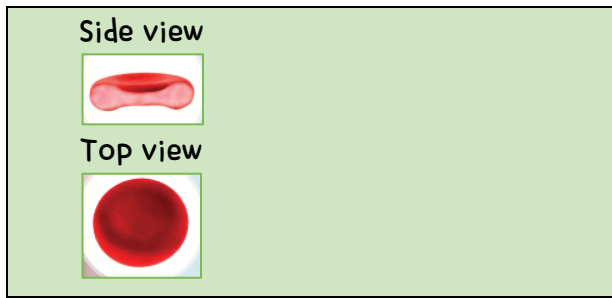
- » Hormones control physiological activities in the body

- » Enzymes are involved in the metabolic processes of cells

Characteristics and functions of blood cell types

Erythrocyte (red blood cell)

CHARACTERISTICS
<ul style="list-style-type: none"> a) Has an elastic plasma membrane b) The biconcave disc shape enables a large TSA/V for efficient gaseous exchange c) It does not have a nucleus at the mature stage so that more haemoglobin can be loaded into it d) It is produced in the bone marrow of bones such as the sternum and ribs e) Can live up to 120 days and is destroyed in the liver or lymph through the phagocytosis process
FUNCTIONS
<ul style="list-style-type: none"> a. Each erythrocyte has a haemoglobin which is the red pigment that gives blood its red colour b. Haemoglobin contains a heme group c. The heme group consists of an iron atom which is the binding site for oxygen d. Haemoglobin combines with oxygen to form oxyhaemoglobin in high oxygen partial pressure conditions e. Oxyhaemoglobin releases oxygen in tissues or cells when the partial pressure of oxygen is low



Leucocyte (white blood cell)

CHARACTERISTICS AND FUNCTIONS

- A) The shape is irregular and is not fixed
- B) Contains nucleus
- C) Does not contain haemoglobin
- D) Produced in the bone marrow
- E) Life span is less than five days
- F) Leucocyte diffuse out of the capillary pore and fight pathogens in tissue fluids
- G) Divided into two types
 - i. Granulocytes (contain granules)
 - ii. Agranulocytes (no granules)

Platelet

CHARACTERISTICS

- 1) Platelets are produced from fragments or scraps of cell cytoplasm that originate from the bone marrows
- 2) The life span is less than one week

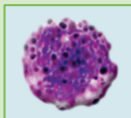
FUNCTIONS

- 1. Involved in the blood clotting process



BASOPHIL

- The number of basophils is lowest in the blood
- It contains heparin that prevents blood clotting



GRANULOCYTES

Include

- Neutrophil
- Eosinophil
- Basophil

NEUTROPHIL

- The nucleus is made up of two to five lobes
- Ingests bacterial cells and dead cells or tissues from wounds by phagocytosis



EOSINOPHIL

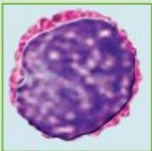

- The nucleus is made up of two lobes
- Releases enzymes that fight inflammation and allergy reaction



AGRANULOCYTES

Include

- Δ Lymphocyte
- Δ Monocyte

LYMPHOCYTE
<ul style="list-style-type: none"> » Contains a large nucleus with very little cytoplasm » Produces antibodies to destroy bacteria and viruses that enter the body » Can also produce antitoxins against toxins that are produced by bacteria or viruses

MONOCYTE
<ul style="list-style-type: none"> ⊕ The biggest leucocyte ⊕ Spherical-shaped nucleus ⊕ Ingests bacteria and dead cells or tissues by phagocytosis


Human blood vessels

Artery

ARTERIES

- ↳ Arteries are blood vessels that transport blood out of the heart
- ↳ The function of the artery is to quickly transport blood at a high pressure to the tissues
- ↳ The blood in the artery is under high pressure because of the pumping action of the heart

AORTA

- ⊞ The aorta is the main artery that leaves the heart
- ⊞ The artery expands when blood is received from the heart
- ⊞ Therefore, the artery wall is elastic to stop it from breaking due to the high-pressured blood that flows through it

ARTERIOLES

- ❖ The branches of an artery become small vessels known as arterioles when they reach the body tissues
- ❖ The arteriole continues to branch out and ends at the capillaries

CAPILLARY NETWORK

- ♥ The group of capillaries is called capillary network

Blood capillaries

CAPILLARIES

- » Capillaries are blood vessels with thin walls, as thick as one cell
- » Blood capillaries allow the exchange of gases to occur between blood and cells through diffusion
- » Nutrients, excretory substances and hormones diffuse through blood capillaries

Vein

VENULES

- ◇ Capillaries rejoin to form larger blood vessels called venules

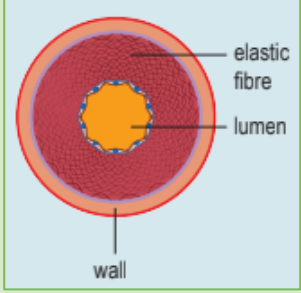
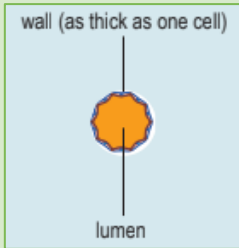
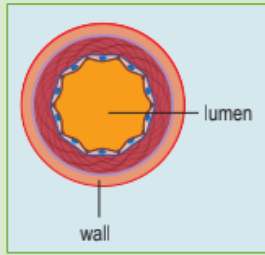
VEINS

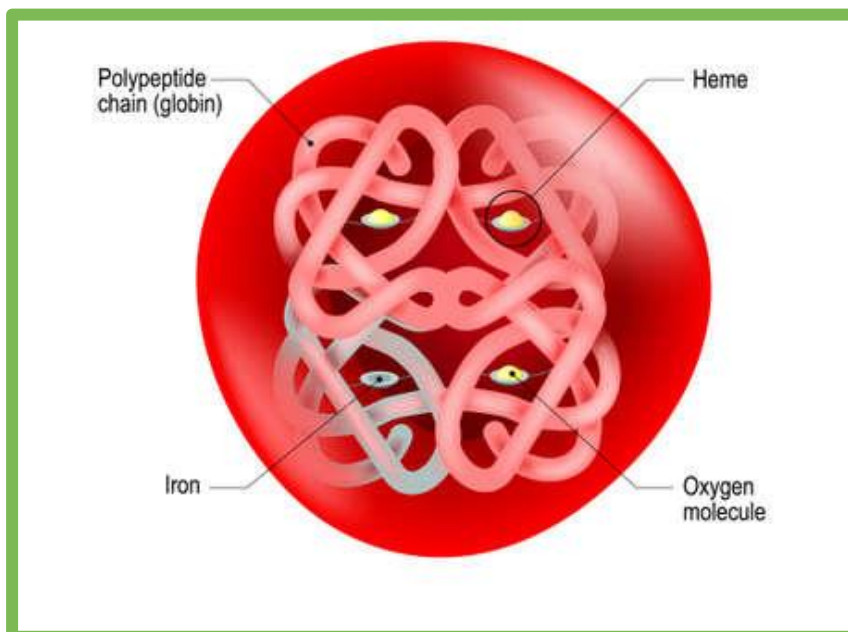
→ The venules combine to form veins that transport blood back to the heart

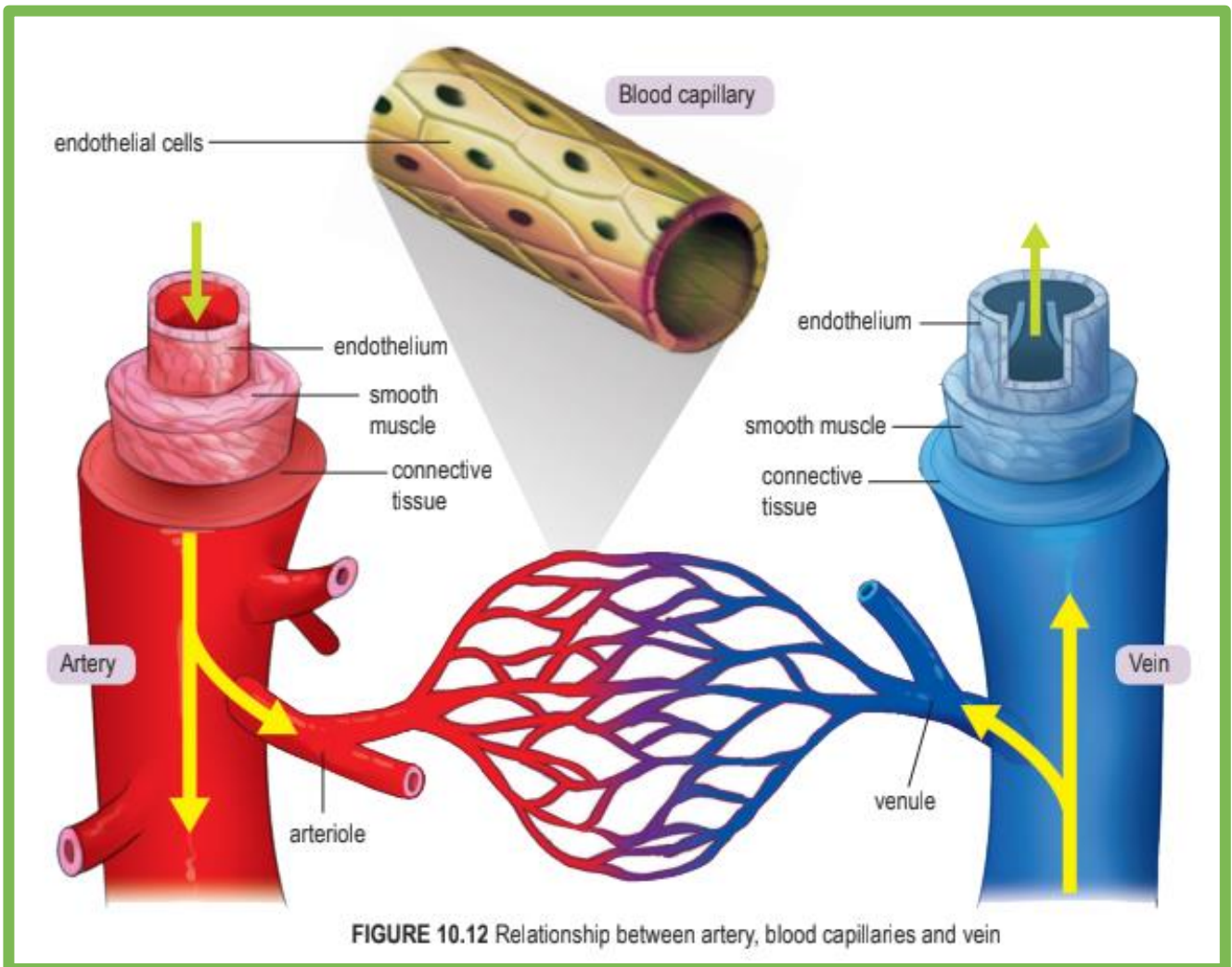
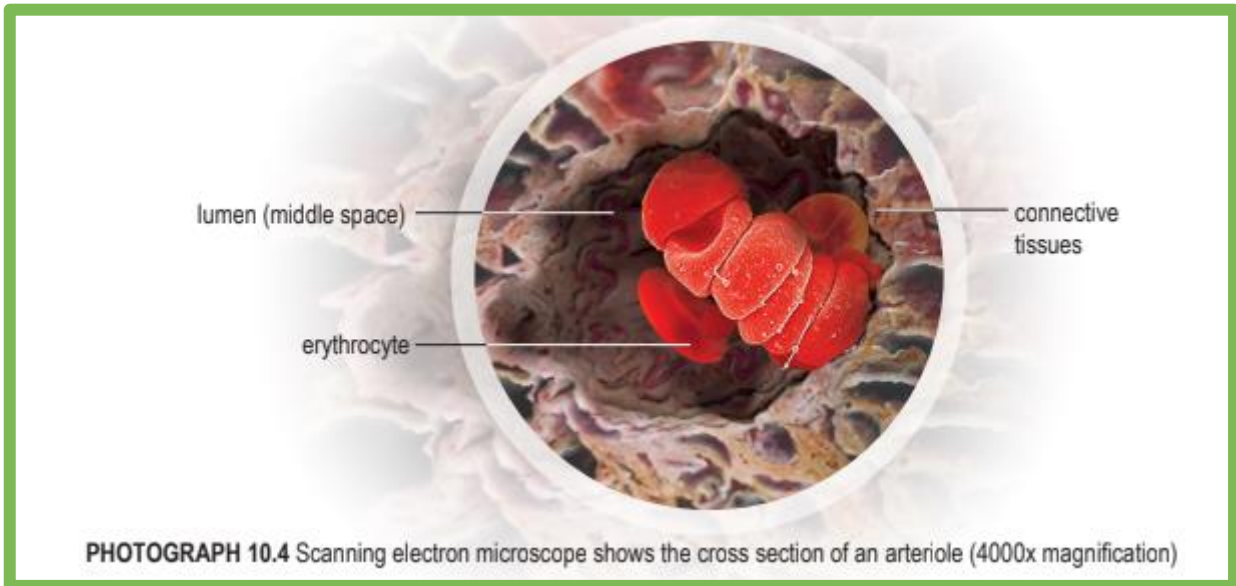
VENA CAVA

○ Vena cava is the main vein that carries deoxygenated blood back to the heart

Differences between arteries, capillaries and veins

CHARACTERISTICS	ARTERY	CAPILLARIES	VEINS
Wall	Wall is thick, muscular and elastic 	Wall is as thick as one cell, not muscular and not elastic 	Wall is thin, less muscular and less elastic 
Lumen	Small	Very tiny	Large
Valve	No valve except semilunar valve at <ul style="list-style-type: none"> ▪ The base of the aorta ▪ The base of the pulmonary artery 	No	Contains valve (To maintain one-way flow of blood)
Blood pressure	High	Low	Very low
The direction of blood flow	From the heart to the entire body	From the artery to the vein	From the whole body to the heart





CHAPTER 10.3 – MECHANISM OF HEARTBEAT

Mechanism of heartbeat

- » The heart is made up of **cardiac muscles** that **intersect** and are **connected** with one another
- » This arrangement **allows electric impulses** to **spread rapidly** through the heart
- » At the same time, it **stimulates** the cardiac muscle cells to **contract simultaneously** and **uniformly**
- » Cardiac muscles are **myogenic**
- » This means that the heart **contracts** and **relaxes** without receiving any **impulse signal** from the **nervous system**
- » If the **cardiac muscles** are **stored** in a **warm oxygenated solution** that **contains nutrients**, these muscles will **contract** and **relax rhythmically** on their own

Blood circulation in humans

- ❖ The **produced force** that enables blood to **circulate** in humans is **generated** by the **pumping** of the heart and the **contraction** of the **skeletal muscles**

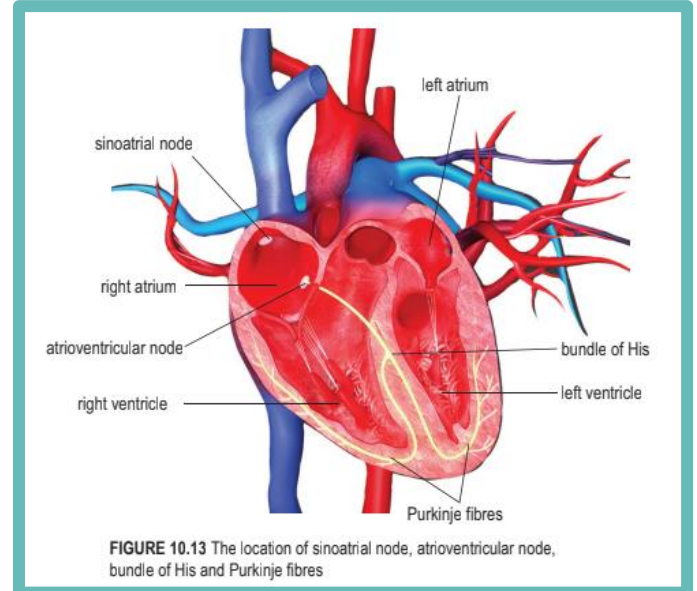


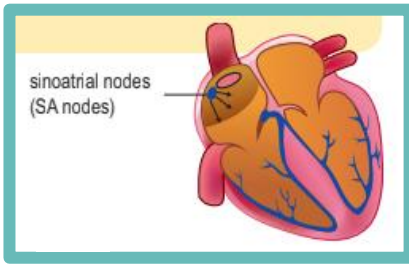
FIGURE 10.13 The location of sinoatrial node, atrioventricular node, bundle of His and Purkinje fibres

PUMPING OF THE HEART

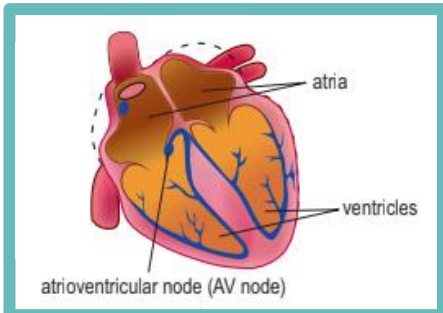
- ⊞ The **contraction** of the heart is **initiated** and **coordinated** by the **pacemaker**
- ⊞ The **pacemaker** is a **group of specific heart muscle cells** that **initiates** the **rate of the heart contraction** and is **located** at the **right atrium wall**
- ⊞ The **pacemaker** **generates electrical impulses** that **spread rapidly** through **both walls of the atrium** and causes the **atrium to contract rhythmically**
- ⊞ The **main pacemaker** is called **sinoatrial node (SA)**

THE SEQUENCE OF HEART CONTRACTION THAT CAUSES THE PUMPING OF THE HEART

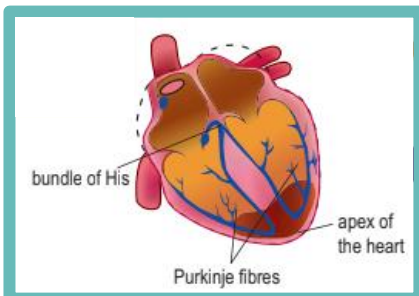
- 1 The **sinoatrial node (SA)** **generates electrical impulses**.



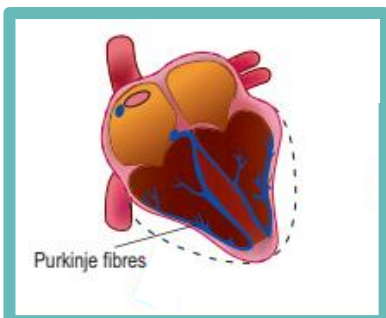
- 2 Electrical impulses spread rapidly in both the atria, causing the atria to contract simultaneously. The contraction of the atria helps to pump blood into the ventricles



- 3 The electrical impulses reach the atrioventricular node. The electrical impulses spread through the bundle of His, and the Purkinje fibres up to the apex of the heart

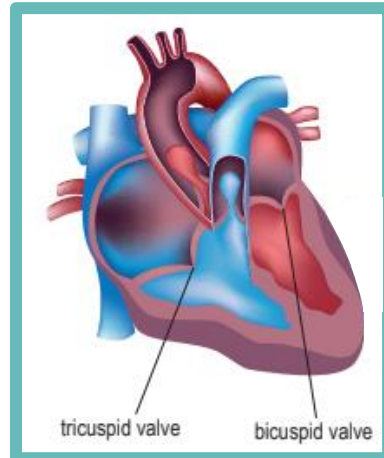


- 4 The electrical impulses spread from the apex of the heart to the whole ventricle wall. As a result, the ventricles contract to pump blood out to the lungs and body

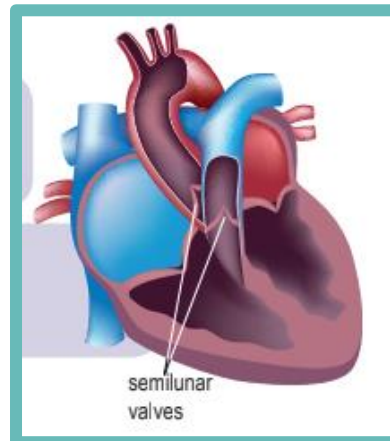


THE LUB-DUB SOUND OF THE HEART

- 1 The first 'lub' sound is produced when the tricuspid valve and the bicuspid valve close



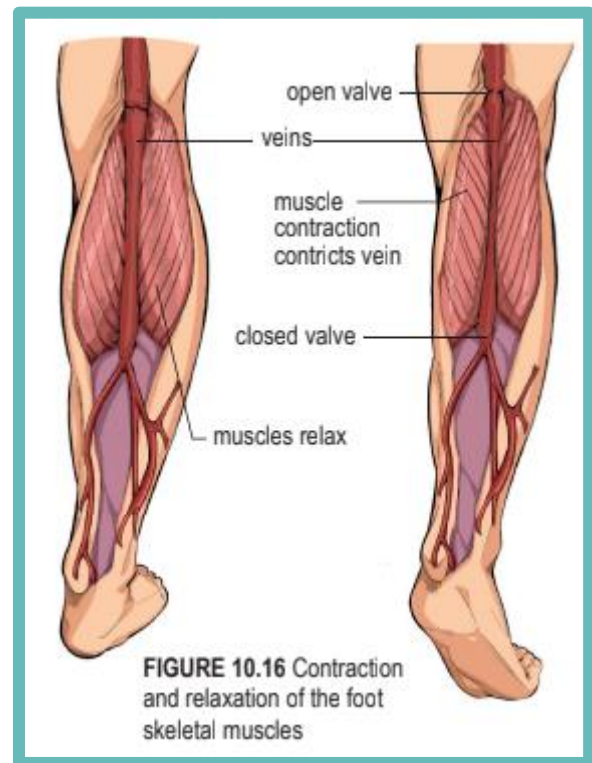
- 2 The second 'dub' sound is produced when the semilunar valves close



CONTRACTION OF SKELETAL MUSCLES AROUND THE VEINS

- ✚ The pumping of the heart helps in the distribution and flow of blood through the arteries, arterioles and blood capillaries
- ✚ However, the force produced by the pumping of the heart is insufficient for the blood flow to continue through the veins and return to the heart
- ✚ Besides, the blood is forced to flow against the force of gravity

- ✚ The presence of valves in the veins ensures that the blood flows in one direction to the heart
- ✚ The blood flow in the veins is assisted by:
 - a) Contraction of the smooth muscles found in the venule and vein walls
 - b) Contraction of skeletal muscles around the veins. The contraction of skeletal muscles presses and constricts the veins, causing the valve to open and allow blood to flow towards the heart. The valve is then closed to prevent the blood from flowing back towards the foot



CHAPTER 10.4 – MECHANISM OF BLOOD CLOTTING

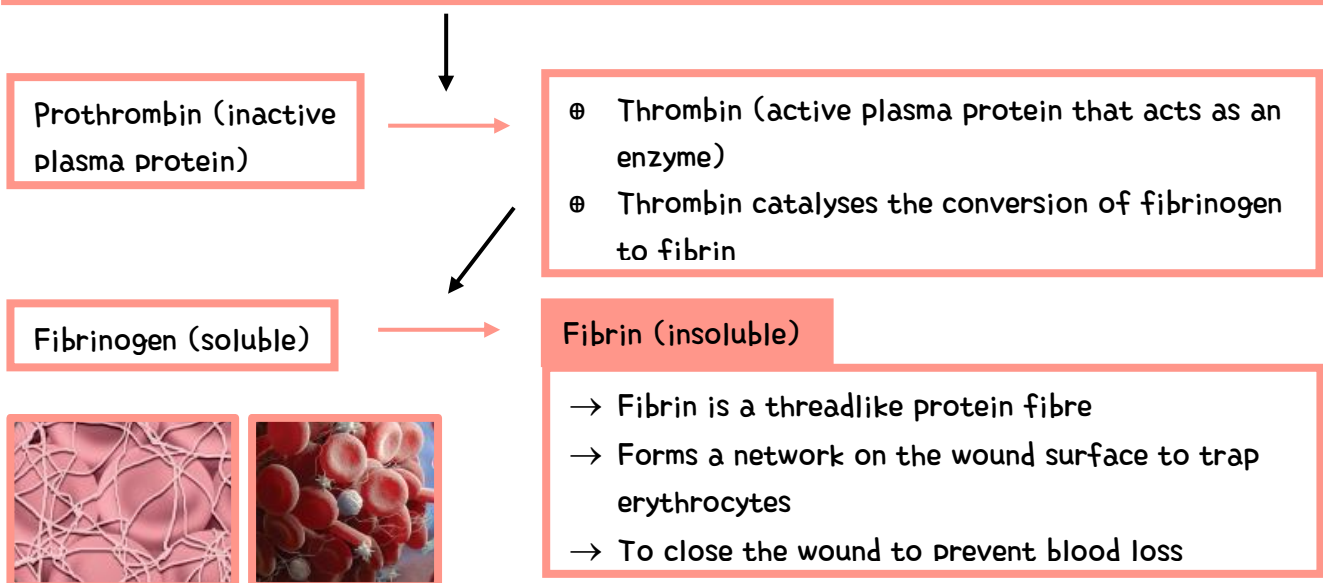
The necessity for blood clotting and mechanism

- ◇ If a finger is injured, blood will flow from the wound until you apply pressure directly on the wound
- ◇ The pressure you apply may appear to restrict bleeding temporarily
- ◇ However, the blood flow is actually stopped by the blood clotting process
- ◇ The blood clot must on the wound because blood clotting will stop or minimise the loss of blood on the injured blood vessels
- ◇ Blood clotting also prevents microorganisms (bacteria) from entering the bloodstream through the damaged blood vessel
- ◇ The blood pressure is also maintained because excessive blood loss will lower blood pressure to a dangerous level

Mechanism of blood clotting

- Blood clotting involves a series of chemical reactions that takes place in the blood when someone is injured to prevent excessive bleeding

- △ The coagulated platelets, damaged cells and clotting factors in the blood plasma will form an activator (thrombokinase)
- △ Thrombokinase, with the aid of calcium ions and vitamin K, converts prothrombin to thrombin



Health issues related to blood clotting

- Under normal conditions, blood does not clot in blood vessels that are not damaged because of some anticoagulants (e.g., heparin)

HAEMOPHILIA

- ↳ Haemophilia is an example of an illness that prevents blood from clotting
- ↳ Haemophilia is a hereditary illness caused by the lack of certain clotting factors in the blood
- ↳ Excessive bleeding due to small wounds or bruises can result in death

THROMBOSIS

- » Formation of a blood clot (thrombus)
- » Thrombosis happens as a result of:
 - 1) Damage in blood vessels
 - 2) Sluggish blood flow that causes clotting factors to accumulate

EMBOLISM

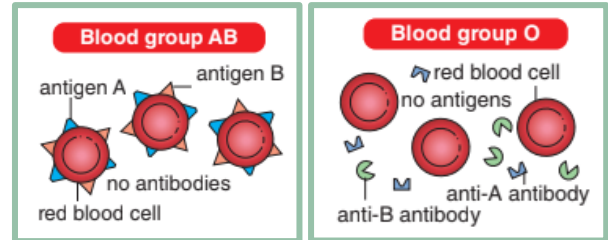
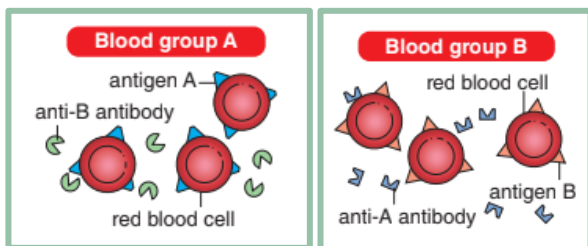
- ⊕ When a blood clot is transported by blood flow, the blood clot is called embolus
- ⊕ If the embolus gets stuck in tiny blood vessel, the blood flow will stop

CHAPTER 10.5 – BLOOD GROUPS OF HUMANS

ABO blood group

- Human blood classified into A, B, AB and O groups
- Donation and transfusion of blood is based on the compatibility of the blood group of the donor and the recipient
- This is because the recipient has antibodies in the blood serum that can act against the antigen on the red blood cells of the donor
- Blood transfusion from a donor to a recipient must take into consideration the blood group type of the donor and the recipient
- If the blood group of both the donor and receiver is not compatible, the red blood cells of the recipient will experience agglutination (coagulation)

Blood group	Antigen on red blood cells	Antibody in the blood serum
A	Antigen A	Anti-B
B	Antigen B	Anti-A
AB	Antigen A & Antigen B	None
O	None	Anti-A & Anti-B



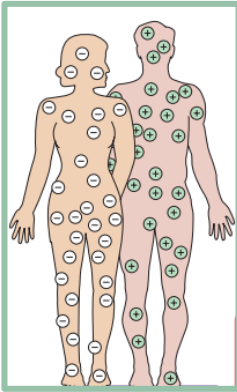
Blood group	Can donate blood (donor)	Can receive blood (recipient)
A	A and AB only	A and O only
B	B and AB only	B and O only
AB	AB only	A, B, AB and O
O	A, B, AB and O	O only

Rhesus Factor

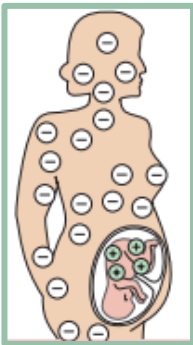
- ❑ Another antigen found on the surface of the red blood cells is the Rhesus factor (Rh factor)
- ❑ The red blood cells of an individual with the Rh factor or antigen D are known as Rh-positive
- ❑ An individual who does not possess the Rh factor or antigen D is known as Rh-negative
- ❑ If the blood of a Rh-positive donor mixes with the blood of a Rh-negative recipient, the blood of the recipient will react by producing the Rhesus antibody or anti-D antibody
- ❑ When the recipient receives another dose of Rh-positive blood, the Rhesus antibody will cause the agglutination of the donor blood cells
- ❑ This situation could result in the death of the recipient

Pregnancy and the Rhesus factor

- Usually, problems will arise when an Rh-negative mother marries an Rh-positive father and conceives and Rh-positive foetus

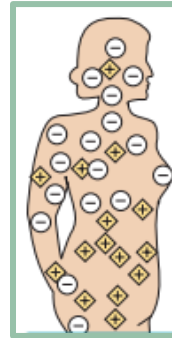


- During the last month of pregnancy, fragments of foetal blood cells containing antigen D cross the placenta and enter the blood circulation of the mother
- As a result, the white blood cells in the mother's blood will react and produce anti-D antibodies that will flow back through the placenta into the foetal blood circulatory system
- The antibodies will destroy the red blood cells of the Rh-positive baby before or immediately after birth

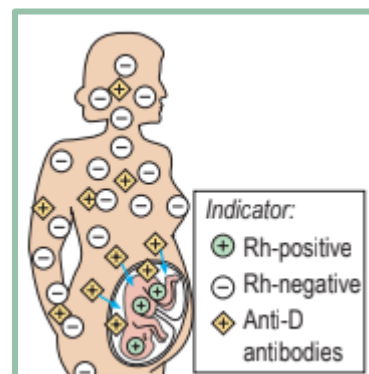


- However, the concentration of antibodies produced is not enough to affect the first child

- But the anti-D antibodies will last in the blood circulatory system of the mother



- The problem arises when the second child is also Rh-positive
- The anti-D antibodies that are present in the mother's blood cross the placenta and destroy the red blood cells of that foetus
- The symptoms of this disease are called erythroblastosis fetalis
- The second foetus dies if the blood is not replaced with Rh-negative blood through blood transfusion
- In a less serious situation, the baby may suffer from anaemia and mental retardation
- However, this problem can now be addressed by treating the affected mother with anti-Rhesus globulins after the first pregnancy to stop the formation of anti-D antibodies



CHAPTER 10.6 – HEALTH ISSUES RELATED TO THE HUMAN CIRCULATORY SYSTEM

The necessity for a healthy circulatory system

- ⊕ Among the practices for maintaining the circulatory system are a balanced intake of food that is low in fat and regular exercise
- ⊕ The practice of not smoking and not drinking alcoholic drinks also ensures a healthy circulatory system

Cardiovascular disease

- ♥ Cardiovascular diseases include diseases related to the heart and the blood circulatory system such as
 - 1 Atherosclerosis
 - 2 Arteriosclerosis
 - 3 Hypertension
 - 4 Stroke
 - 5 Angina
 - 6 Myocardial infarction

ATHEROSCLEROSIS

- Atherosclerosis is the formation and deposition of plaque on the artery walls
- The plaque is formed from cholesterol, lipid, dead muscle tissues and coagulated platelets
- The plaque will clog and narrow the lumen in blood vessels
- Atherosclerosis is the early stage of arteriosclerosis

ARTERIOSCLEROSIS

- Arteriosclerosis occurs when calcium is deposited on the plaque and causes the artery to become hard and lose its elasticity

HYPERTENSION

- ❖ The restricted blood flow can cause hypertension
- ❖ Hypertension causes fine arteries to break and the patient can suffer from stroke if this happens in the brain

STROKE

- Stroke is also caused by blood clots (thrombus) that clog the flow of blood in the brain

ANGINA

- If the lumen of the coronary artery (artery for the heart) is narrowed, the insufficient oxygen supply to the heart muscles can cause angina (severe chest pain)

MYOCARDIAL INFARCTION

- ✓ If the artery is completely clogged, myocardial infarction (heart attack) will occur

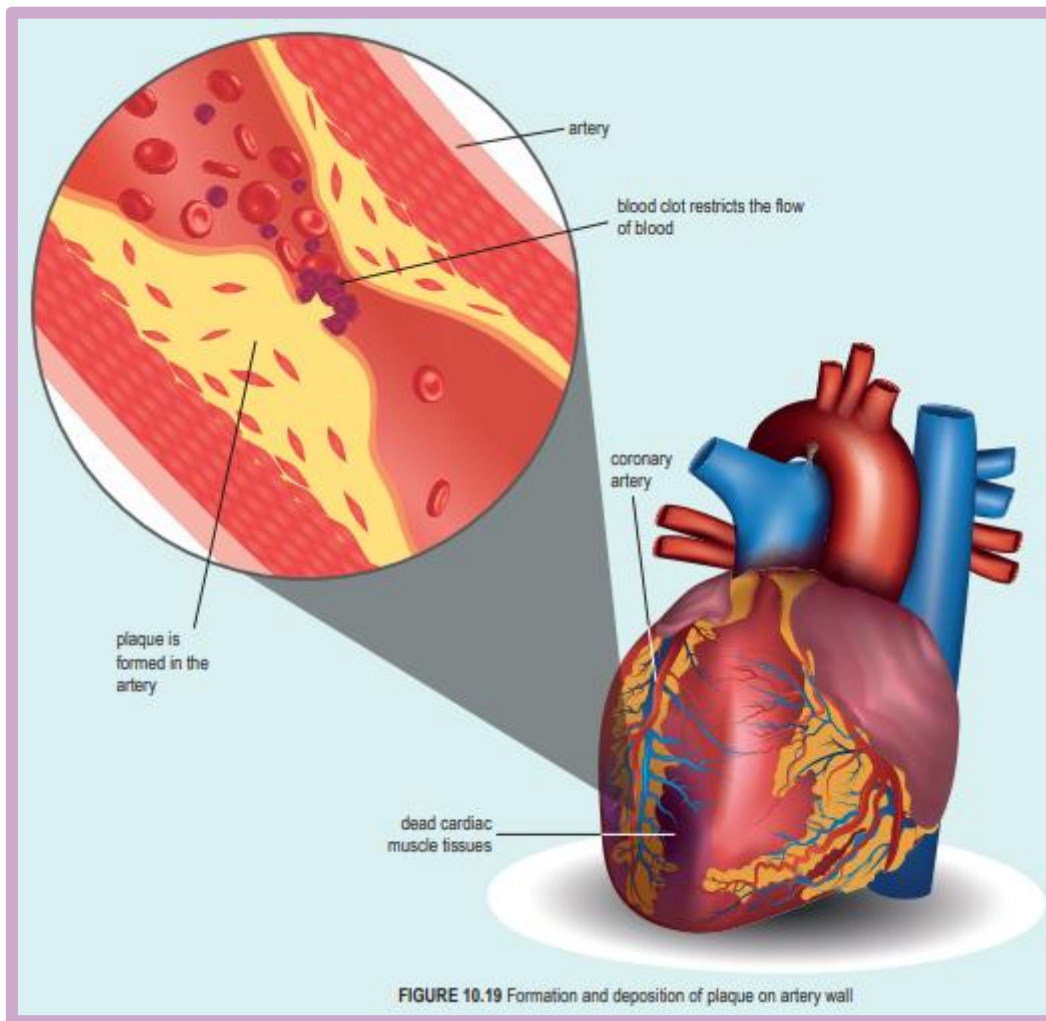


FIGURE 10.19 Formation and deposition of plaque on artery wall

CHAPTER 10.7 – HUMAN LYMPHATIC SYSTEM

The formation of tissue fluid

- ⊞ In addition to the blood circulatory system, there is one more system in the body whose function is closely related to the blood circulatory system
- ⊞ This system is called the lymphatic system

EXCHANGE OF SUBSTANCES BETWEEN BLOOD CAPILLARIES AND BODY CELLS

STEP 1

- ↘ Blood that reaches the arterial end of the blood capillary has a high pressure due to the small diameter of capillaries and the pumping force of the heart

STEP 2

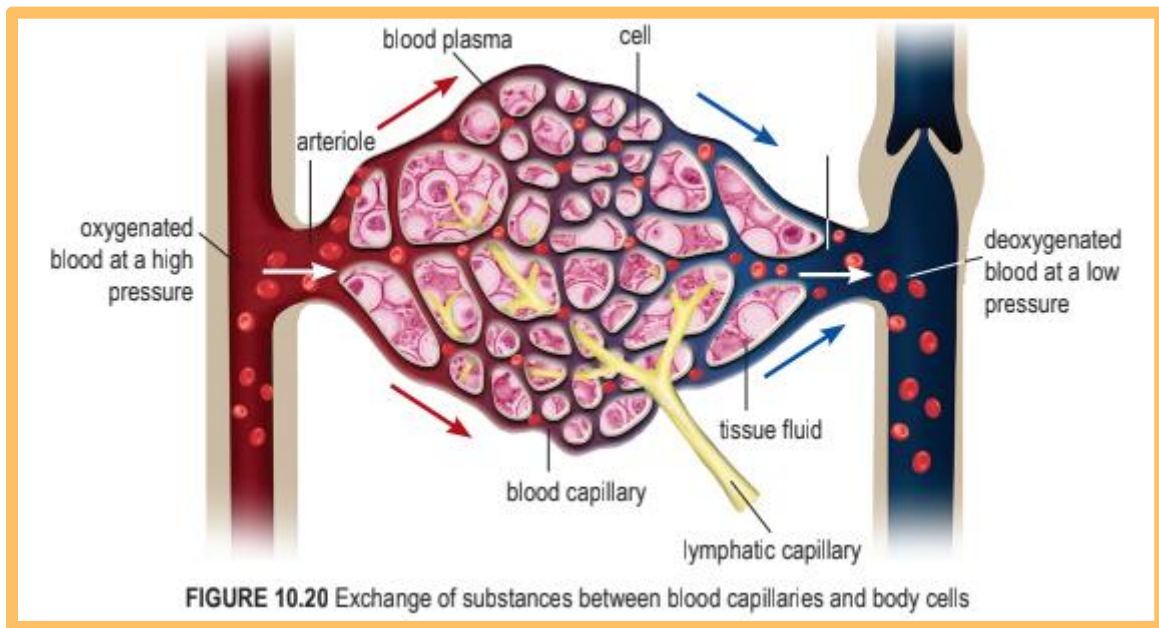
- This pressure allows the blood plasma to diffuse continuously from the blood capillaries to the intercellular space

STEP 3

- » Blood plasma that occupies the intercellular space constantly bathes cells is called tissue fluid
- » The tissue fluid does not contain any erythrocyte, platelet and plasma protein because these are too large to diffuse out of the blood capillaries

STEP 4

- ◇ Tissue fluid allows the exchange of materials in the blood and cells to occur
- ◇ Nutrients and oxygen diffuse from tissue fluid to body cells
- ◇ Simultaneously, excretory products and carbon dioxide diffuse from body cells to blood capillaries through the tissue fluid



Lymph formation and components of the lymphatic system

- ✚ At the **venule end** of the blood capillary, blood plasma is **hypertonic** compared to the tissue fluid surrounding it
- ✚ Blood pressure is also **lower**
- ✚ As a result, the **reabsorption** of water, mineral salts and waste takes place in the venule capillary
- ✚ However, only **85%** of the **fluid** that **leaves** the blood at the **arteriole end** of blood capillary **diffuses back** into the venule end
- ✚ This remainder **forms** about **4 litres** of fluid that is **lost** from capillaries each day
- ✚ The lost fluid is **collected** and **returned** to the blood through the **lymphatic capillary**, which is the **smallest vessel** in the lymphatic system

✚ This **fluid** is known as **lymph** and is **pale yellow** in colour

COMPARISON BETWEEN LYMPH AND TISSUE FLUID

Δ Similarity

SIMILARITY
Both contain plasma without 1) Plasma protein 2) Erythrocytes 3) platelets

Δ Differences

LYMPH	TISSUE FLUID
Higher content of fat and fat-soluble substances	Low content of fat and fat-soluble substances
Higher content of lymphocytes	Low content of lymphocytes

COMPARISON BETWEEN LYMPH AND BLOOD

❖ Similarity

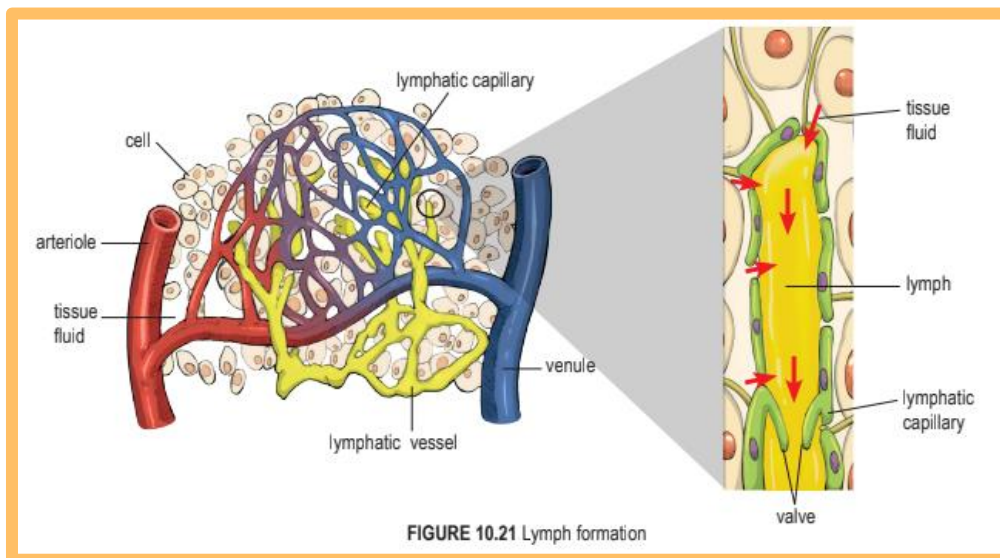
SIMILARITY
Both contain all the contents of plasma such as
a) Nutrients
b) Hormones
c) Enzymes
d) Cellular waste
e) Respiratory gases
f) Leucocytes

❖ Differences

LYMPH	BLOOD
Does not contain plasma protein, erythrocyte and platelet	Contains plasma proteins, erythrocytes and platelets

LYMPH FORMATION

- ⊕ The lymphatic capillary wall consists of one layer of cells only
- ⊕ The lymphatic capillary differs from blood capillary because one of its ends is blocked or closed while the other end is connected to the lymphatic vessel
- ⊕ Lymphatic capillaries found in intercellular spaces merge to form a larger lymphatic vessel
- ⊕ Along the lymphatic vessel, there are lymph nodes at a certain distance



LYMPHATIC SYSTEM

→ The lymphatic system consists of organs such as

- a. Lymph nodes
- b. Spleen
- c. Thymus gland
- d. Bone marrow
- e. Tonsils

f. Appendix

- The lymphatic system does not have its own pump to circulate the lymph along the lymphatic vessel
- The flow of lymph is aided by
 - i. heartbeat pulse
 - ii. concentration of skeletal muscles

- iii. peristalsis in the digestive tract
 - iv. changes in pressure during inhalation and exhalation of breath
- In the lymphatic vessel, **one-way valves ensure** the lymph **flows continuously** to the heart
- These valves also **prevent** the lymph from **flowing back**

□ All lymphatic vessels will eventually **join with one of the two main lymphatic vessels** which are the

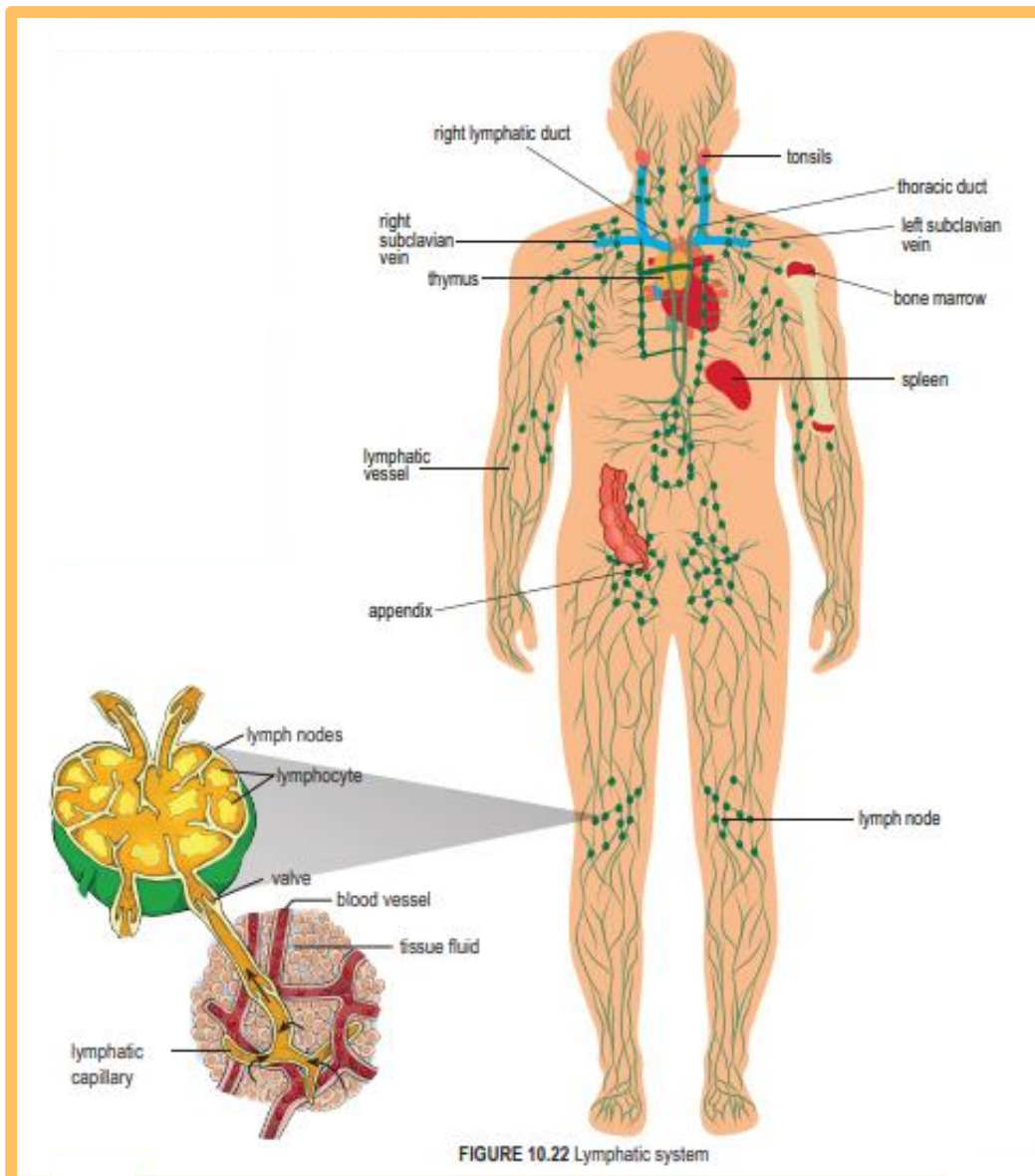
1. Thoracic Duct

The thoracic duct **receives lymph** from the **left side of the head, neck and chest**, and **all the body parts below the ribs**

2. Right Lymphatic Duct

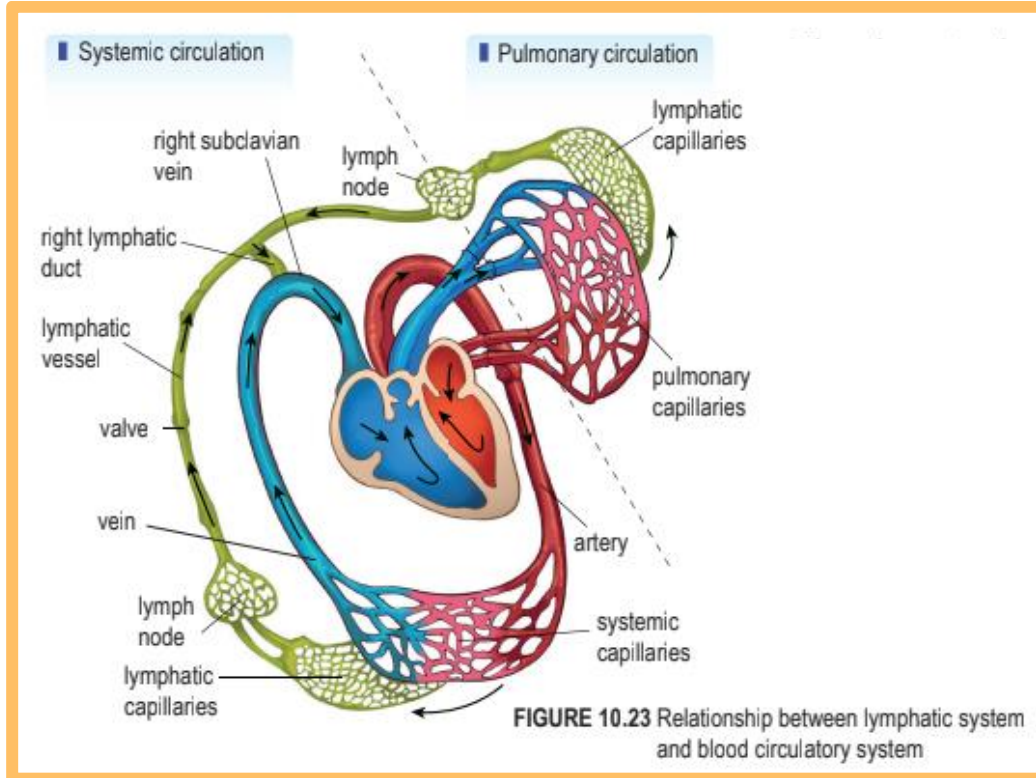
The right lymphatic duct **receives lymph** from the **right hand, chest and right side of the head and neck**

RELATIONSHIP BETWEEN THE BLOOD CIRCULATORY SYSTEM AND THE LYMPHATIC SYSTEM



- ❑ The thoracic duct will deliver its content into the left subclavian vein while the right lymphatic duct will transport lymph into the right subclavian vein

- ❑ So, the lymph collected from the whole body will flow back into the blood circulatory system



The necessity of the lymphatic system

COMPLEMENTS THE BLOOD CIRCULATORY SYSTEM

- ⊕ The lymphatic system returns the excess tissue fluid in the intercellular space into the blood flow
- ⊕ The composition, pressure and volume of blood are maintained at a normal range

BODY DEFENCE

- ♥ Lymph nodes produce and store lymphocytes that are involved in the production of antibodies

TRANSPORTATION OF FAT-SOLUBLE SUBSTANCES

- ⊞ Fats and fat-soluble substances diffuse into the lacteal in the villus of the small intestine
- ⊞ Lacteals are lymphatic capillaries
- ⊞ Lipid droplets are transported to the thoracic duct and blood circulatory system through the left subclavian vein

CHAPTER 10.8 – HEALTH ISSUES RELATED TO THE HUMAN LYMPHATIC SYSTEM

Oedema

- Tissue fluid that is not returned to the blood circulatory system will **accumulate** in the intercellular space
- This will result in the **swelling** of the body tissues
- This condition is known as **oedema**
- Oedema may be caused by a number of factors



Causes of oedema

PREGNANCY

- ✓ The body will **produce more** body fluid to **fulfil** the **needs** of a **growing foetus**

PROLONGED BEDRIDDEN PATIENTS

- Paralysed or stroke patients with **limited mobility** can **suffer** from **oedema** in the **legs**

DEFICIENCY IN PLASMA PROTEIN

- **Deficiency of albumin** in the blood

PARASITIC INFECTION

- ⊕ The **parasite worm *Brugia* sp.** infects the **lymphatic vessel** and **prevents** the **flow** of lymphatic fluid
- ⊕ The **infected part** (e.g., leg will swell)
- ⊕ The patient **contracts lymphatic filariasis**
- ⊕ This worm is **transmitted** through **mosquito bites**

