CIRCULATORY SYSTEM

OPEN CIRCULATORY SYSTEM

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, substance exchange between haemolymph and body cells occurs through diffusion.
- When the heart relaxes, haemolymph flows back into the heart through tiny openings called **ostium**.

Circulatory System of Fish

- The heart of the fish has two chambers, that is, an atrium (plural: atria) and 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.**

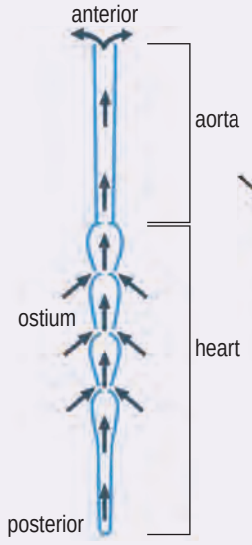


FIGURE 10.3 Dorsal view of insect heart

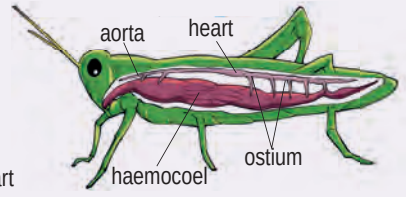
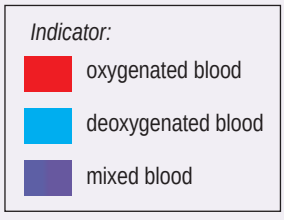


FIGURE 10.4 The open circulatory system in insects



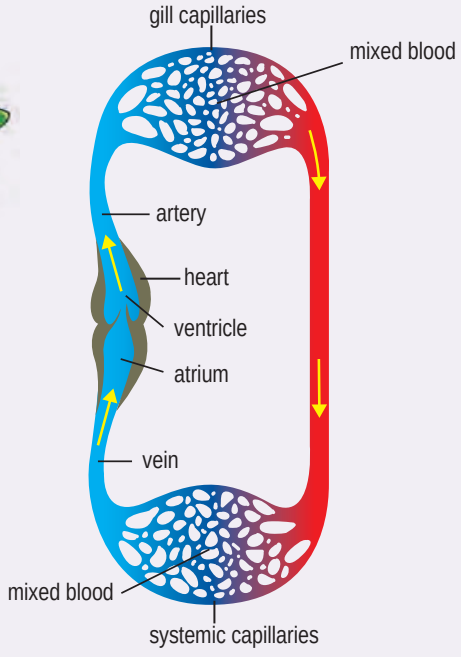


FIGURE 10.5 The blood circulatory system of fish

CLOSED CIRCULATORY SYSTEM

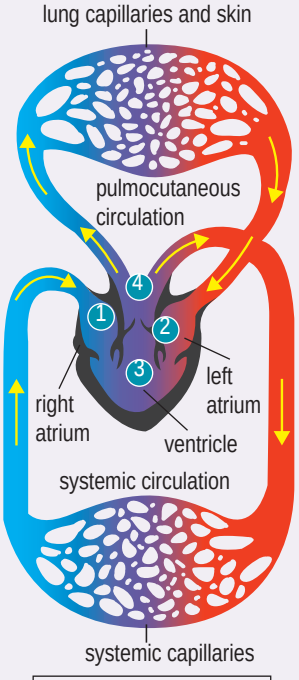
Circulatory System of Amphibians

- The heart of an amphibian has three chambers, that is, two atria and a ventricle. Unlike the single circulatory system of fish, blood flows in two directions: **pulmocutaneous circulation** and **systemic circulation**. Therefore, 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 of 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.

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.

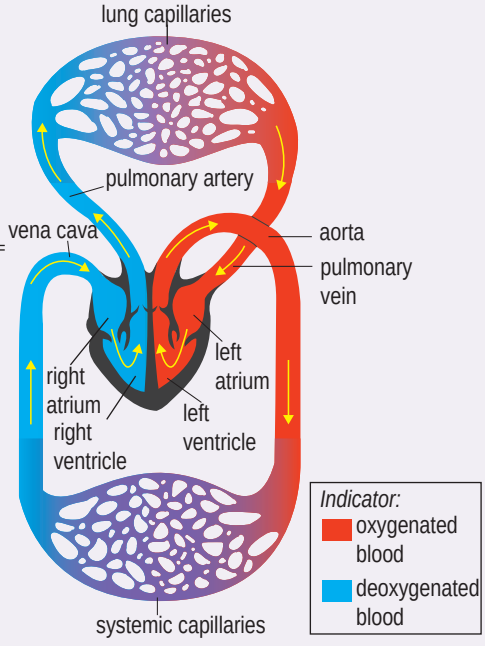
FIGURE 10.6 The blood circulatory system of amphibians

Circulatory System of Humans

- The human heart consists of four chambers: two atria and two ventricles that are separated completely.
- Humans have a double circulatory system. This means that in one complete circulatory cycle, blood flows in the blood vessels through the heart twice. 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.

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.

FIGURE 10.7 The blood circulatory system of humans

CHAPTER 10

TABLE 10.1 Similarities and differences between circulatory systems in complex multicellular organisms

Similarities				
The circulatory system is found in all multicellular organisms.				
The circulatory system consists of a heart to pump blood or haemolymph (in insects).				
The circulatory system functions to transport nutrients and wastes.				
The heart has valves that ensure blood flows in one direction.				
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 and one ventricle)	Three (two atria and one ventricle)	Four (two atria and 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 deoxygenated blood in the ventricle)

Formative Practice 10.1

1 State two differences between the circulatory systems of fish and humans.

2 Explain why the blood circulatory system of amphibians is considered as a closed and incomplete blood circulatory system.

3 The flatworm is a multicellular organism. However, the flatworm does not require a specialised transportation system to move substances in and out of the cell. Explain why.

4 Explain why insects need one separate system (the tracheal system) to transport oxygen.

10.2 Circulatory System of Humans

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

- **Blood**: A type of connective tissue that is made up of blood plasma, blood cells and platelets. Blood acts as a medium of transportation.
- **Heart**: Functions as a muscular pump that circulates blood to the whole body.
- **Blood vessels**: Consist of arteries, capillaries and veins that are connected to the heart, and transport blood to all the body tissues.

Malaysian Innovation

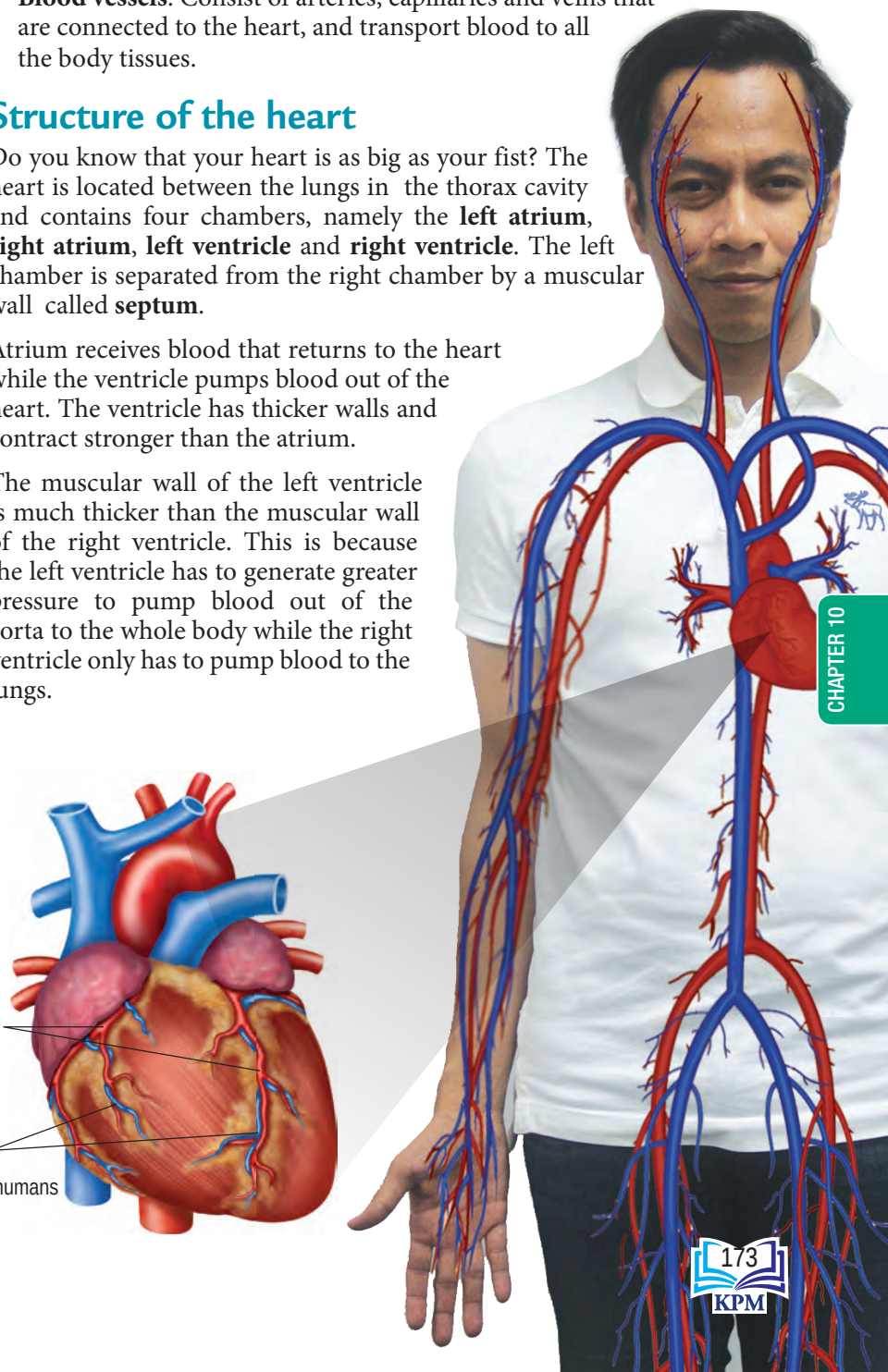
A group of researchers in Malaysia have produced a device called MyThrob that can be used as a smart examination and monitoring tool for heart diseases. The device studies the original algorithm that can detect abnormal heartbeat and is suitable to be used for monitoring at home.

Structure of the heart

Do you know that your heart is as big as your fist? The heart is located between the lungs in the thorax cavity and contains four chambers, namely the **left atrium**, **right atrium**, **left ventricle** and **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 while the 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 while **coronary veins** transport deoxygenated blood.

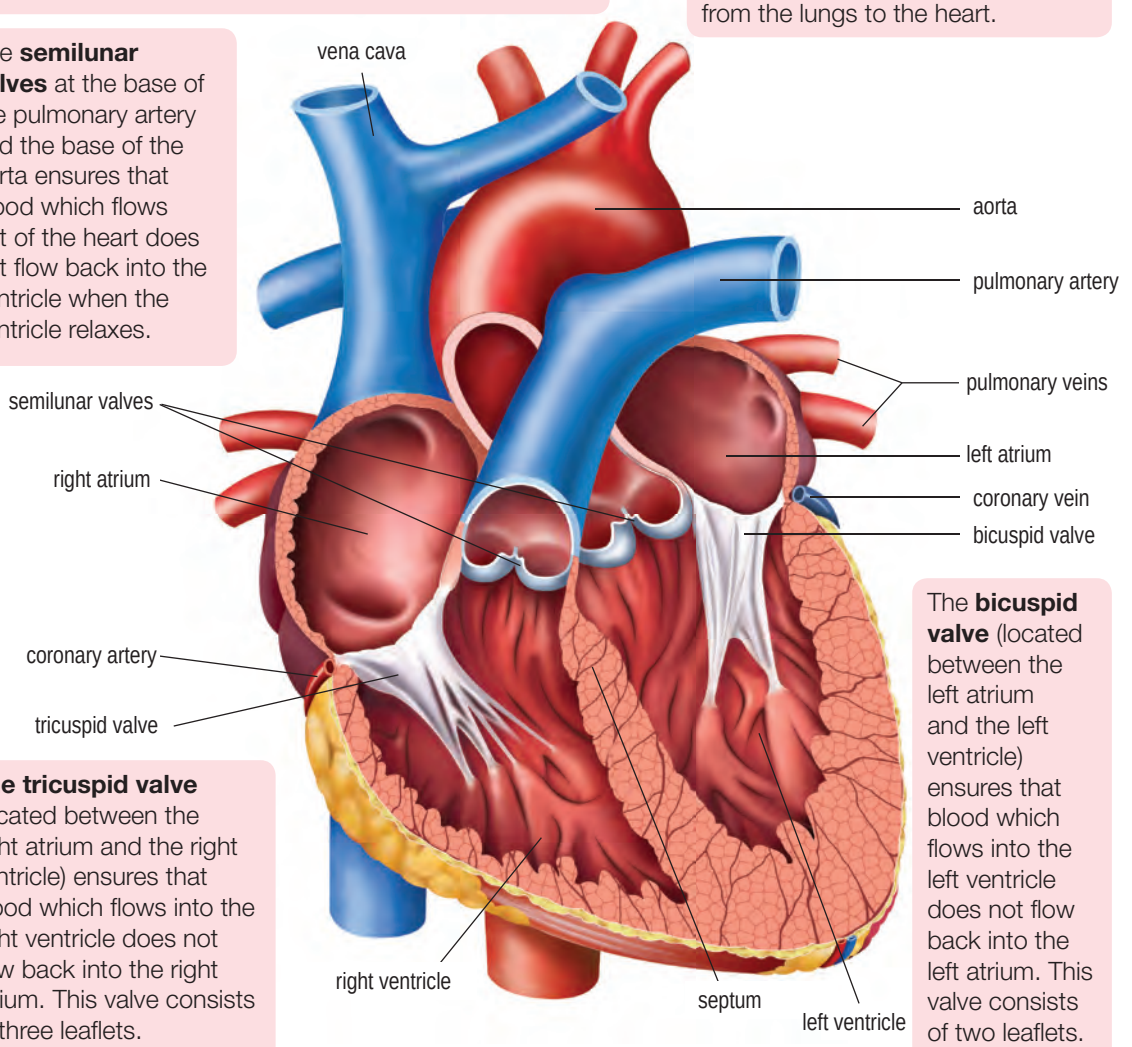
TABLE 10.8 The circulatory system of humans

10.2.1 10.2.4 10.2.5

Aorta is the main blood artery that transports oxygenated blood to the whole body while the **vena cava** is the main vein that transports deoxygenated blood back to the heart.

The **pulmonary artery** transports deoxygenated blood from the heart to the lungs while the **pulmonary veins** transports oxygenated blood from the lungs to the heart.

The **semilunar valves** at the base of the pulmonary artery and the base of the aorta ensures that blood which flows out of the heart does not flow back into the ventricle when the ventricle relaxes.



The **bicuspid valve** (located between the left atrium and the left ventricle) ensures that blood which flows into the left ventricle does not flow back into the left atrium. This valve consists of two leaflets.

The tricuspid valve (located between the right atrium and the right ventricle) ensures that blood which flows into the right ventricle does not flow back into the right atrium. This valve consists of three leaflets.

The **septum** separates the left part of the heart from the right part of the heart and ensures that the oxygenated blood does not mix with the deoxygenated blood.

FIGURE 10.9 Longitudinal section of a human heart

Brainstorm!

What would happen to an individual if the bicuspid valve does not close completely when the ventricle relaxes?

ICT 10.2

Video: Animation of the heart valves (Accessed on 21 August 2019)

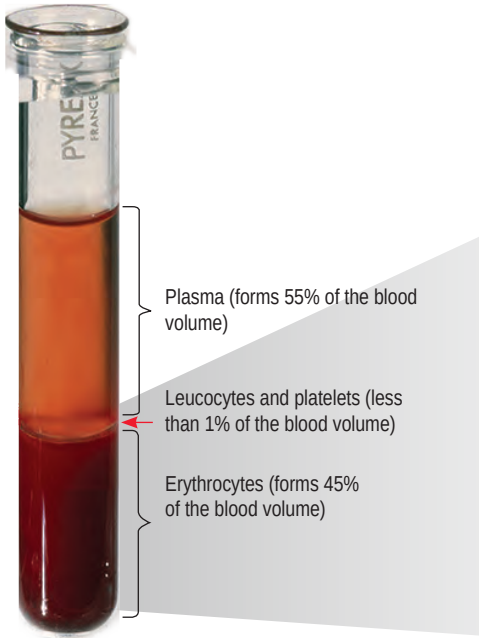
10.2.4 10.2.5

Composition of human blood

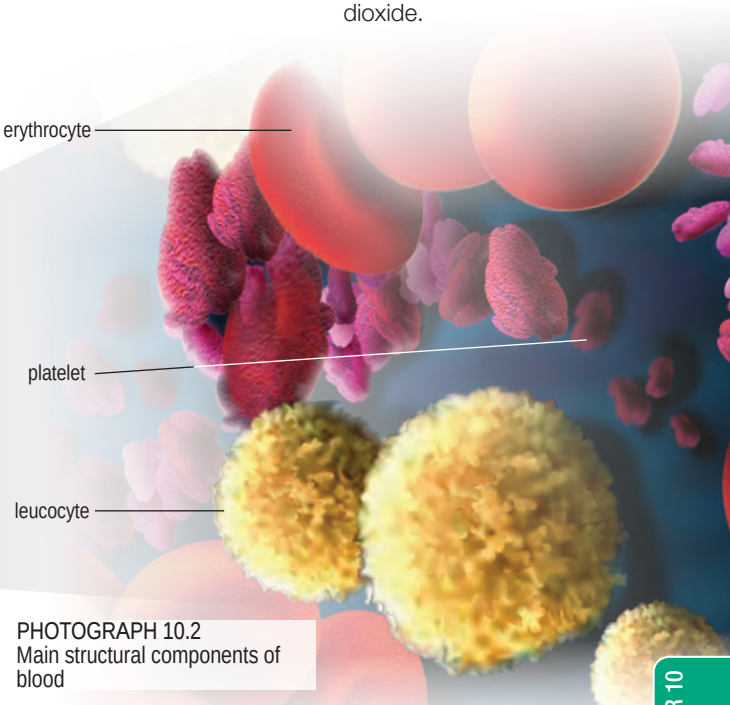
The human blood consists of 55% plasma and 45% cell components. **Plasma** is the medium of transportation in the body. The components of blood cells consist of **red blood cells** or **erythrocytes**, **platelets** and **white blood cells** or **leucocytes** (Photographs 10.1 and 10.2).

Biological Lens

Perfluorocarbon (PFC) emulsions can be potentially used as artificial blood. Studies have shown that PFC has the capacity like blood to transport oxygen and carbon dioxide.



PHOTOGRAPH 10.1 Main components of blood



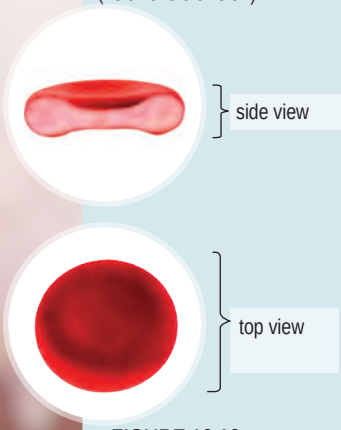
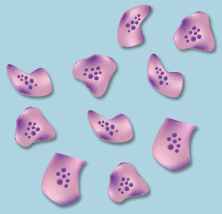
PHOTOGRAPH 10.2
Main structural components of blood

TABLE 10.2 Blood plasma components and the main function of each component

Component	Main function
Water	Blood plasma consists of 90% water. Water is a medium of transportation and a solvent for respiratory gas, ions, digestive products and excretory substances.
Plasma proteins	• Fibrinogen plays a role in blood clotting. • Albumin controls blood osmotic pressure. • Globulin is a type of antibody that is involved in the body's defence.
Solutes – nutrients such as glucose, excretory substances such as urea and respiratory gas	• Nutrients are important for energy, growth and maintenance of health. • Excretory substances are toxic substances that need to be disposed off 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.

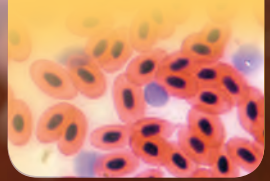
Table 10.3 shows the characteristics and functions of each blood cell type.

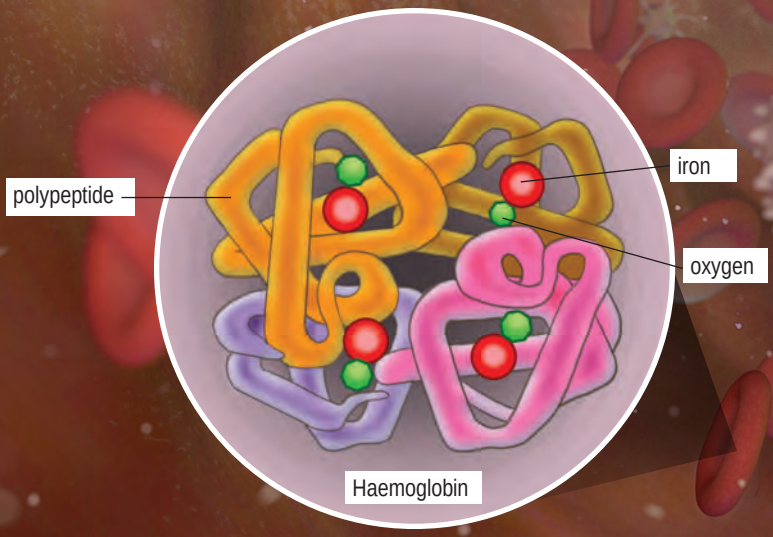
TABLE 10.3 Characteristics and functions of blood cell types

Blood cell type	Characteristics	Functions
Erythrocyte (red blood cell)  FIGURE 10.10 Erythrocyte structure	• Has an elastic plasma membrane • The **biconcave disc** shape enables a large TSA/V for efficient gaseous exchange • It does not have a nucleus at the mature stage so that more **haemoglobin** can be loaded into it • It is produced in the **bone marrow** of bones such as the sternum and ribs • Can live up to 120 days and is destroyed in the **liver** or **lymph** through the phagocytosis process.	• Each erythrocyte has a **haemoglobin** which is the red pigment that gives blood its red colour. • Haemoglobin contains a heme group. The heme group consists of an iron atom which is the binding site for oxygen. • Haemoglobin combines with oxygen to form **oxyhaemoglobin** in high oxygen partial pressure conditions. • Oxyhaemoglobin releases oxygen in tissues or cells when the partial pressure of oxygen is low.
Platelet  FIGURE 10.11 Platelet	• Platelets are produced from fragments or scraps of cell cytoplasm that originate from the bone marrows. • The life span is less than one week.	• Involved in the blood clotting process

Brainstorm!

The red blood cell of frogs has a nucleus and is larger than the red blood cell of humans. What are the advantages and disadvantages of nucleated red blood cells?





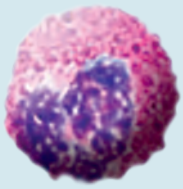
Blood cell type	Characteristics and functions
Leucocyte (white blood cell)	• The shape is irregular and is not fixed • Contains nucleus • Does not contain haemoglobin • Produced in the bone marrow • Life span is less than five days • Leucocyte can diffuse out of the capillary pore and fight pathogens in tissue fluids. It is divided into two types: granulocytes (contain granules) and agranulocytes (no granules). • Granulocytes include neutrophils, eosinophils and basophils. Agranulocytes include lymphocytes and monocytes.

LEUCOCYTES

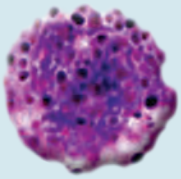
Granulocytes

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

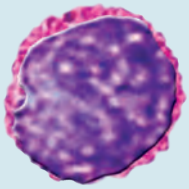


Basophil
- The number of basophils is lowest in the blood
- It contains heparin that prevents blood clotting



Agranulocyte

Lymphocyte
- 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
- The biggest leucocyte
- Spherical-shaped nucleus
- Ingests bacteria and dead cells or tissues by phagocytosis

PHOTOGRAPH 10.3 Photomicrograph of leucocytes

Human blood vessels

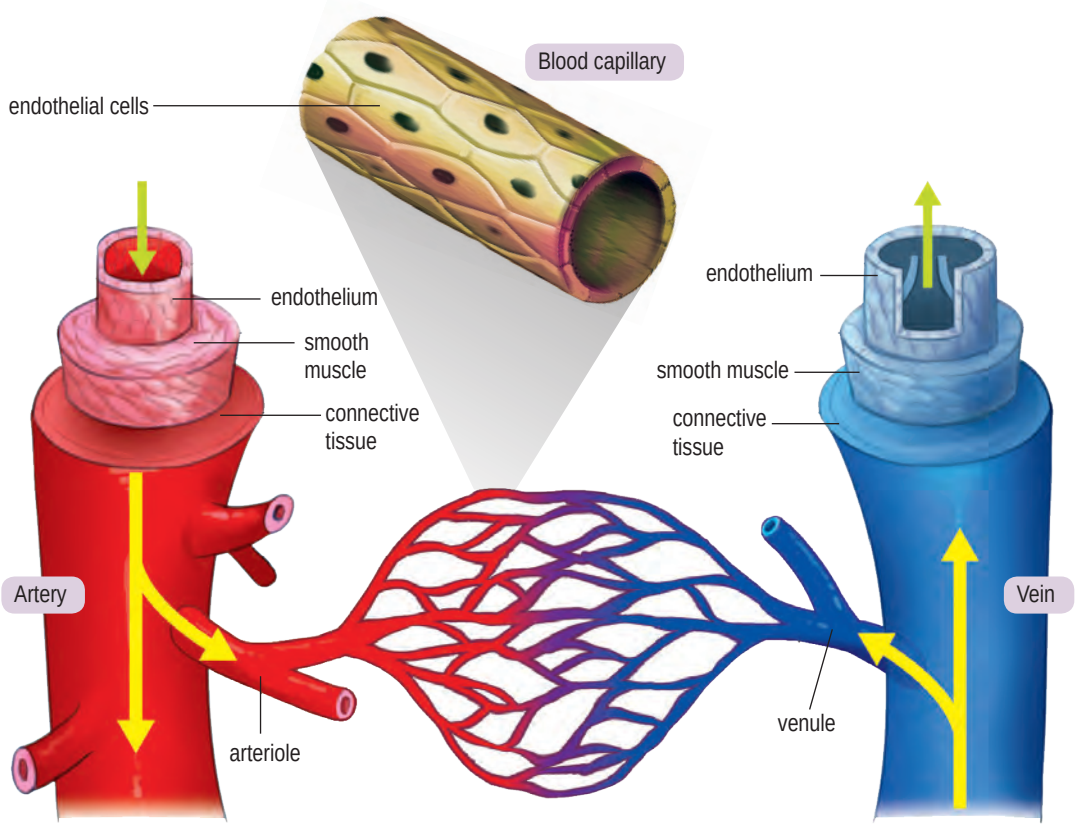


FIGURE 10.12 Relationship between artery, blood capillaries and vein

ARTERY

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.

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.

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. The group of capillaries is called **capillary network**.

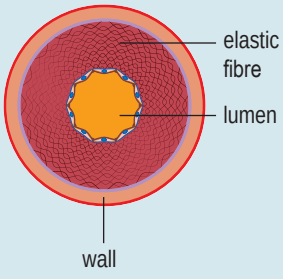
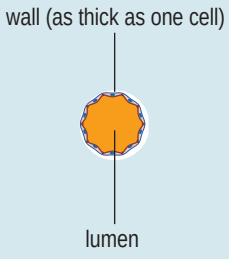
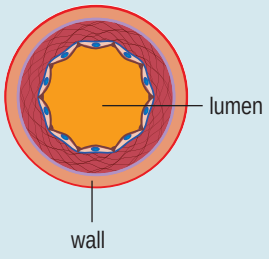
BLOOD CAPILLARIES

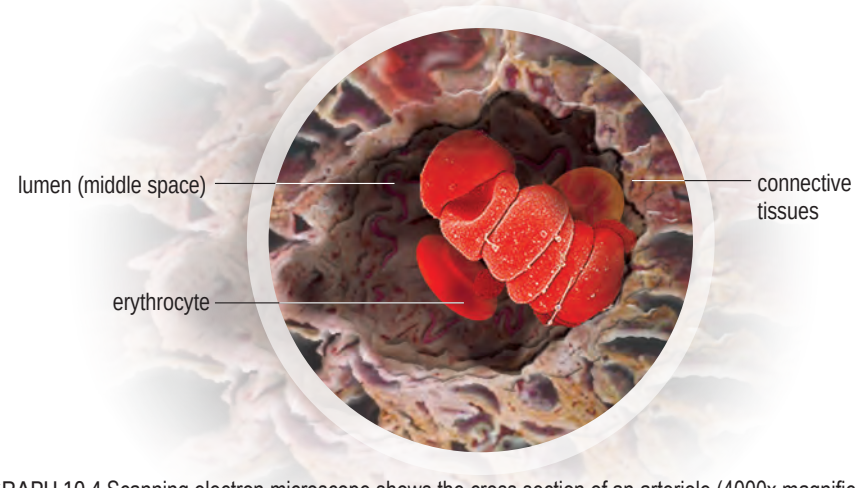
Capillaries are blood vessels with thin walls, as thick as one cell. Blood capillaries allow the exchange of gases to occur between blood and cells through diffusion. Nutrients, excretory substances and hormones diffuse through blood capillaries.

VEIN

Capillaries rejoin to form larger blood vessels called **venules**. The venules combine to form **veins** that transport blood back to the heart. **Vena cava** is the main vein that carries deoxygenated blood back to the heart. The differences between arteries, capillaries and veins are given in Table 10.4.

TABLE 10.4 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 for semilunar valve at the base of the aorta and at the base of the pulmonary artery	No	Contain valves 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



PHOTOGRAPH 10.4 Scanning electron microscope shows the cross section of an arteriole (4000x magnification)

CHAPTER 10

Formative Practice 10.2

1 What is the function of the bicuspid valve?

2 Explain why some individuals feel nauseous and faint immediately after donating blood? Why do some blood donors need to take iron pills?

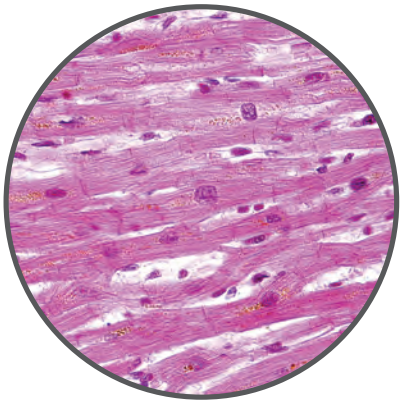
3 State two differences between the structures of erythrocyte and leucocyte.

4 Explain why the left ventricle has a thicker muscular wall than the right ventricle.

10.2.3

10.3 Mechanism of Heartbeat

How is blood circulated to the whole body? In every contraction, the heart acts as a pump that pumps blood to the whole body. How is every heartbeat triggered and sustained?



PHOTOGRAPH 10.5
Cardiac muscle tissue

The heart is made up of cardiac muscles (Photograph 10.5) that intersect and are connected with one another. This arrangement allows electric impulses to spread rapidly through the heart and at the same time, 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.

Our World of Biology

The "*Medtronic Micra*" pacemaker is the smallest artificial pacemaker in the world. The size is about the size of a vitamin pill and is placed in the heart without surgery. The artificial pacemaker sends small electrical charges to stimulate heartbeat.

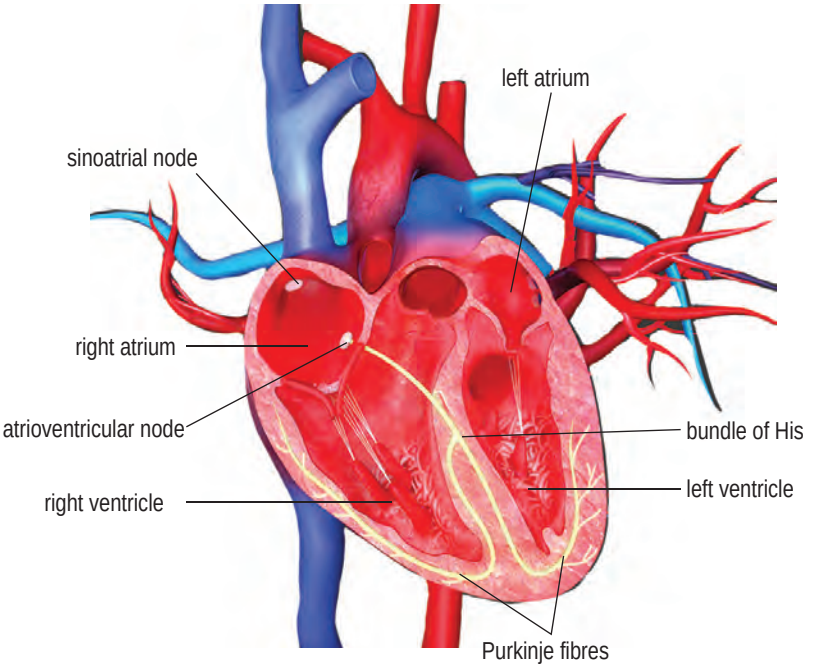


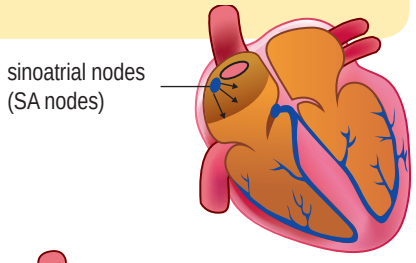
FIGURE 10.13 The location of sinoatrial node, atrioventricular node, bundle of His and Purkinje fibres

Pumping of the heart

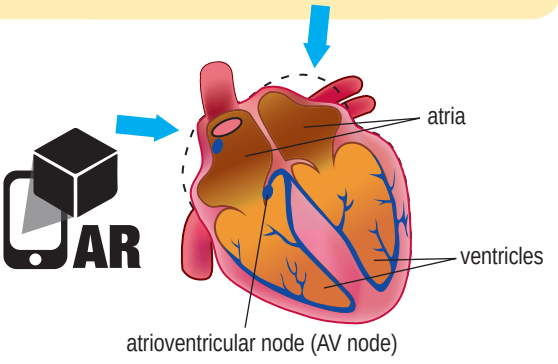
The contraction of the heart is initiated and coordinated by the **pacemaker**. The pacemaker is a group of specific heart muscle cells that initiates the rate of heart contraction and is located at the right atrium wall (Figure 10.14).

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 muscle contraction that causes the pumping is shown in Figure 10.14.

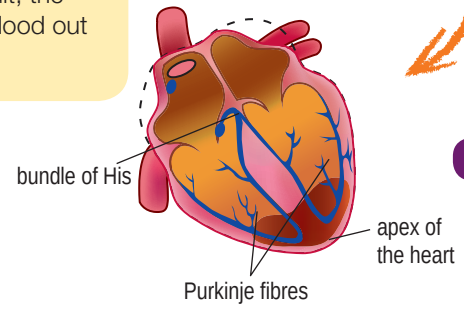
1 The sinoatrial node (SA) generates electrical impulses.



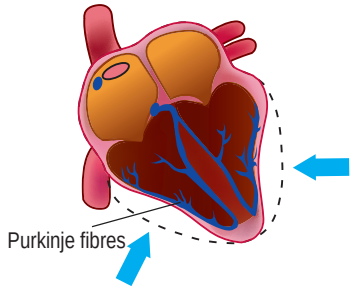
2 Electrical impulses spread rapidly in both the atria, causing the atria to contract simultaneously. The contraction of the atria helps to pump blood into the ventricles.



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.



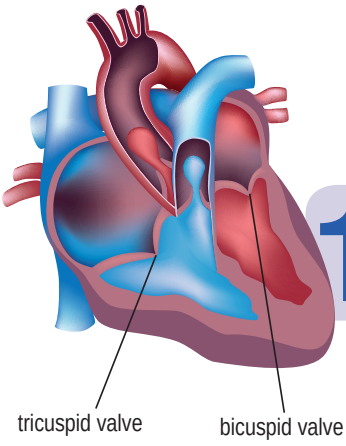
Across the fields

Electrical impulses in the heart can be detected by putting electrodes on the skin. The electrocardiogram is a record of the electrical activity that triggers every heartbeat.

FIGURE 10.14 The sequence of heart contraction that causes the pumping of the heart

CHAPTER 10

During heart pumping, the **lub-dub sound** can be heard. Do you know what causes this lub-dub sound?
The lub-dub sound is the closing sound of the heart valves.



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.

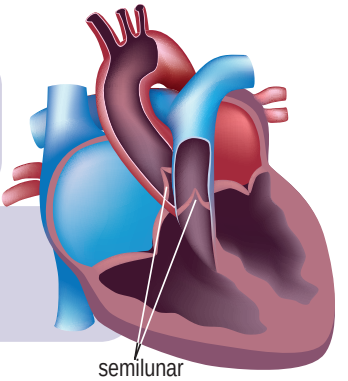


FIGURE 10.15 The lub-dub sound of the heart

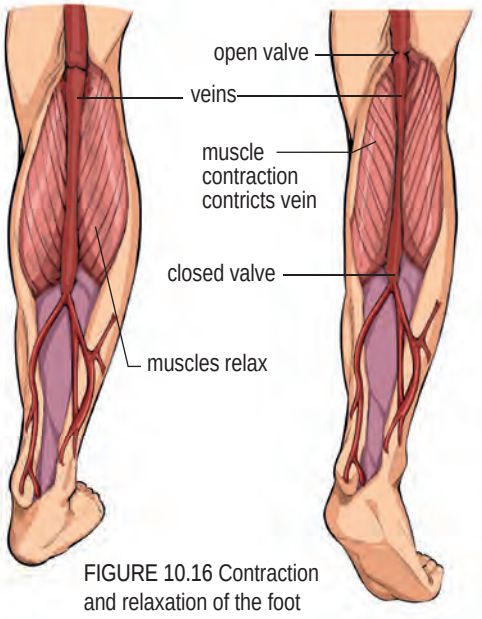


FIGURE 10.16 Contraction and relaxation of the foot skeletal muscles

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 valve 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 (Figure 10.16).

Brainstorm!

What would happen to the valve in the blood vessels of our legs if we stand or sit for too long?

Formative Practice 10.3

1 Name the main heart pacemaker.

2 What does the term myogenic mean?

3 Explain why a person who stands too long may faint.

4 In what circumstances would fingers turn pale?

10.4 Mechanism of Blood Clotting

The necessity for blood clotting mechanism

STEM Bulletin

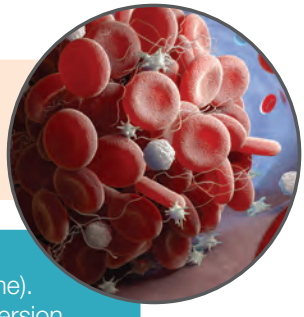
Scientists have developed a nanomagnetic particle that contains thrombin. This nanoparticle is injected into the injured part to trigger blood clotting and to stop bleeding.

What happens when your 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.

Why must the blood clot on the wound? Blood clotting will stop or minimise the loss of blood on the injured blood vessel. Blood clotting also prevents microorganisms such as 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. How does blood clotting occur?

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.



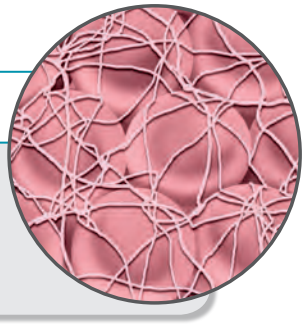
The coagulated platelets, damaged cells and clotting factors in the blood plasma will form an activator (**thrombokinase**). Thrombokinase, with the aid of calcium ions and vitamin K, converts prothrombin to thrombin.

Prothrombin (inactive plasma protein)

Thrombin (active plasma protein that acts as an enzyme). Thrombin catalyses the conversion of fibrinogen to fibrin.

Fibrinogen (soluble)

Fibrin (insoluble)



Fibrin is a threadlike protein fibre that forms a network on the wound surface to trap erythrocytes and to close the wound to prevent blood loss.

TABLE 10.17
Mechanism of blood clotting

Health issues related to blood clotting

Under normal conditions, blood does not clot in blood vessels that are not damaged because of some anticoagulants such as heparin. What happens when the blood clotting mechanism of an individual does not function?

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.

Our World of Biology

When you sit for too long, the risk of thrombosis in legs will increase. Make sure that you move your legs once in a while.

THROMBOSIS

- Formation of a blood clot (**thrombus**).
- Thrombosis happens as a result of:
  - damage in blood vessels, or
  - sluggish blood flow that causes clotting factors to accumulate

Activity Zone

Work in groups to collect and interpret information about thrombosis, embolism and haemophilia. Present your findings to the class.

EMBOLISM

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

Formative Practice 10.4

1 At the end of the blood clotting mechanism, fibrin will be formed to trap erythrocytes. Explain the meaning of fibrin and its function.

2 Describe two health issues related to blood clotting.

3 Explain the mechanism of blood clotting.

4 Explain why the formation of blood clots in the blood vessel can cause a heart attack.

10.5 Blood Groups of Humans

ABO blood group

Do you know your blood group? Human blood is 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 (Table 10.6). If the blood group of both the donor and receiver is not compatible, the red blood cells of the recipient will experience **agglutination** (coagulation).

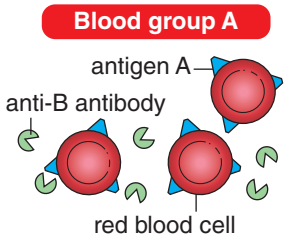


FIGURE 10.18 Antigens and antibodies in different blood groups

TABLE 10.5 Antigen and antibody in blood groups

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 and Antigen B	No
O	No	Anti-A and Anti-B

TABLE 10.6 Compatibility of blood donor group with the recipient

Blood group	Can donate blood to blood groups	Can receive blood from blood groups
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

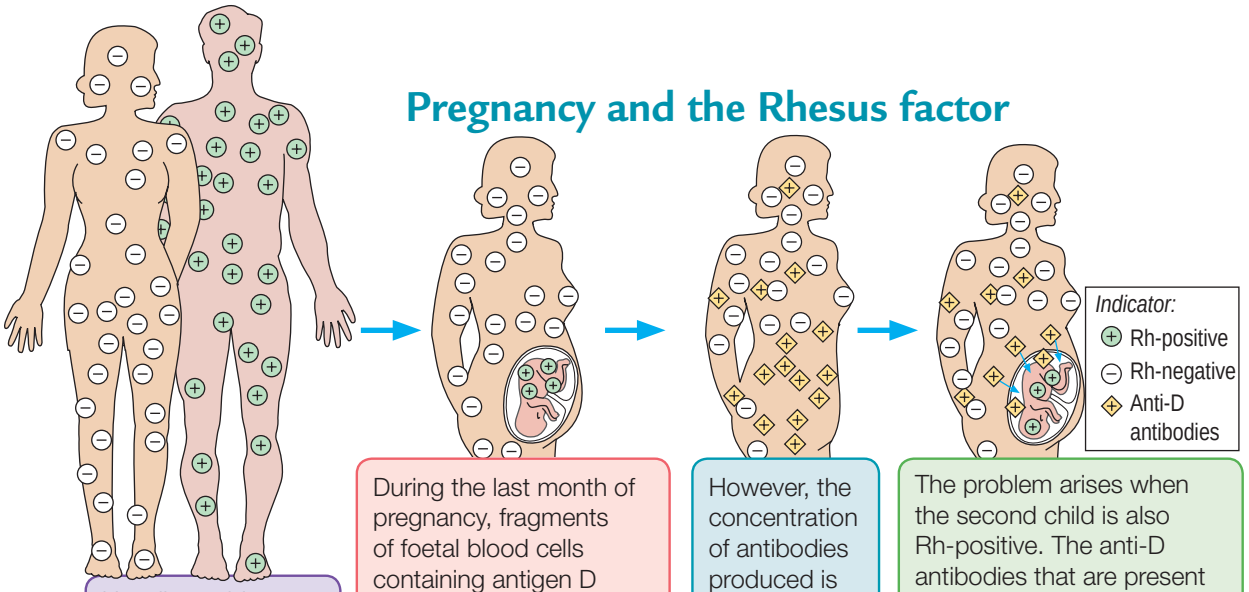
Rhesus Factor

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.

10.5.1 10.5.2 10.5.3

Pregnancy and the Rhesus factor



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

Formative Practice 10.5

1 State the blood group which is the universal donor.

2 Predict what will happen if the blood group of both recipient and donor is not compatible.

3 Three babies P, Q and R have blood groups B, O and AB respectively. Three pairs of parents have the following blood groups:

The first pair of parents: B and O
The second pair of parents: A and B
The third pair of parents: AB and O

Match the babies with their correct parents.

4 An Rh-positive male marries an Rh-negative female. The first Rh-positive child is alive but the second child who is also Rh-positive did not survive. Explain why.

10.6 Health Issues Related to the Human Circulatory System

The necessity for a healthy circulatory system

Activity Zone

Work in groups and conduct a case study on the practices of maintaining a healthy human circulatory system.

A healthy circulatory system is important to ensure optimum health. How do we ensure that our circulatory system is healthy? 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 diseases

Do you know that cardiovascular diseases are the leading cause of death in our country? **Cardiovascular diseases** include diseases related to the heart and the blood circulatory system such as atherosclerosis, arteriosclerosis, angina, hypertension, myocardial infarction (heart attack) and stroke.

Activity Zone

Discuss a suitable treatment for heart failure.

CARDIOVASCULAR DISEASES
• **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.
• 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** is also caused by blood clots (thrombus) that clog the flow of blood in the brain.
• Atherosclerosis is the early stage of **arteriosclerosis**. • Arteriosclerosis occurs when calcium is deposited on the plaque and causes the artery to become hard and lose its elasticity.
• 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). • If the artery is completely clogged, **myocardial infarction** (heart attack) will occur.

10.6.1 10.6.2

PHOTOGRAPH 10.6 Myocardial infarction (heart attack)

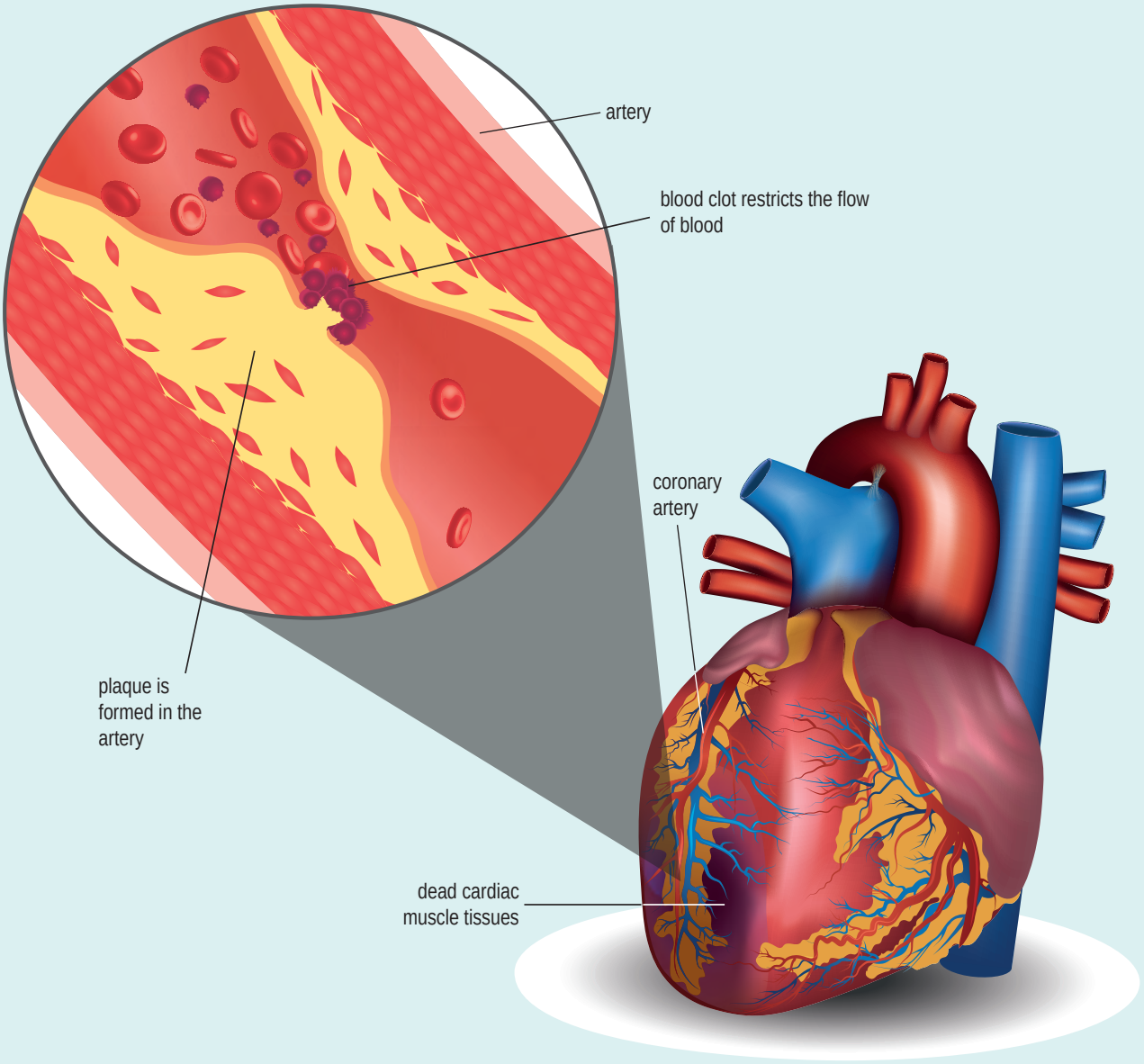


FIGURE 10.19 Formation and deposition of plaque on artery wall

STEM Bulletin

Nanotechnology is used in the diagnosis and treatment of atherosclerosis and plaque formation in arteries. In this technique, nanoparticles are designed to resemble high-density lipoprotein cholesterol (HDL) ("good" cholesterol) to help reduce plaque.

What is the treatment for a patient who suffers from heart failure? What are the risk factors that contribute to cardiovascular diseases and what can we do to ensure that the cardiovascular system is healthy?

Formative Practice 10.6

1 What is the meaning of myocardial infarction?

2 Explain how stroke happens.

3 In your opinion, what are the factors that contribute to an individual's risk of getting cardiovascular disease?

4 Explain how atherosclerosis happens.

10.6.1 10.6.2

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**. The formation of tissue fluid is illustrated in Figure 10.20.

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.

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

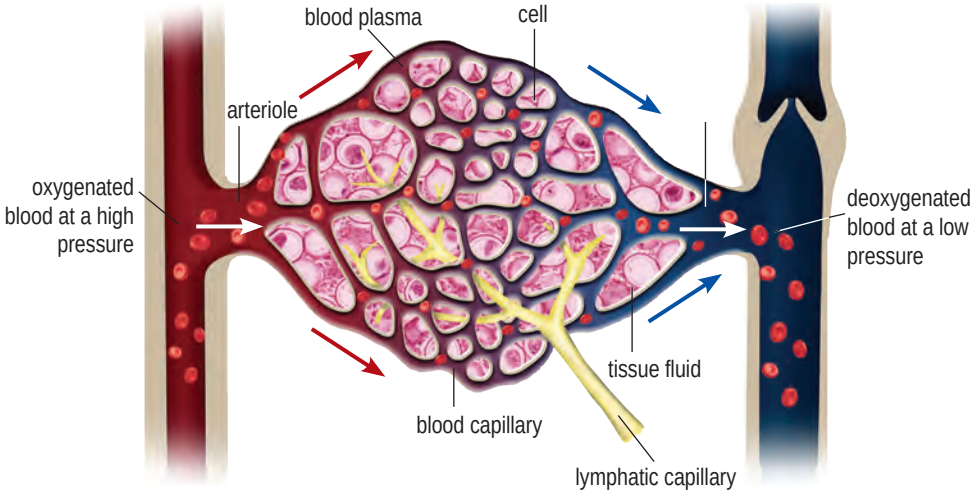


FIGURE 10.20 Exchange of substances between blood capillaries and body cells

3

- Blood plasma that occupies the intercellular space and 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.

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. What happens to the remaining 15% that is left in the intercellular space? This remainder forms about 4 litres of fluid that is lost from capillaries each day. How does the blood circulatory system regain this fluid?

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. Table 10.7 and Table 10.8 show the similarities and differences between lymph with tissue fluid and blood.

TABLE 10.7 Comparison between lymph and tissue fluid

Similarity	
Both contain plasma without the plasma proteins, erythrocytes and platelets.	
Differences	
Lymph	**Tissue fluid**
Higher content of fat and fat-soluble substances	Low content of fat and fat-soluble substances
High content of lymphocytes	Low content of lymphocytes

TABLE 10.8 Comparison between lymph and blood

Similarity	
Both contain all the contents of plasma such as nutrients, hormones, enzymes, cellular wastes, respiratory gases and leucocytes.	
Differences	
Lymph	**Blood**
Does not contain plasma protein, erythrocyte and platelet	Contains plasma proteins, erythrocytes and platelets

The lymphatic capillary wall consists of **one layer of cells** only. The lymphatic capillary differs from blood capillary because one of its end is **blocked** or closed while the other end is connected to the **lymphatic vessel** (Figure10.21). **Lymphatic capillaries** found in intercellular spaces merge to form a larger lymphatic vessel. Along the lymphatic vessel, there are lymph nodes at certain distances.

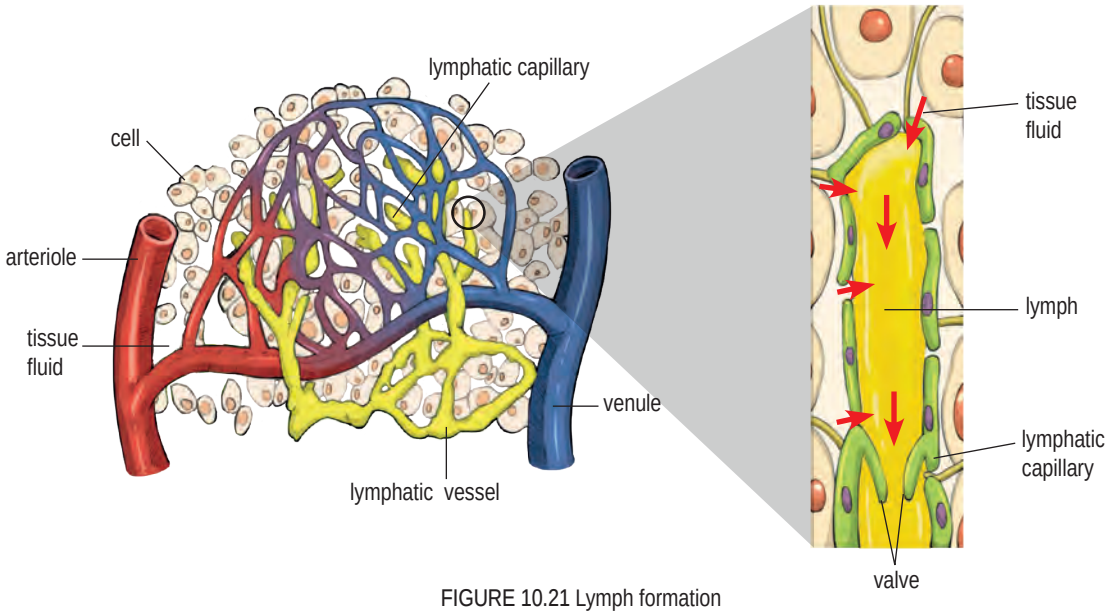


FIGURE 10.21 Lymph formation

The lymphatic system consists of organs such as **lymph nodes**, **spleen**, **thymus gland**, **bone marrow**, **tonsils** and **appendix** (Figure 10.22). The lymphatic system does not have its own pump to circulate the lymph along the lymphatic vessel. The flow of lymph is aided by **heartbeat pulse**, **contraction of skeletal muscles**, **peristalsis in the digestive tract** and 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.

Relationship between the blood circulatory system and the lymphatic system

All lymphatic vessels will eventually join with one of the two main lymphatic vessels which are the **thoracic duct** dan **right lymphatic duct** (Figure 10.22).

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

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

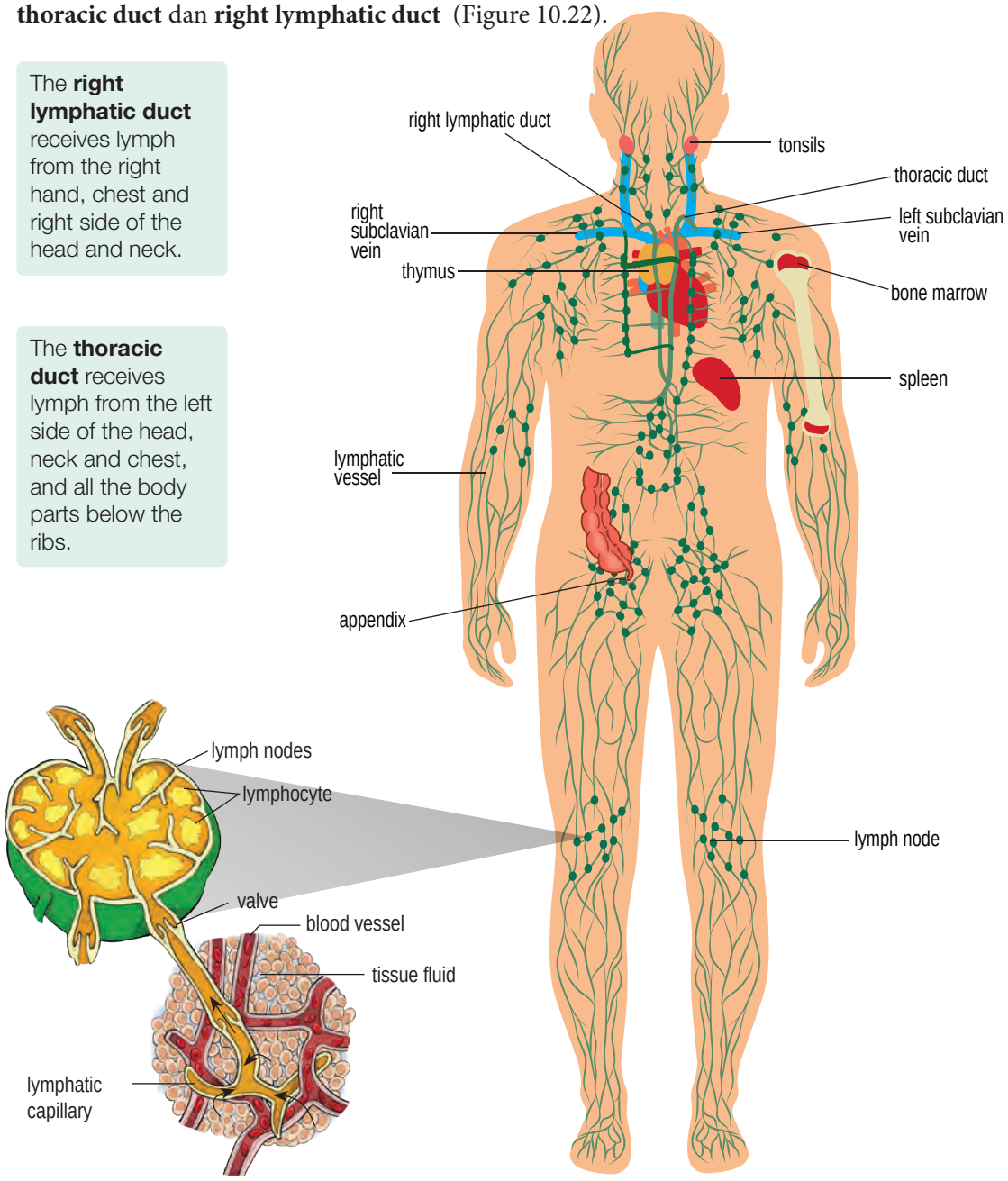


FIGURE 10.22 Lymphatic system

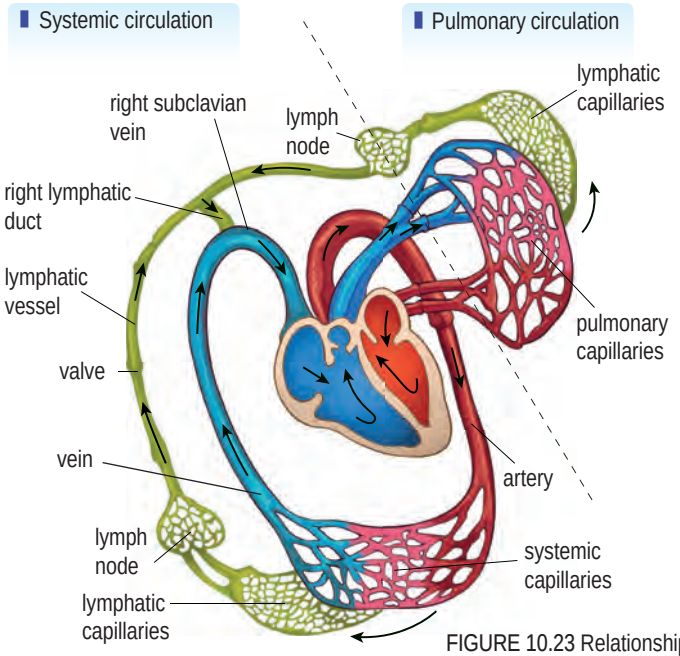


FIGURE 10.23 Relationship between lymphatic system and blood circulatory system

The thoracic duct will deliver its contents 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. Figure 10.23 shows the relationship between the lymphatic system and the blood circulatory system that complement each other.

The necessity of the lymphatic system

The necessity of the lymphatic system is summarised in Figure 10.24.

NECESSITIES OF THE LYMPHATIC SYSTEM

BODY DEFENCE

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

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.

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.

FIGURE 10.24 The necessity of the lymphatic system

Formative Practice 10.7

1 Name the two main lymphatic vessels.

2 State three main functions of the lymphatic system.

3 State the differences between the composition of blood plasma, tissue fluid and lymph.

4 After eating fatty food, the number of lipid molecules in the lymph increases by 1%. Explain why.

10.8 Health Issues Related to the Human Lymphatic System

Brainstorm!

Why do our legs swell after we sit for too long?

Have you ever wondered what would happen if our lymphatic system does not function properly? What would happen if the excess tissue fluid is not returned to the blood flow? 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** (Photograph 10.7). Oedema may be caused by a number of factors (Figure 10.25).

CAUSES OF OEDEMA

PREGNANCY

The body will produce more body fluid to fulfill the needs of a growing foetus.

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, for example, leg will swell.
- The patient contracts lymphatic filariasis (Photograph 10.8).
- This worm is transmitted through mosquito bites.

PROLONGED BEDRIDDEN PATIENTS

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

FIGURE 10.25 Causes of oedema

normal leg leg with oedema

PHOTOGRAPH 10.7
Oedema

PHOTOGRAPH 10.8
Swollen leg caused by lymphatic filariasis

Formative Practice 10.8

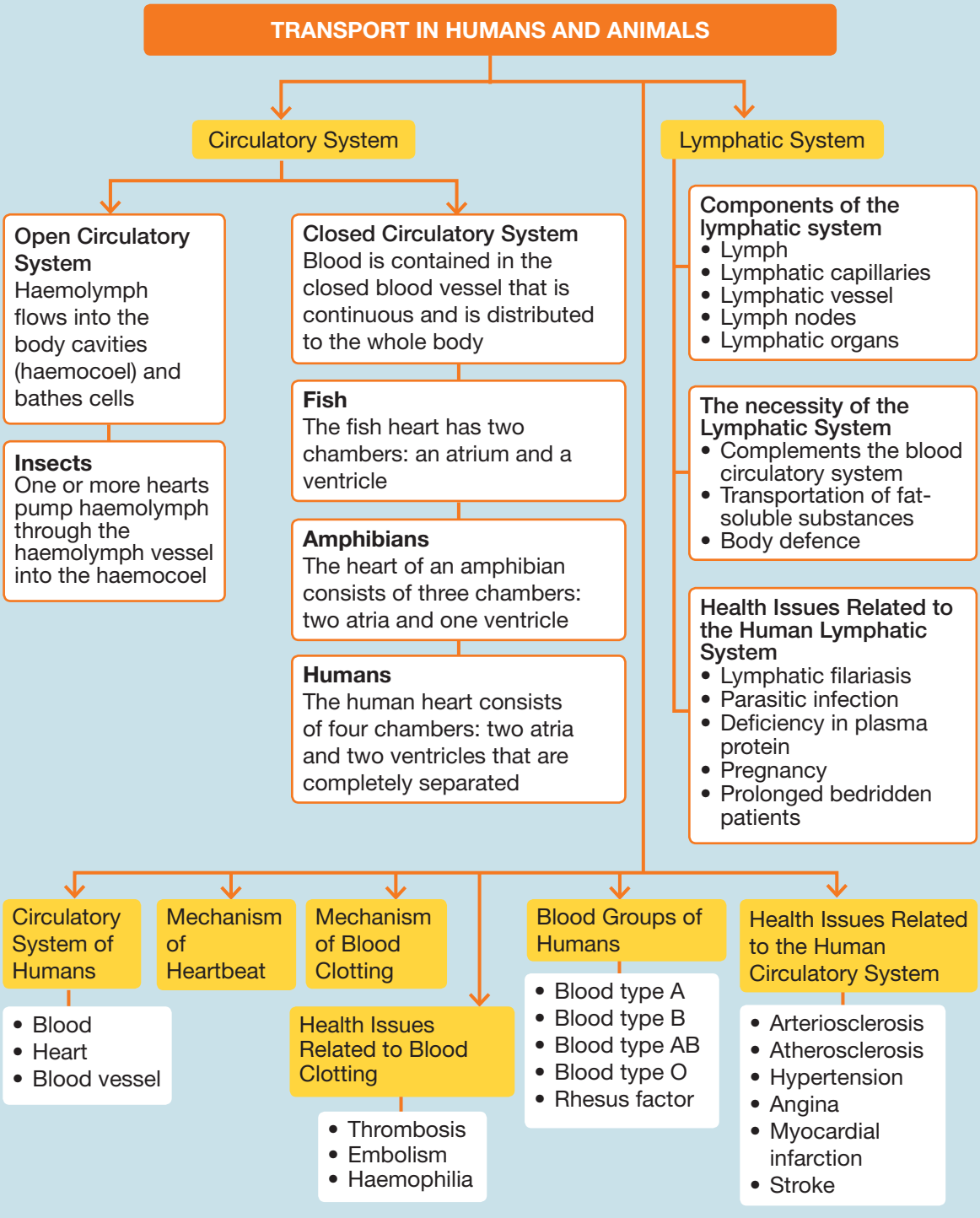
1 How do parasitic infections happen?

2 Explain what would happen when the tissue fluid fails to return to the blood circulatory system.

3 Predict what would happen to the legs of a patient who has been bedridden for a long period of time? Explain your answer.

4 Lipid droplets or fat globules cannot diffuse into the villus blood capillary but must diffuse through the lacteal. Explain why.

Summary


TRANSPORT IN HUMANS AND ANIMALS
Circulatory System
Lymphatic System
Open Circulatory System
Haemolymph flows into the body cavities (haemocoel) and bathes cells
Insects
One or more hearts pump haemolymph through the haemolymph vessel into the haemocoel
Closed Circulatory System
Blood is contained in the closed blood vessel that is continuous and is distributed to the whole body
Fish
The fish heart has two chambers: an atrium and a ventricle
Amphibians
The heart of an amphibian consists of three chambers: two atria and one ventricle
Humans
The human heart consists of four chambers: two atria and two ventricles that are completely separated
Components of the lymphatic system
• Lymph
• Lymphatic capillaries
• Lymphatic vessel
• Lymph nodes
• Lymphatic organs
The necessity of the Lymphatic System
• Complements the blood circulatory system
• Transportation of fat-soluble substances
• Body defence
Health Issues Related to the Human Lymphatic System
• Lymphatic filariasis
• Parasitic infection
• Deficiency in plasma protein
• Pregnancy
• Prolonged bedridden patients
Circulatory System of Humans
• Blood
• Heart
• Blood vessel
Mechanism of Heartbeat
Mechanism of Blood Clotting
Health Issues Related to Blood Clotting
• Thrombosis
• Embolism
• Haemophilia
Blood Groups of Humans
• Blood type A
• Blood type B
• Blood type AB
• Blood type O
• Rhesus factor
Health Issues Related to the Human Circulatory System
• Arteriosclerosis
• Atherosclerosis
• Hypertension
• Angina
• Myocardial infarction
• Stroke