6 Transport in Humans

Study Station ▸▸

A Blood

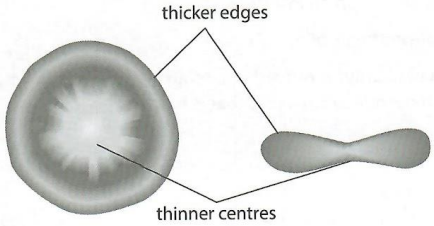
Learning Outcome

- Recognise the components of blood and state their functions.

1. **Blood** is a fluid tissue. It consists of different types of cells — red blood cells, white blood cells and platelets, suspended in a fluid called plasma.
2. The mammalian red blood cell contains **haemoglobin**, a red pigment, which combines reversibly with oxygen. This enables the red blood cell to transport oxygen from the lungs to the rest of the body.

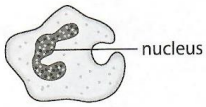
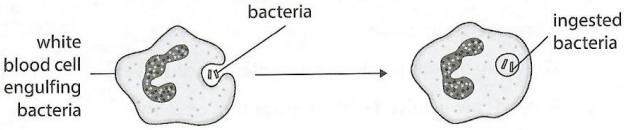
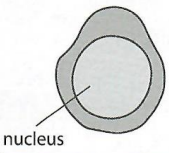
$$\underset{\text{(purplish-red colour)}}{\text{haemoglobin}} + \text{oxygen} \underset{\text{in tissues of low oxygen concentration}}{\overset{\text{in lungs}}{\rightleftharpoons}} \underset{\text{(bright red colour)}}{\text{oxyhaemoglobin}}$$

3. The red blood cell is a circular, flattened **biconcave** disc with its centre thinner than the edges. This increases the surface area-to-volume ratio and allows the cell to absorb and release oxygen at a faster rate.



4. The absence of a nucleus in the red blood cell increases its capacity for haemoglobin and therefore, more oxygen.
5. Red blood cells are flexible and can change into bell-shaped structures to squeeze through narrow blood vessels.
6. There are two types of white blood cells — phagocytes and lymphocytes. Both are irregular in shape and have a nucleus.

7. The table below describes some functions of white blood cells.

White Blood Cell	Function
Phagocyte 	Performs **phagocytosis**, the process by which a white blood cell engulfs and destroys foreign particles such as bacteria 
Lymphocyte 	Produce antibodies that • recognise foreign particles • destroy bacteria and viruses • cause bacteria to clump together to facilitate phagocytosis • neutralise toxins produced by bacteria

8. Blood platelets are fragments of cytoplasm that play a part in blood clotting.
   - The **clotting** of blood helps to seal wounds to reduce excessive blood loss and prevent the entry of foreign particles and infection by pathogens.
   - Platelets contain enzymes that aid the conversion of **fibrinogen**, a soluble plasma protein, to insoluble **fibrin** threads.
   - The fibrin threads entangle blood cells to form a clot or scab which seals the wound.
9. Plasma is a pale yellowish fluid which serves as a transport medium.

Components of Plasma	Substances That Plasma Transports
• Mainly water • Red and white blood cells • Glucose, salts, proteins, amino acids, fats, vitamins • Metabolic wastes • Hormones	• Blood cells: around the body • Nutrients: from the small intestine to other parts of the body • Metabolic wastes: from organs where they are produced to the organs such as the kidneys and lungs for removal • Hormones: from endocrine glands to target organs

10. **Tissue** or **organ transplant** is the replacement of badly damaged or diseased tissue or organ with a healthy one from a donor.
    - **Tissue rejection** can occur when the transplanted tissue is rejected by the recipient's immune system and treated like a foreign body. The recipient's immune system may respond by producing antibodies to destroy the transplanted organ.
    - If the transplanted tissue came from the patient, tissue rejection would not be a problem. An example of this is the replacement of burnt skin using undamaged skin from another part of the patient's body.
    - A tissue match (where the tissue to be transplanted is genetically similar to the recipient) will greatly reduce the risk of rejection.
    - Immunosuppressive drugs can be used to inhibit or suppress the recipient's immune system. These drugs make the recipient more susceptible to infections and have to be taken for life.

Link Discover Biology (3rd Edition) Textbook — Section 6.1

Checkpoint 6.1

1. Which of the following statements is **false**?
   - **A** Fibrinogen is involved in clotting.
   - **B** White blood cells produce antibodies to fight diseases.
   - **C** Platelets are involved in the transport of oxygen.
   - **D** Haemoglobin is a pigment found in red blood cells.

2. The plasma component of blood is responsible for _____.
   - **A** transporting mineral salts around the body
   - **B** engulfing foreign particles through phagocytosis
   - **C** transporting mainly dissolved oxygen around the body
   - **D** producing antibodies and chemicals which destroy microorganisms

Tip

The functions of the components of blood have been asked in examination questions. One example can be found in O GCE 'O' Level Science (Biology) Oct/Nov 2019 Paper 1 Q30 or N GCE N(A) Level Science (Biology) Sep/Oct 2020 Paper 5 Q13.

3. (a) Name the **two** types of blood cells.
   (b) Adam has a cut on his thumb. Describe how the body prevents blood loss from the injury.

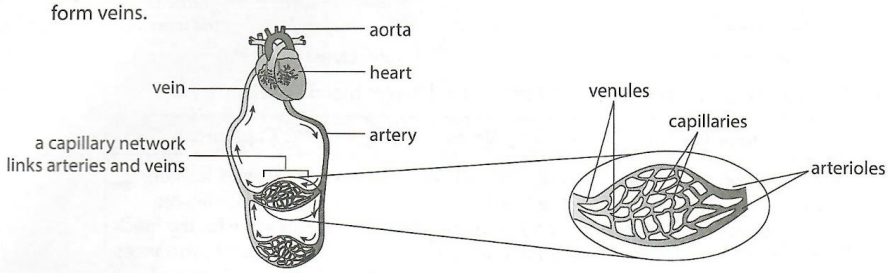
B Human Circulatory System

Learning Outcomes

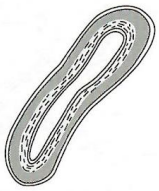
- Identify the main blood vessels that connect the heart, lungs, liver and kidney.
- Relate the structure of arteries, veins and capillaries to their functions.

1. Blood transports oxygen and nutrients to all parts of the body and transports waste materials out of the body by flowing continuously around the body in a closed system. This flow of blood is called **blood circulation**.

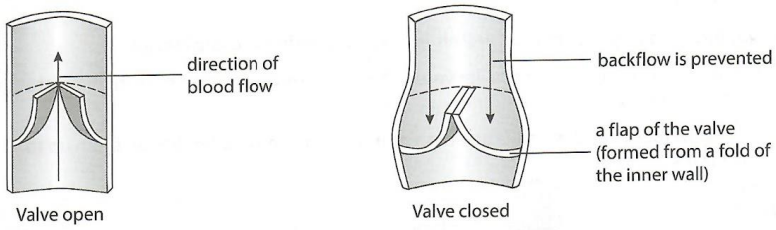
2. The human transport system is known as the **circulatory system**. It consists of the heart, different types of blood vessels and blood.
   - The three main types of blood vessels are **arteries**, **veins** and **capillaries**.
   - The arteries branch to form smaller vessels called **arterioles**, which branch further to form blood capillaries.
   - Capillaries merge as they leave an organ or tissue to form **venules**. Venules join up to form veins.



3. The table below shows a comparison between the three main types of blood vessels.

	Arteries	Veins	Capillaries
Structure	• Thicker muscular walls with more elastic tissue to withstand higher blood pressure • Elastic walls can stretch and spring back (recoil), pushing blood forward in spurts and giving rise to the pulse • Valves absent  Cross-section of an artery	• Thinner muscular walls with little elastic tissue • Valves that close to prevent backflow of blood are present  Cross-section of a vein	• Walls are one-cell thick and partially permeable with no muscular or elastic tissue • Extensive branching increases the total cross-sectional area and slows down blood flow and give more time for the exchange of substances  Cross-section of a capillary
Blood Pressure and Flow	High pressure, blood is fast-moving	Lower pressure than in the arteries, blood moves smoothly and slowly	Low pressure, blood is slow-moving

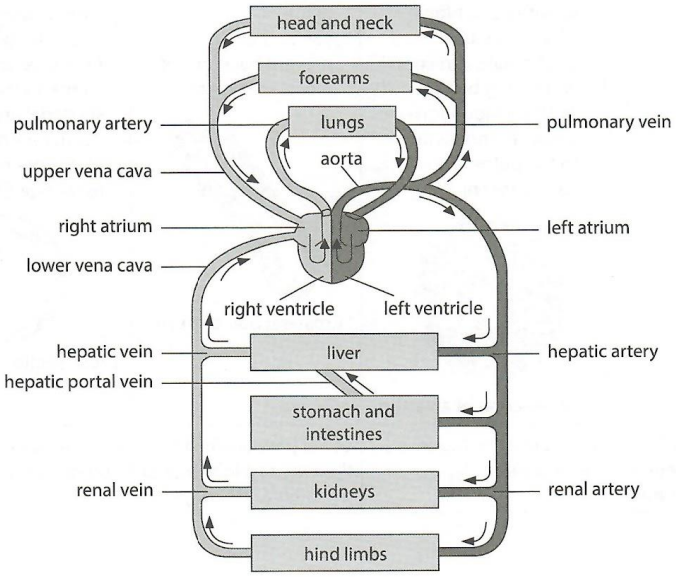
4. The diagram below shows how the valves in the veins work to prevent the backflow of blood.



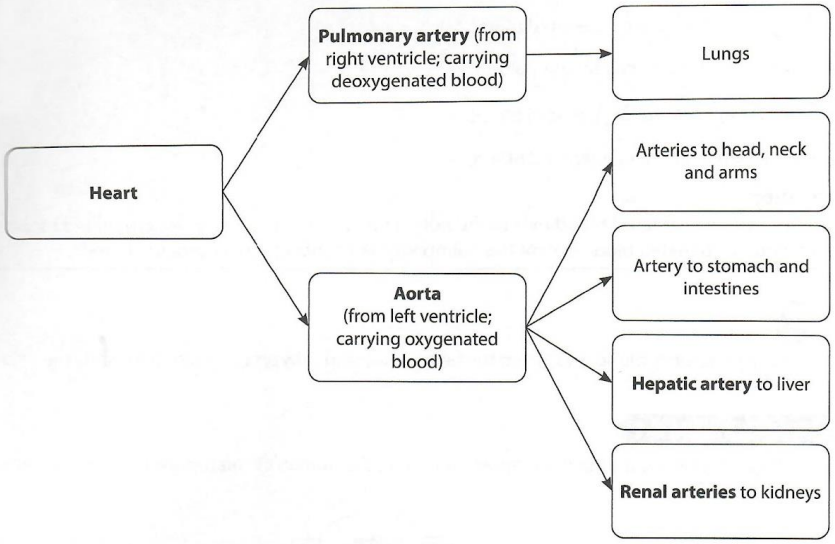
5. The table below describes the functions of the different blood vessels.

Arteries	Veins	Capillaries
• Carry blood away from the heart • Carry oxygenated blood (except for pulmonary arteries which carry deoxygenated blood from the heart to the lungs)	• Carry blood towards the heart • Carry deoxygenated blood (except for pulmonary veins which carry oxygenated blood from the lungs to the heart)	• Link arteries to veins • Partially permeable walls allow for the quick exchange of substances between blood and tissue cells

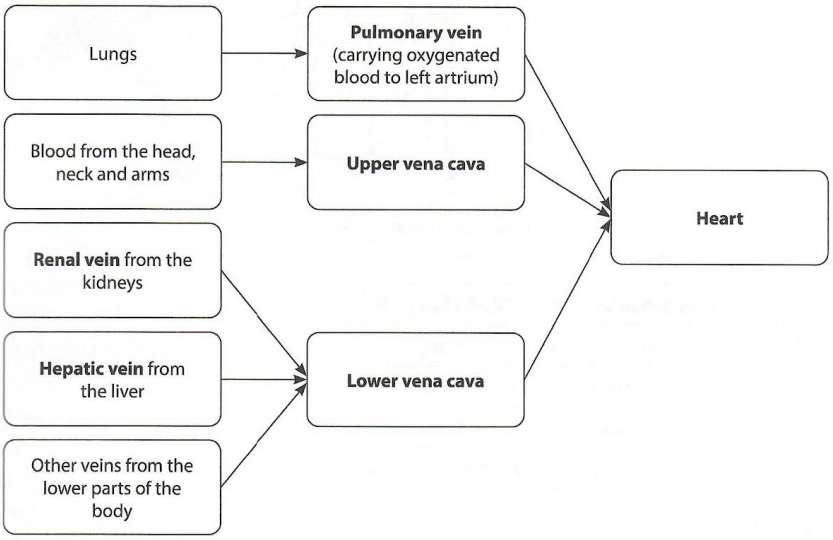
6. The diagram shows the main blood vessels in the human body.



7. The diagram below describes the main arteries in the body.



8. The diagram below describes the main veins in the body.



9. The **hepatic portal vein** arises from the veins from the small intestines and enters the liver.

Common Errors

✗ Arteries always carry oxygenated blood.

✓ Not all arteries carry oxygenated blood.

✗ Veins always carry deoxygenated blood.

✓ Not all veins carry deoxygenated blood.

Explanation

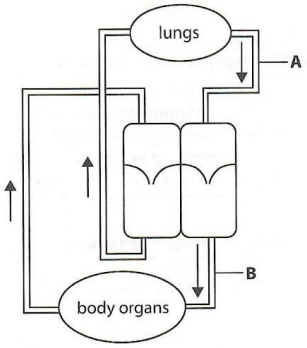
All arteries carry oxygenated blood except the pulmonary arteries that carry deoxygenated blood. All veins carry deoxygenated blood except the pulmonary veins that carry oxygenated blood.

Tip

Arteries always carry blood away from the heart while veins always carry blood towards the heart.

Worked Example 6.1

The diagram below is a simplified representation of the human circulatory system. Identify blood vessels **A** and **B**.



	Blood Vessel A	Blood Vessel B
A	Aorta	Pulmonary vein
B	Pulmonary artery	Lower vena cava
C	Pulmonary vein	Aorta
D	Lower vena cava	Pulmonary artery

Solution

Option **C** is the correct answer.

Explanation

- Blood from the heart is transported to the rest of the body through the aorta (vessel **B**) and returns via the lower vena cava.
- Blood is transported from the heart to the lungs via the pulmonary artery and returns to the heart via the pulmonary vein (vessel **A**).

Link Discover Biology (3rd Edition) Textbook — Sections 6.2 and 6.3

Checkpoint 6.2

1. Which of the following blood vessels carries deoxygenated blood from the right ventricle to the lungs?

   A Aorta

   B Vena cava

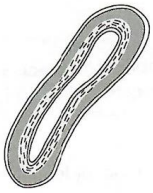
   C Pulmonary vein

   D Pulmonary artery

Tip

Questions requiring students to identify blood vessels of the heart have appeared in the examinations. One example can be found in O GCE 'O' Level Science (Biology) Oct/Nov 2021 Paper 1 Q29 or N GCE N(A) Level Science (Biology) Sep/Oct 2020 Paper 6 Q1.

2. The diagrams show the cross-sections of two blood vessels, **A** and **B**.



Blood vessel **A**

Blood vessel **B**

   (a) State the type of blood vessels shown.

   (b) Give reasons for your answer in (a).

Tip

Questions requiring students to identify blood vessels have appeared in the examinations. One example can be found in O GCE 'O' Level Science (Biology) Oct/Nov 2020 Paper 1 Q29 or N GCE N(A) Level Science (Biology) Sep/Oct 2012 Paper 6 Q2.

C The Heart

Learning Outcome

- Relate the structure of the heart to its function, with emphasis on muscular contractions and the valves.

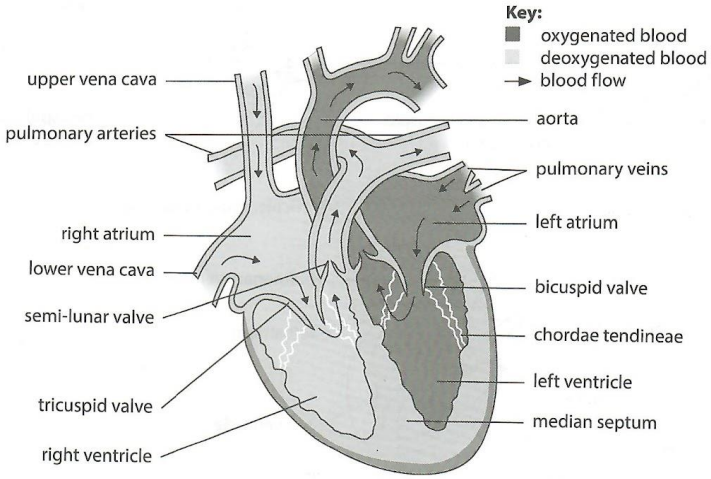
1. The **heart** sits between the lungs in the centre of the chest. It is tilted slightly to the left of the breastbone.
2. The heart has four **chambers**.
   - The upper two chambers are called **atria** (singular: **atrium**). The atria have thinner muscular walls than the ventricles as they only have to pump blood into the ventricles.
   - The lower two chambers are called **ventricles**. Ventricles have thick muscular walls as they force blood out of the heart to other parts of the body.
   - The wall of the left ventricle is thicker than the wall of the right ventricle as it must pump blood to the rest of the body, which requires a high pressure.
   - The right ventricle has thinner walls than the left as it only pumps blood to the lungs which are near the heart.

Tip

The thickness of the muscular layer of the heart chambers and blood vessels is related to the pressure that they need to generate or withstand respectively.

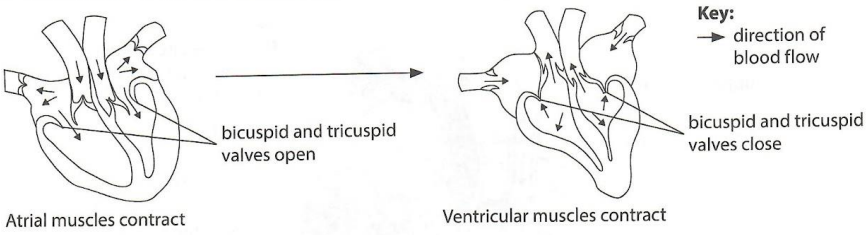
3. The **median septum** is a muscular wall that runs down the middle of the heart and separates the right and left sides of the heart.
   - It prevents deoxygenated blood in the right side of the heart from mixing with oxygenated blood in the left side.
   - Mixing deoxygenated with oxygenated blood will reduce the amount of oxygen carried to the tissue cells.
   - Patients with a hole in the median septum are said to have a hole in the heart. They may suffer from fatigue, shortness of breath, and in serious cases, heart failure.
4. **Valves** found in the heart prevent the backflow of blood by ensuring blood flows only in one direction. The valves include the **tricuspid valve**, the **bicuspid valve** and the **semi-lunar valves** in the aorta and pulmonary vein.

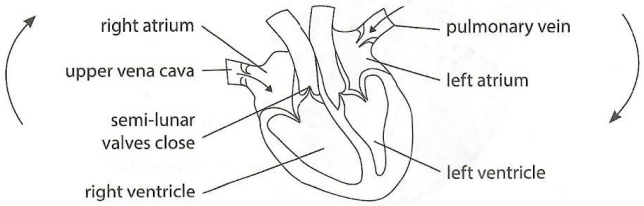
5. The diagram shows the longitudinal section of the heart and the main blood vessels.



6. When the atria and ventricles are relaxed, the atria receive blood at low pressure from the veins.
7. As the muscles of the atria contract, the increased pressure causes blood to push through the tricuspid and bicuspid valves to flow into the ventricles.
8. When the muscles of the ventricles contract, the increased pressure forces the tricuspid and bicuspid valves to close.
   - The tricuspid valve is located between the right atrium and right ventricle and has three flaps which are attached to the walls of the right ventricle by the **chordae tendineae**.
   - The bicuspid valve is similar to the tricuspid valve in structure and function, except that it is located between the left atrium and left ventricle and has two flaps instead of three.
   - Closure of these valves prevent the backflow of blood into the atria, producing a "lub" sound.
   - The semi-lunar valves in the pulmonary artery and the aorta open to allow blood to flow out of the heart.
9. When the muscles of the ventricles contract, the muscles of the atria are relaxed.
   - The right atrium receives blood pressure from the upper and lower vena cavae.
   - The left atrium receives blood from the pulmonary veins.
10. When the muscles of the ventricles relax, the decrease in pressure causes the semi-lunar valves to close, producing a softer "dub" sound.

11. The muscles of the atria contract again and the whole cycle repeats.





12. A pulse is produced after every ventricular contraction. By counting the number of pulse beats per minute, we get the number of heartbeats per minute. The rate of heartbeat varies with the age and size of an individual. The average normal heartbeat of an adult is 72 beats per minute.

Tip

- It is important to take note of the type of blood, oxygenated or deoxygenated, that flows into the various heart chambers and blood vessels connected to the heart.
- Oxygenated blood flows through the left chambers of the heart while deoxygenated blood flows through the right chambers of the heart.

Worked Example 6.2

(a) Some blood from a patient's left ventricle keeps leaking into the left atrium as the heart beats. Suggest which structure in the heart is not functioning properly.

(b) Suggest how the condition in (a) would affect the volume of blood flowing out of the heart.

Solution

(a) The bicuspid valve could be faulty.

(b) As some blood leaks back into the atrium, the volume of blood pumped out of the heart to the rest of the body will be reduced.

Explanation
The bicuspid valve lies between the left atrium and left ventricle. It prevents the backflow of blood into the left atrium.

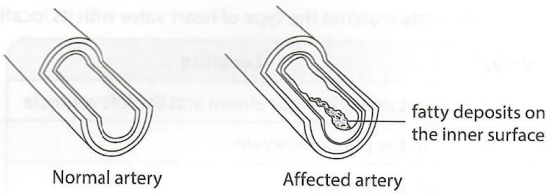
Link Discover Biology (3rd Edition) Textbook — Section 6.3

D Coronary Heart Disease

Learning Outcomes

- Describe coronary heart disease.
- State the causes of coronary heart disease and the preventive measures.

1. Two coronary arteries branch out from the aorta and wrap around the outside of the heart. These arteries carry blood and nutrients to the muscles of the heart.
2. **Coronary heart disease** is a very common heart disease that causes a reduction in the amount of blood reaching the heart muscles.
3. A **heart attack** can result when the blood supply to the heart muscles is reduced due to a coronary occlusion (blockage) in the coronary arteries. The region of heart muscle that does not receive sufficient oxygen and nutrients dies. Extensive heart muscle damage can be fatal as the heart can no longer pump blood to various parts of the body.
4. Coronary heart disease is caused by **atherosclerosis** of the coronary arteries.
   - Atherosclerosis occurs when fatty substances such as cholesterol and saturated fats are deposited onto the inner surface of the coronary arteries and form plaques over time.
   - The fatty deposits narrow the lumen of the arteries and increase the blood pressure flowing to the heart.
   - The affected arteries develop rough inner surfaces. This increases the risk of a blot clot forming or becoming trapped in the artery.
   - When the coronary arteries are completely blocked, blood and oxygen supply to the heart muscles may be cut off.
   - Without oxygen, the heart muscles may be damaged, leading to a heart attack.



5. The following table shows the risk factors and preventive measures against coronary heart disease.

Risk Factor	Preventive Measure
Unhealthy diet • A diet rich in cholesterol and saturated animal fats increases the risk of high blood pressure and heart attack	Substitute animal fats for polyunsaturated plant fats which do not stick to the inner surfaces of arteries and may lower cholesterol levels
Smoking • Carbon monoxide and nicotine increase the risk of heart disease • Nicotine increases blood pressure and the risk of blood clotting in arteries	Reduce or avoid smoking
Family history • High blood pressure and high blood cholesterol can run in the family	Engage in regular exercise to strengthen the heart and maintain elasticity of arterial walls
Age • The risk of a heart attack increases with age	
Sedentary lifestyle • Inactivity leads to the build-up of fatty deposits that block the arteries	

Link Discover Biology (3rd Edition) Textbook — Section 6.4

Checkpoint 6.3

1. Which of the following **correctly** matches the type of heart valve with its location?

	Heart Valve	Location
A	Tricuspid valve	Between the right atrium and the left ventricle
B	Semi-lunar valve	In the pulmonary vein
C	Semi-lunar valve	In the aorta
D	Bicuspid valve	Between the left atrium and the right atrium

2. Coronary heart disease affects the normal functions of coronary arteries. Which of the following is **not** a change caused by the disease on the arteries?

   A Increased blood pressure to heart muscles

   B Development of a rough inner surface

   C Increased clot formation in the lumen of the arteries

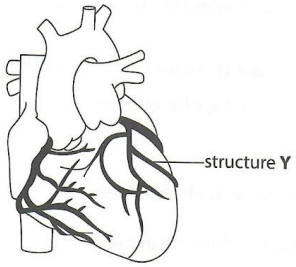
   D Widening of the lumen of the arteries

3. Heart valves keep blood flowing through the heart in the correct direction.
   (a) Explain how heart valves ensure a one-way flow of blood in the right side of the heart.
   (b) Give **one** structural difference between the valves separating the atria and the ventricles on the left side and right side of the heart.

Tip

The locations and functions of heart valves have been asked examination questions. One example can be found in O GCE 'O' Level Science (Biology) Oct/Nov 2014 Paper 1 Q29 or N GCE N(A) Level Science (Biology) Sep/Oct 2016 Paper 6 Q4.

4. The diagram shows the external view of the human heart.



   (a) Identify structure **Y**.
   (b) State **two** factors that can cause structure **Y** to become occluded.
   (c) Suggest what could happen to a person if structure **Y** is completely blocked.

Tip

The causes of coronary heart disease have been asked examination questions. One example can be found in O GCE 'O' Level Science (Biology) Oct/Nov 2017 Paper 4 Q3 or N GCE N(A) Level Science (Biology) Sep/Oct 2020 Paper 6 Q1.

Test Station ▸▸

1. Atherosclerosis refers to the narrowing of the _____.
   - **A** atrium
   - **B** arteries
   - **C** veins
   - **D** ventricles

2. Which of the following statements about blood capillaries is **not** true?
   - **A** They connect the arteries and veins.
   - **B** They contain elastic tissue to withstand the high pressure of the blood flowing through them.
   - **C** They form a dense network around organs to enable efficient transport of nutrients.
   - **D** They have walls that are one-cell thick for efficient diffusion of substances.

3. (a) Describe coronary heart disease. [2]
   (b) List **four** common causes of coronary heart disease. [4]

4. Figure 6.1 shows the cross-section of the human heart.

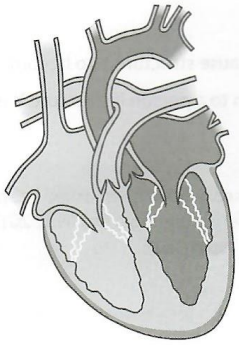


Figure 6.1

   (a) State and explain the difference between the structure of the walls of the atria and the ventricles. [3]
   (b) State and explain the difference between the structure of the walls of the left and right ventricles. [3]

5. (a) State **three** functions of blood. [3]
   (b) Describe the direction of blood flow into and out of the right chambers of the heart. [3]
   (c) Describe the direction of blood flow into and out of the left chambers of the heart. [3]