Edexcel International AS Biology

Your notes

The Circulatory System

Contents

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The Need for a Circulatory System

- The cells of all living organisms need a **constant supply of reactants** for metabolism, e.g. oxygen and glucose
- Single-celled organisms can gain oxygen and glucose directly from their surroundings and the molecules can **diffuse to all parts of the cell quickly** due to **short diffusion distances**
- Larger organisms, however, are made up of many layers of cells, meaning that the time taken for substances such as glucose and oxygen to diffuse to every cell in the body would be far too long
  - The diffusion distances involved are **too great**
  - Large organisms often have **high energy requirements**, so the delivery of reactants for metabolism needs to happen quickly
- To solve this problem their exchange surfaces are connected to a **mass transport system**, for example
  - The digestive system is connected to the circulatory system
  - The lungs are connected to the circulatory system
- **Mass transport** is the **bulk movement** of gases or liquids in **one direction**, usually via a system of vessels and tubes
- The **circulatory system** in mammals is a well-studied example of a mass transport system; the one-way flow of blood within the blood vessels carries essential nutrients and gases to all the cells of the body
- Mass transport systems help to
  - Bring substances **quickly** from one exchange site to another
  - **Maintain diffusion gradients** at exchange sites and between cells and their fluid surroundings
  - Ensure **effective cell activity** by supplying reactants and removing waste products

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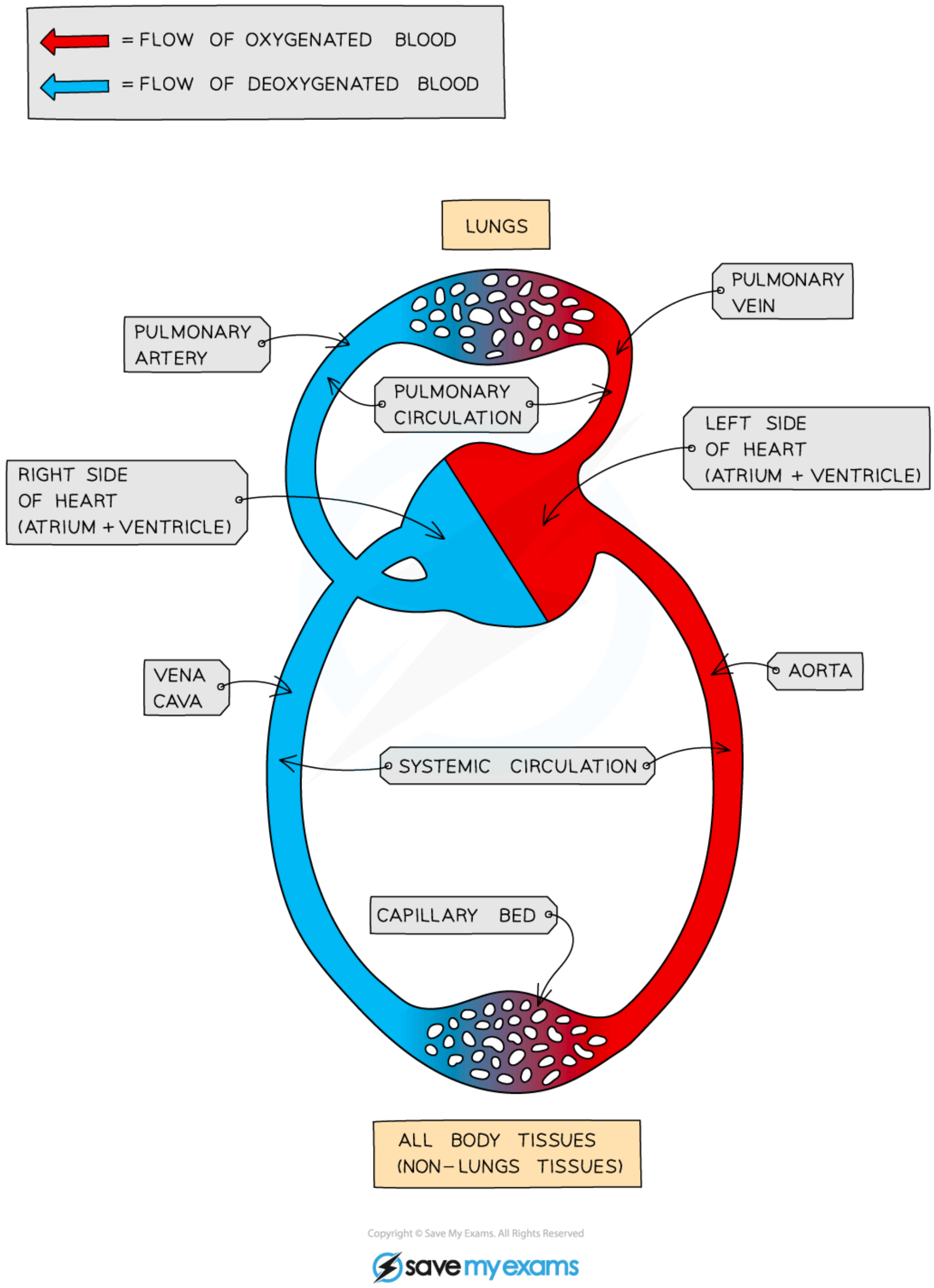

Mammals have a circulatory system known as a double circulatory system; the blood travels around the body in two separate circuits known as the pulmonary and systemic circulation

Blood Vessels: Structure & Function

- The body contains several different types of blood vessel
  - **Arteries** transport blood away from the heart, usually at high pressure, to the tissues
    - Remember; **a**rteries carry blood **a**way from the heart
  - **Arterioles;** arteries branch into narrower blood vessels called arterioles which transport blood into capillaries
  - **Veins**: transport blood to the heart, usually at low pressure
    - Remember; ve**in**s carry blood **in**to the heart
  - **Venules;** these narrower blood vessels transport blood from the capillaries to the veins
  - **Capillaries** are microscopic blood vessels that carry blood to the cells
- Blood flows through the lumen of a blood vessel; the size of the lumen varies depending on the type of blood vessel
  - Arteries have a narrow lumen and the veins a wider lumen
- The walls of each type of blood vessel have a **structure that relates to the function** of the vessel

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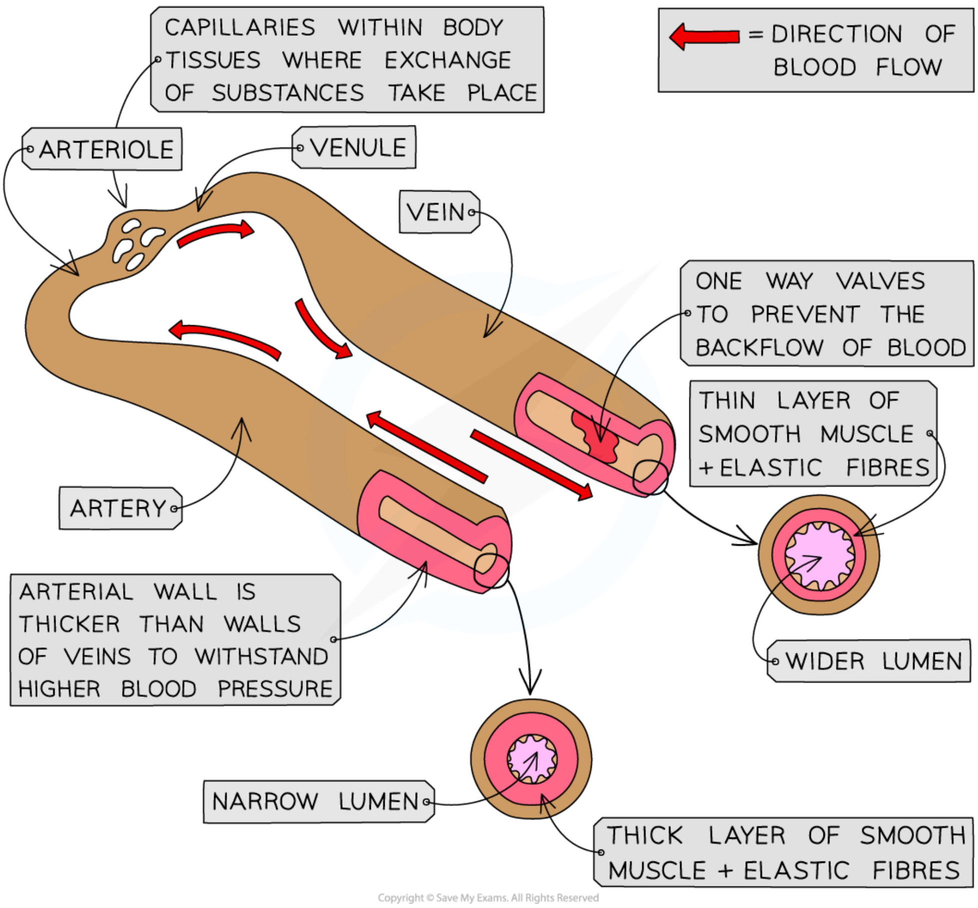

The blood vessels form a continuous network; the structure of each allows it to carry out its function

Arteries

- Artery walls consist of three layers
  - The **endothelium**, sometimes referred to as the *tunica intima*
    - The endothelium is one cell thick and lines the lumen of all blood vessels.
    - It is very smooth and **reduces friction** for free blood flow
    - In arteries the endothelium is **highly folded**, enabling it to expand under high pressure
  - **Smooth muscle** and **elastic tissue**, sometimes referred to as the *tunica media*
    - This layer is thick in arteries
    - The layer of muscle cells strengthen the arteries so they can **withstand high pressure**
    - It also enables them to constrict and narrow the lumen for reduced blood flow
      - **Contraction** of the muscle causes constriction of the lumen

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        - This is useful for diverting blood flow away from certain locations e.g. away from the digestive system during exercise
      - The elastic tissue helps to **maintain blood pressure** in the arteries
        - It stretches and **recoils** to even out any fluctuations in pressure
  - The outer wall, sometimes referred to as the *tunica adventitia*, or *tunica externa*
    - Contains the structural protein **collagen**
    - Collagen is a strong protein that **protects blood vessels** from damage by over-stretching
- Arteries have a **narrow lumen** which helps to maintain a high blood pressure
- A pulse is present in arteries as they stretch to accommodate an increased volume of blood with each heart beat

Veins

- Veins return blood to the heart
- They receive blood that has passed through capillary networks, so the blood pressure is very low
- Veins contain the same layers as arteries but in different proportions
  - The **smooth muscle and elastic layer** is much thinner in veins
    - There is no need for a thick muscular layer as veins don't have to withstand high pressure
- The **lumen** of the vein is much wider than that of an artery
  - A larger lumen helps to ensure that blood returns to the heart at an adequate speed
  - A large lumen reduces friction between the blood and the endothelium of the vein
    - The rate of blood flow is slower in veins but a larger lumen means the volume of blood delivered per unit of time is equal to that of arteries
- Veins contain **valves**
  - These prevent the backflow of blood, helping return blood to the heart
- A **pulse is absent** in veins due to the increased distance from the heart

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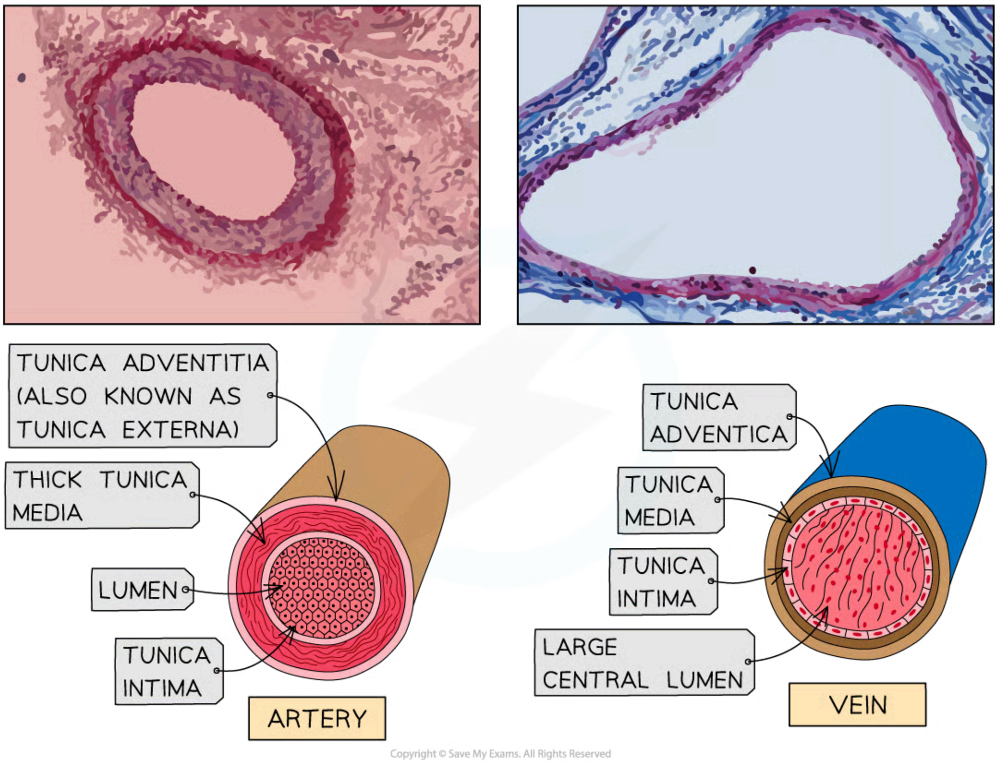

Arteries have a thick layer of elastic and muscle tissue and a narrow lumen, while veins have a thin layer of elastic and muscle tissue and a wide lumen

Capillaries

- Capillaries have thin walls which are permeable, allowing substances to leave the blood to reach the body's tissues
- They can form networks called **capillary beds** which are very important **exchange surfaces** within the circulatory system
  - A **large number** of capillaries **branch between cells**
    - Substances can diffuse between the blood and cells quickly as there is a short diffusion distance
- Capillaries have a lumen that is very **narrow in diameter**
  - Red blood cells need to pass through the capillaries in single file
  - This forces the blood to travel slowly which provides more time for **diffusion** to occur
- The **wall of the capillary is a single layer of endothelial cells**
  - This layer also lines the lumen in arteries and veins
  - The wall is only one cell thick; this **reduces the diffusion distance** for oxygen and carbon dioxide between the blood and the tissues of the body

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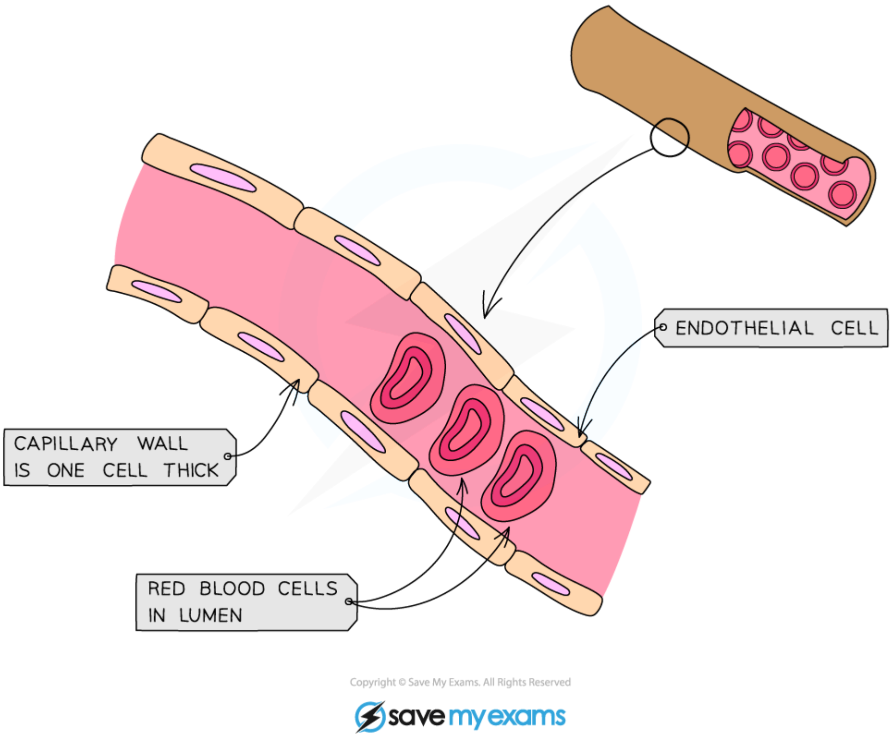
- The cells of the wall have gaps called **pores** which allow blood plasma to leak out and form tissue fluid
- **White blood cells** can combat infection in affected tissues by squeezing through the pores in the capillary walls



Capillaries have a narrow lumen and walls that are one cell thick

Examiner Tips and Tricks

You need to know about the **structure** and **function** of arteries, veins and capillaries; for "explain" questions remember to pair a description of a structural feature to an explanation of how it helps the blood vessel to function. For example, "Capillary walls are one-cell thick, which enables quick diffusion of substances due to the short diffusion distance."

Remember that muscle tissue **contracts** and elastic tissue **recoils.**

Remember that **capillary walls** are one cell thick; they do **not** have cell walls.

Your notes

The cardiac cycle

- Circulatory systems are systems which **transport fluids** containing materials needed by the organism, as well as waste materials that need to be removed
- **Circulatory systems** are described as being either **open or closed**
  - In a closed circulatory system blood is pumped around the body and is always contained within a network of blood vessels
  - In an open circulatory system the blood, or blood equivalent, is inside the body cavity and bathes the organs
- Circulatory systems can also be either **double or single**
  - Double circulatory systems have two loops; one to the lungs and one to the body
  - Single circulatory systems have one loop that includes the lungs and the body
- **Humans have a closed, double circulatory system;** in one complete circuit of the body blood passes through the heart twice
  - The **right side** of the heart pumps **deoxygenated** blood to the lungs for gas exchange; this is the **pulmonary circulatory system**
  - Blood then returns to the **left side** of the heart, so that **oxygenated** blood can be pumped at high pressure around the body; this is the **systemic circulatory system**

Heart structure

- The human heart has a mass of around 300 g and is roughly the size of a closed fist
- The heart is a hollow, muscular organ located in the chest cavity
- It is protected in the chest cavity by the **pericardium**, a tough and fibrous sac
- The heart is divided into four chambers
  - The two top chambers are **atria**
  - The bottom two chambers are **ventricles**
- The left and right sides of the heart are separated by a wall of muscular tissue called the **septum**
  - The septum is very important for ensuring blood doesn't mix between the left and right sides of the heart

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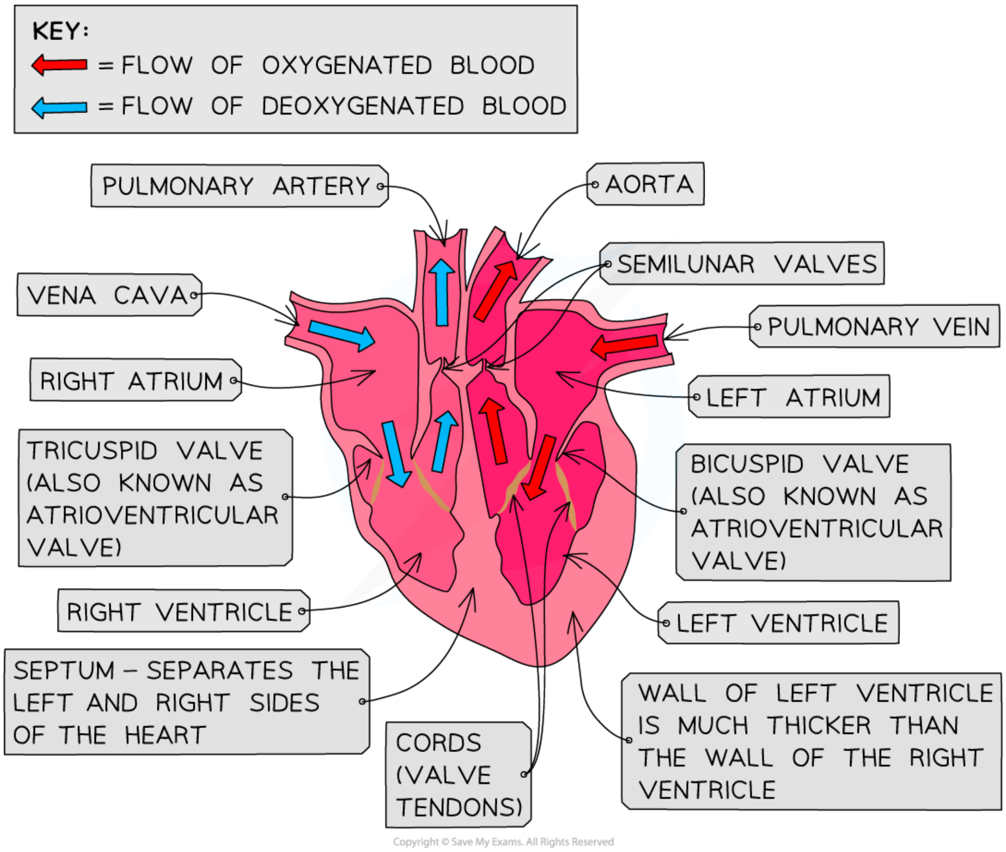
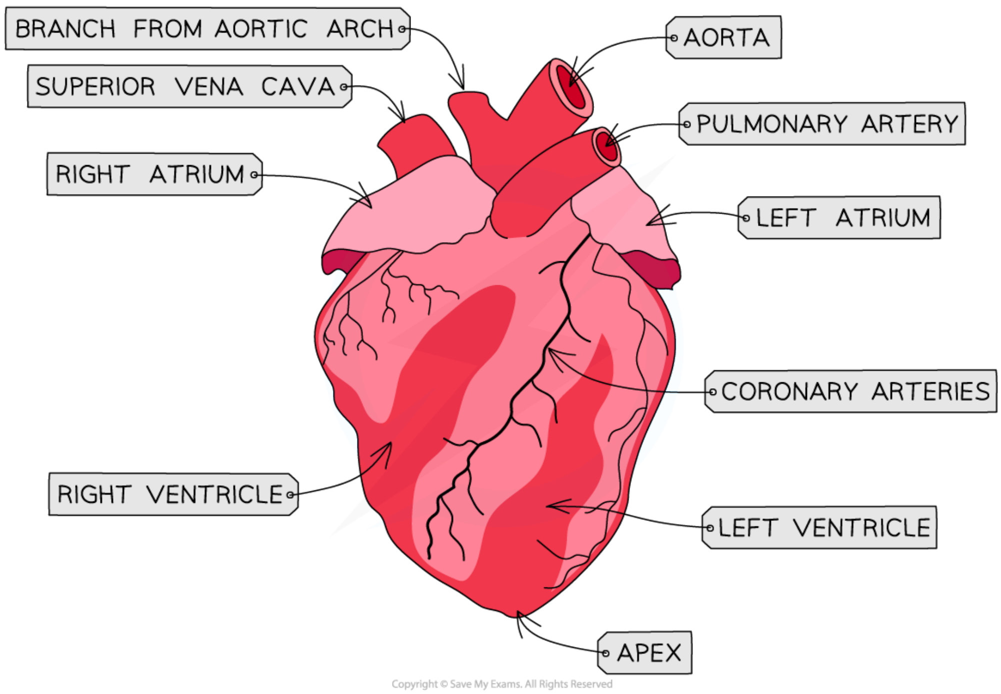


The human heart is adapted for pumping blood around the body



The heart is a muscular organ; the muscle itself is supplied with blood by the coronary arteries, enabling it to pump blood via a series of major blood vessels

Your notes

Valves in the heart

- Valves are important for keeping blood flowing forward in the **right direction** and for maintaining the correct pressure in the chambers of the heart
  - The right atrium and right ventricle are separated by an **atrioventricular (AV) valve** known as the **tricuspid valve**
    - Remember; the **ri**ght side of the heart has a **tri**cuspid valve
  - The left atrium and left ventricle are separated by another AV known as the **bicuspid valve**
  - The right ventricle and the pulmonary artery are separated by a **semilunar (SL) valve** known as the **pulmonary valve**
  - The left ventricle and aorta are separated by another SL valve known as the **aortic valve**
- Valves in the heart
  - Open when the pressure of blood behind them is greater than the pressure in front of them
  - Close when the pressure of blood in front of them is greater than the pressure behind them
- The valves are attached to the heart walls by **valve tendons,** or **cords**; these prevent the valves from flipping inside out under high pressure

Adaptations of the Structures of the Heart Table

Structure	Function
Left ventricle	Thicker muscle than right ventricle for strong contraction to pump blood all the way around the body; the right ventricle in comparison only has to pump blood to the nearby lungs
Ventricles	Thicker walls than atria to pump blood out of the heart; the atria in comparison only pump blood into the ventricles
Atrioventricular (AV) valves	Prevent backflow of blood from ventricles into atria
Semilunar (SL) valves	Prevent backflow of blood from the aorta or pulmonary artery into the ventricles

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Blood vessels and the heart

- There are two blood vessels bringing blood into the heart; the **vena cava** and **pulmonary vein**
  - The vena cava brings blood from the body
  - The pulmonary vein brings blood from the lungs
- There are two blood vessels taking blood away from the heart; the **pulmonary artery** and **aorta**
  - The pulmonary artery takes blood to the lungs
  - The aorta takes blood to the body
- The muscle of the heart itself is supplied with blood by a series of blood vessels known as the **coronary arteries**
  - The coronary arteries can be seen running across the surface of the heart

Examiner Tips and Tricks

When looking at a diagram of a heart remember that the right side of the heart will appear on the left of the diagram, as if you are looking at someone else's heart in front of you

The cardiac cycle

- The **cardiac cycle** is the series of events that take place in **one heartbeat**, including **muscle contraction** and **relaxation**
  - The contraction of the heart is called **systole**, while the relaxation of the heart is called **diastole**
- One cardiac cycle is followed by another in a **continuous process**
  - There is no gap between cycles where blood stops flowing

Volume and pressure changes

- **Contraction** of the heart muscle causes a **decrease in volume** in the corresponding chamber of the heart, which then **increases** again when the muscle **relaxes**
- Volume changes lead to **corresponding pressure changes**
  - When volume decreases, **pressure increases**
  - When volume increases, **pressure decreases**
- Throughout the cardiac cycle, **heart valves open and close** as a result of **pressure changes** in different regions of the heart
  - Valves **open** when the pressure of blood **behind them is greater than the pressure in front of them**

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- They **close** when the pressure of blood **in front of them is greater than the pressure behind them**

- Valves are an important mechanism **to stop blood flowing backwards**

Atrial systole

- The walls of the **atria contract**
  - Atrial volume decreases
  - Atrial pressure increases
- The pressure in the atria rises above that in the ventricles, **forcing the atrioventricular (AV) valves open**
- Blood is forced into the ventricles
  - There is a slight increase in ventricular pressure and chamber volume as the **ventricles receive the blood from the atria**
- The ventricles are relaxed at this point; **ventricular diastole** coincides with atrial systole

Ventricular systole

- The walls of the ventricles contract
  - Ventricular volume decreases
  - Ventricular pressure increases
- The pressure in the ventricles rises above that in the atria
  - This **forces the AV valves to close**, preventing back flow of blood
- The pressure in the ventricles rises above that in the aorta and pulmonary artery
  - This **forces the semilunar (SL) valves open** so blood is forced into the arteries and out of the heart
- During this period the atria are relaxing; **atrial diastole** coincides with ventricular systole
  - The blood flow to the heart continues, so the relaxed **atria begin to fill with blood** again

Diastole

- The **ventricles and atria are both relaxed**
- Pressure in the ventricles drops below that in the aorta and pulmonary artery, forcing the **SL valves** to **close**
- The atria continue to fill with blood
  - **Blood returns to the heart** via the vena cava and pulmonary vein
- Pressure in the atria rises above that in the ventricles, forcing the **AV valves open**
- **Blood flows passively into the ventricles** without need of atrial systole

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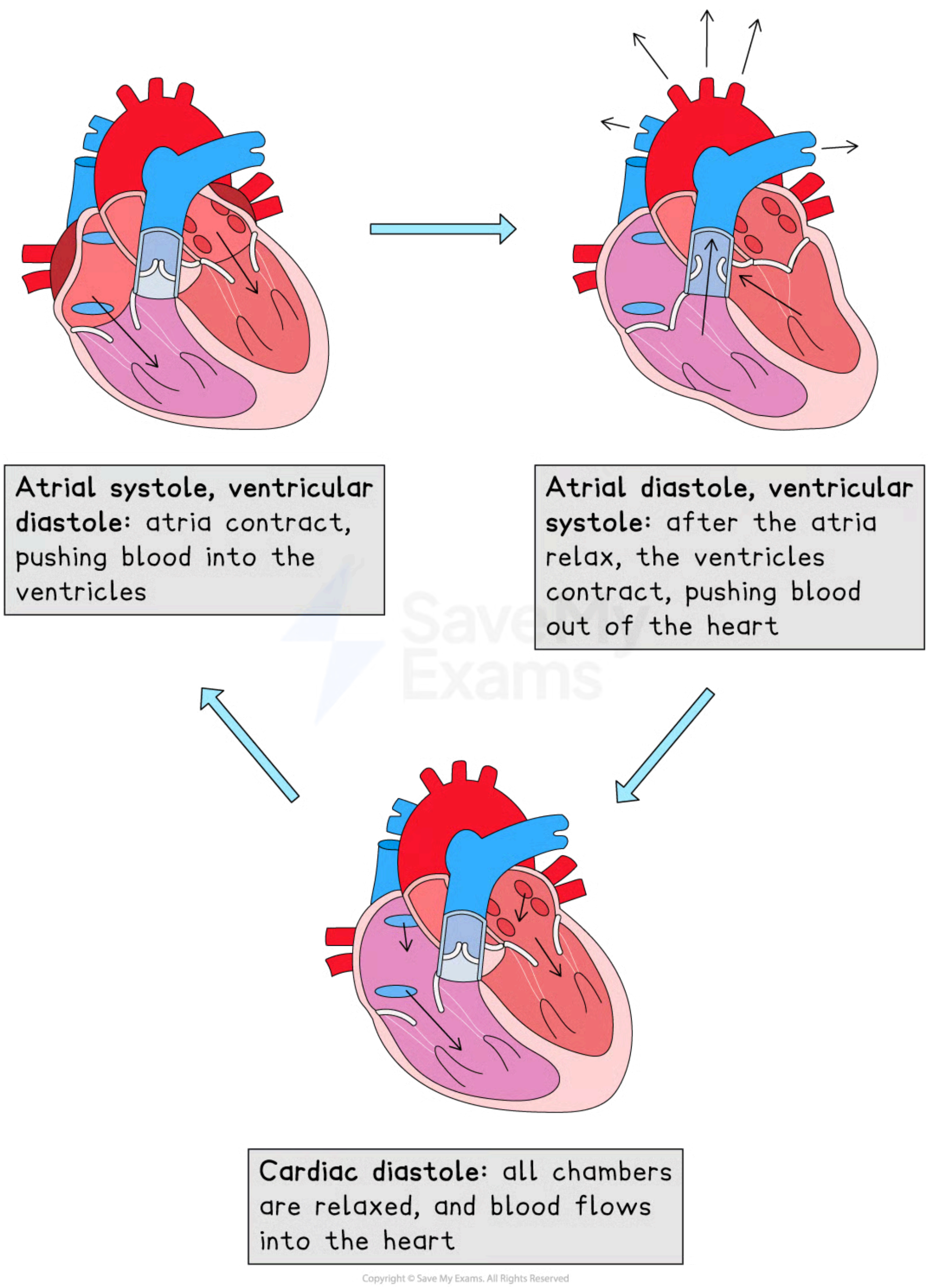
- The cycle then begins again with atrial systole



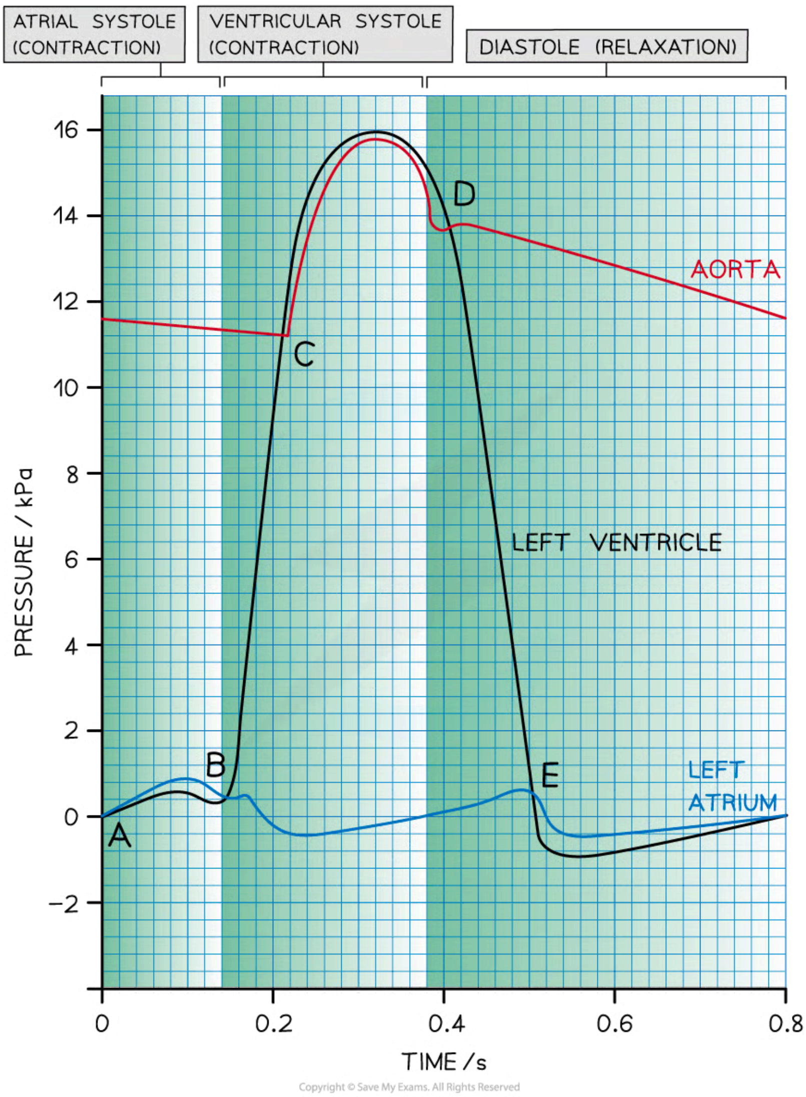
The events of the cardiac cycle allow the heart to pump blood to the lungs and body

Valves during the cardiac cycle table

Stage in cardiac cycle	Atrioventricular valves	Semilunar valves
Atrial systole	Open	Closed

Your notes

Ventricular systole	Closed	Open
Diastole	Open	Closed



The pressure changes in the cardiac cycle can be analysed

Analysing the cardiac cycle

- The lines on the graph represent the **pressure** of the left atrium, aorta, and the left ventricle
- The points at which the **lines cross each other** are important because they indicate when **valves open and close**

Point A – the end of diastole

- The atrium has filled with blood during the preceding diastole

- Pressure is higher in the atrium than in the ventricle, so the **AV valve is open**

Between points A and B – atrial systole

- **Left atrium contracts,** causing an increase in atrial pressure and forcing blood into the left ventricle
- Ventricular pressure increases slightly as it fills with blood
- Pressure is higher in the atrium than in the ventricle, so the **AV valve is open**

Point B – beginning of ventricular systole

- **Left ventricle contracts** causing the ventricular pressure to increase
- Pressure in the left atrium drops as the muscle relaxes
- Pressure in the ventricle exceeds pressure in the atrium, so the **AV valve shuts**

Point C – ventricular systole

- The ventricle continues to contract
- Pressure in the left ventricle exceeds that in the aorta
- **Aortic valve opens** and blood is forced into the aorta

Point D – beginning of diastole

- Left ventricle has been emptied of blood
- Muscles in the walls of the left ventricle relax and pressure falls below that in the newly filled aorta
- **Aortic valve closes**

Between points D and E – early diastole

- The ventricle **remains relaxed** and ventricular pressure continues to decrease
- In the meantime, blood is **flowing into the relaxed atrium** from the pulmonary vein, causing an increase in pressure

Point E – diastole

- The relaxed left atrium fills with blood, causing the pressure in the atrium to exceed that in the newly emptied ventricle
- **AV valve opens**

After point E – late diastole

- There is a short period of time during which the **left ventricle expands** due to relaxing muscles
- This increases the internal volume of the left ventricle and **decreases the ventricular pressure**
- At the same time, blood is flowing slowly through the newly opened AV valve into the left ventricle, causing a **brief decrease in pressure** in the left atrium

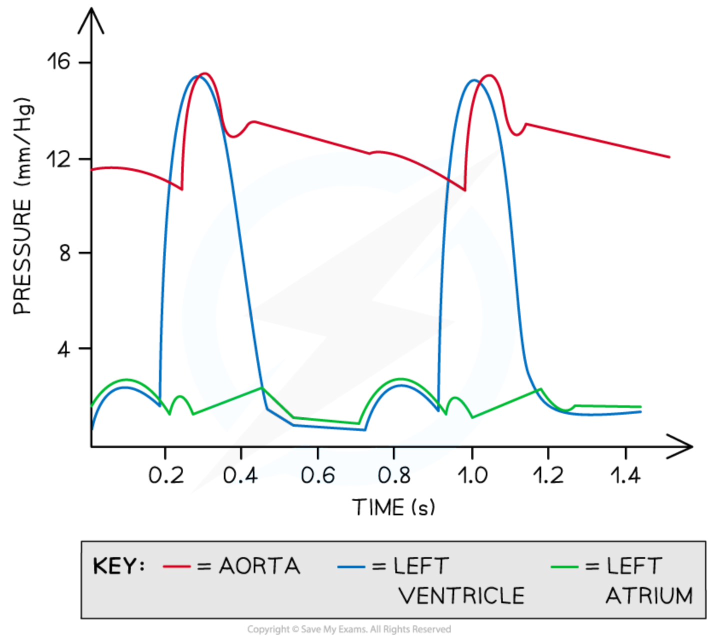
- The pressure in both the atrium and ventricle then **increases slowly** as they continue to fill with blood

Your notes

Worked Example

The graph below shows the cardiac cycle.

Calculate the heart rate of this person. Give your answer in beats per minute.



Answer:

Step 1: Work out the length of one heart beat

It takes 0.7 seconds for completion of one cardiac cycle, which is **one heart beat**

So there is 1 cycle in 0.7 seconds

Step 2: Calculate how many heart beats occur per second

Divide by 0.7 to find out how many cycles in 1 second

1 ÷ 0.7 = 1.43 beats in 1 second

Step 3: Calculate how many heart beats occur per minute

Multiply by 60 to find out how many cycles in 60 seconds

1.43 × 60 = 85.71 beats in 60 seconds

So the heart rate is **85.71 beats min^{-1}**

Examiner Tips and Tricks

You might be asked to interpret the graph of the cardiac cycle so it is important you understand it and can analyse where each stage of the cycle is happening. Common areas of assessment are about the pressure and volume changes, where valves open and close, and when blood starts flowing in or out of specific chambers.

Your notes

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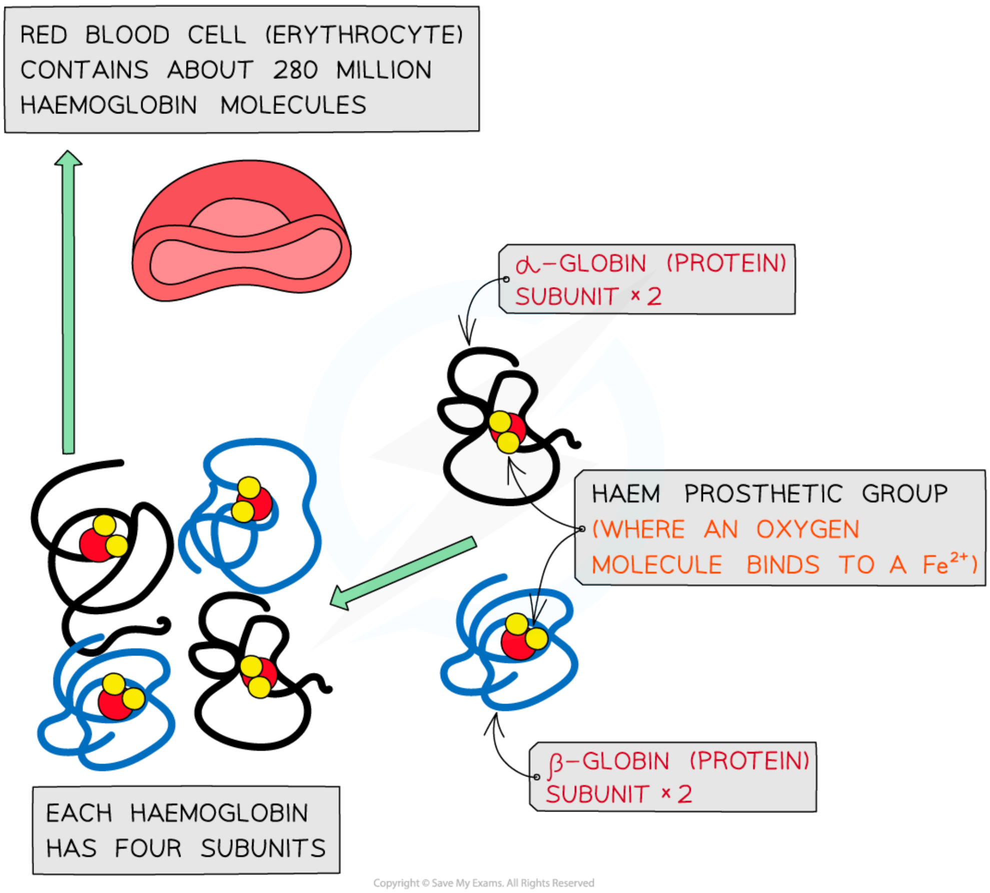
Haemoglobin Structure & Function

Transport of oxygen

- The majority of oxygen transported around the body is **bound to the protein haemoglobin in red blood cells**
  - Red blood cells are also known as **erythrocytes**
- Each molecule of haemoglobin contains **four haem groups**, each able to bond with one molecule of oxygen
  - This means that each molecule of haemoglobin can carry four oxygen molecules, or eight oxygen atoms in total



Haemoglobin proteins are made up of four subunits, each of which contains a region called a haem group to which oxygen can bind

- When oxygen binds to haemoglobin, oxyhaemoglobin is formed

Oxygen + Haemoglobin ⇌ Oxyhaemoglobin

$$4O_2 + Hb \rightleftharpoons Hb4O_2$$

- The binding of the first oxygen molecule results in a conformational change in the structure of the haemoglobin molecule, making it easier for each successive oxygen molecule to bind; this is **cooperative binding**
- The reverse of this process happens when oxygen dissociates in the tissues

Your notes

Carbon dioxide transport

- Waste carbon dioxide produced during respiration diffuses from the tissues into the blood
- There are three main ways in which carbon dioxide is transported around the body
  - A very small percentage of carbon dioxide dissolves directly in the blood plasma and is transported in solution
  - Carbon dioxide can **bind to haemoglobin**, forming **carbaminohaemoglobin**
  - A much larger percentage of carbon dioxide is transported in the form of **hydrogen carbonate ions (HCO^{3-})**

Formation of hydrogen carbonate ions

- Carbon dioxide **diffuses into red blood cells**
- Inside red blood cells, carbon dioxide combines with water to form H_2CO_3

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

-
  - Red blood cells contain the enzyme **carbonic anhydrase** which catalyses the reaction between carbon dioxide and water
  - Without carbonic anhydrase this reaction proceeds very slowly
  - The plasma contains very little carbonic anhydrase hence H_2CO_3 forms **more slowly in plasma** than in the cytoplasm of red blood cells
- Carbonic acid dissociates readily into H^+ and HCO^{3-} ions

$$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

- Hydrogen ions can combine with haemoglobin, forming **haemoglobinic acid** and preventing the H^+ ions from **lowering the pH** of the red blood cell
  - Haemoglobin is said to act as a **buffer** in this situation
- The hydrogen carbonate ions diffuse out of the red blood cell **into the blood plasma** where they are transported in solution

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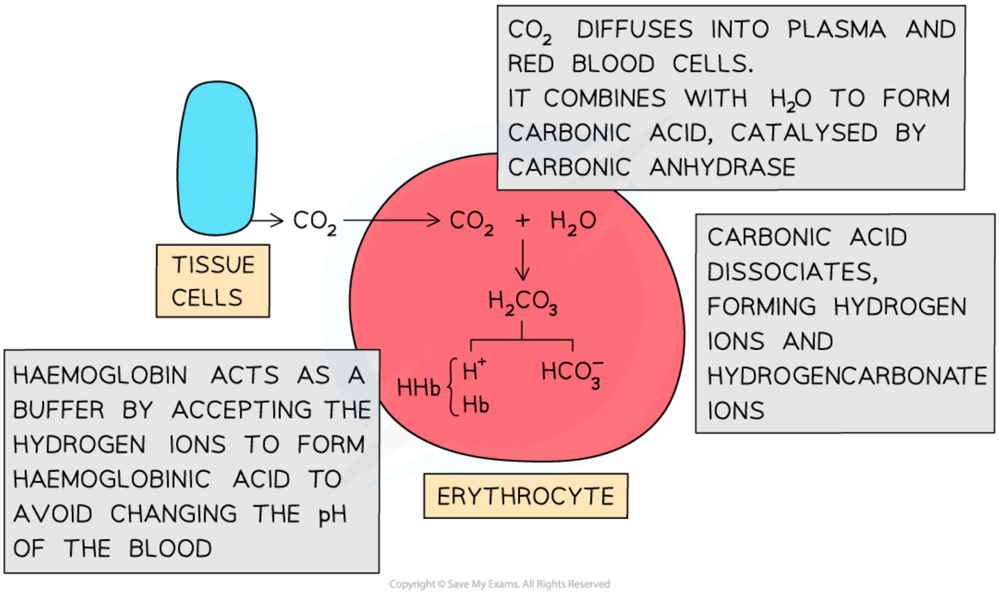


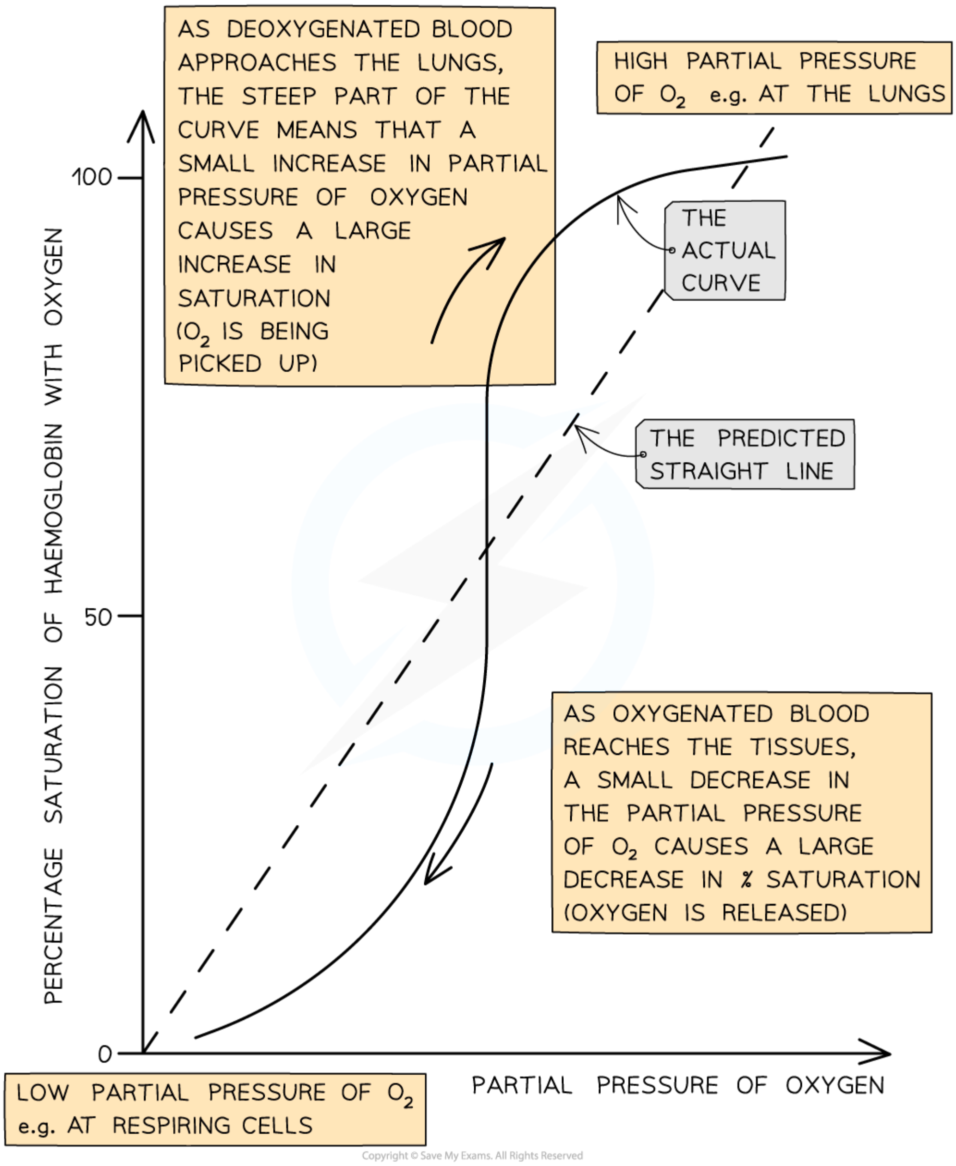
Carbon dioxide can be transported in the form of hydrogen carbonate ions

Association & Dissociation of Haemoglobin

The oxygen dissociation curve

- The oxygen dissociation curve shows the **rate at which oxygen associates, and also dissociates, with haemoglobin** at different **partial pressures of oxygen (pO_2)**
  - Partial pressure of oxygen refers to the **pressure exerted by oxygen within a mixture of gases**; it is a **measure of oxygen concentration**
  - Haemoglobin is referred to as being saturated when **all of its oxygen binding sites are taken up with oxygen**; so when it contains **four oxygen molecules**
- The ease with which haemoglobin binds and dissociates with oxygen can be described as its **affinity for oxygen**
  - When haemoglobin has a high affinity it **binds easily** and **dissociates slowly**
  - When haemoglobin has a low affinity for oxygen it **binds slowly** and **dissociates easily**
- In other liquids, such as water, we would expect oxygen to becomes associated with water, or to dissolve, at a **constant rate**, providing a **straight line** on a graph, but with haemoglobin **oxygen binds at different rates as the pO_2 changes**; hence the resulting curve
  - It can be said that haemoglobin's **affinity for oxygen changes at different partial pressures of oxygen**

Your notes



Oxygen binds to haemoglobin at different rates as the partial pressure of oxygen changes; the resulting curve is known as the oxygen dissociation curve

Explaining the shape of the curve

- The curved shape of the oxygen dissociation curve for haemoglobin can be explained as follows
  - Due to the shape of the haemoglobin molecule, it is **difficult for the first oxygen molecule to bind** to haemoglobin; this means that binding of the first oxygen occurs slowly, explaining the relatively **shallow curve at the bottom left** corner of the graph
  - After the first oxygen molecule binds to haemoglobin, the **haemoglobin protein changes shape**, or conformation, making it **easier for the next oxygen molecules to bind**; this speeds up binding of the remaining oxygen molecules and explains the **steeper part of the curve in the middle** of the graph

Your notes

- The shape changes of haemoglobin leading to easier oxygen binding is known as **cooperative binding**

- As the haemoglobin molecule approaches saturation it takes longer for the fourth oxygen molecule to bind due to the shortage of remaining binding sites, explaining the **levelling off of the curve in the top right** corner of the graph

Your notes

Interpreting the curve

- When the curve is read from left to right, it provides information about the **rate at which haemoglobin binds to oxygen** at different partial pressures of oxygen
  - At **low pO_2**, in the bottom left corner of the graph, **oxygen binds slowly to haemoglobin**; this means that haemoglobin cannot pick up oxygen and become saturated as blood passes through the body's oxygen-depleted tissues
    - Haemoglobin has a **low affinity for oxygen at low pO_2,** so saturation percentage is low
  - At **medium pO_2**, in the central region of the graph, oxygen **binds more easily to haemoglobin** and **saturation increases quickly**; at this point on the graph a **small increase in pO_2 causes a large increase in haemoglobin saturation**
  - At high pO_2, in the top right corner of the graph, **oxygen binds easily to haemoglobin**; this means that haemoglobin can pick up oxygen and become saturated as blood passes through the lungs
    - Haemoglobin has a **high affinity for oxygen at high pO_2,** so saturation percentage is high
    - Note that at this point on the graph **increasing the pO_2 by a large amount only has a small effect on the percentage saturation of haemoglobin**; this is because most oxygen binding sites on haemoglobin are already occupied
- When read from right to left, the curve provides information about the **rate at which haemoglobin dissociates with oxygen** at different partial pressures of oxygen
  - In the lungs, where **pO_2 is high**, there is **very little dissociation** of oxygen from haemoglobin
  - At **medium pO_2, oxygen dissociates readily from haemoglobin**, as shown by the **steep region of the curve**; this region **corresponds with the partial pressures of oxygen present in the respiring tissues** of the body, so ready release of oxygen is important for cellular respiration
    - At this point on the graph a **small decrease in pO_2 causes a large decrease in percentage saturation** of haemoglobin, leading to easy release of plenty of oxygen to the cells
  - At **low pO_2 dissociation slows again**; there are few oxygen molecules left on the binding sites, and the release of the final oxygen molecule becomes more difficult, in a similar way to the slow binding of the first oxygen molecule

The Bohr effect

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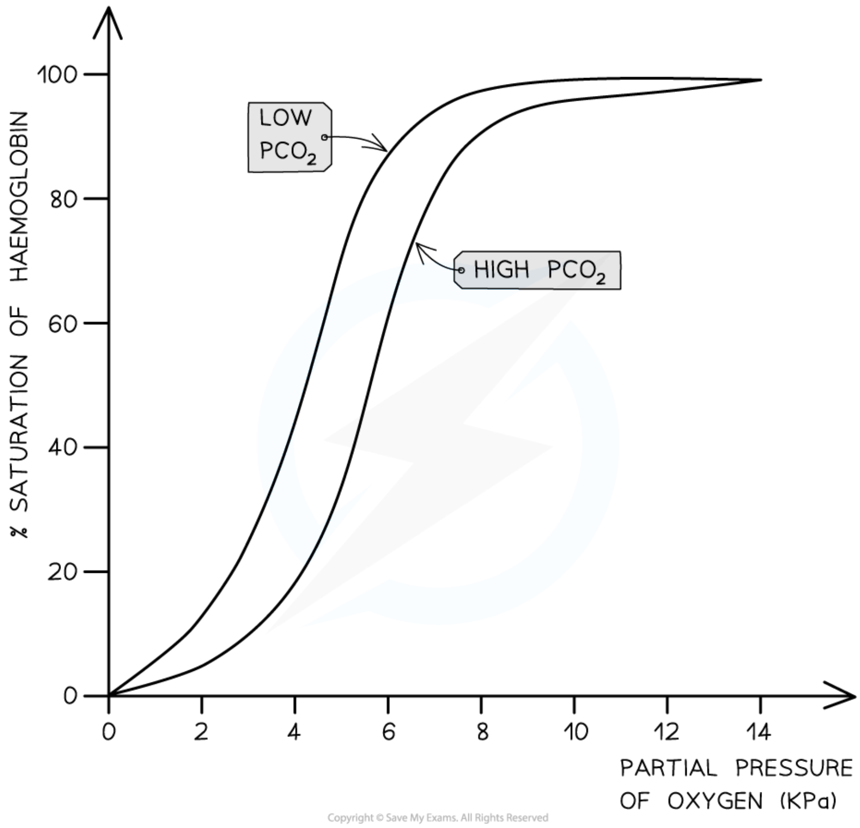
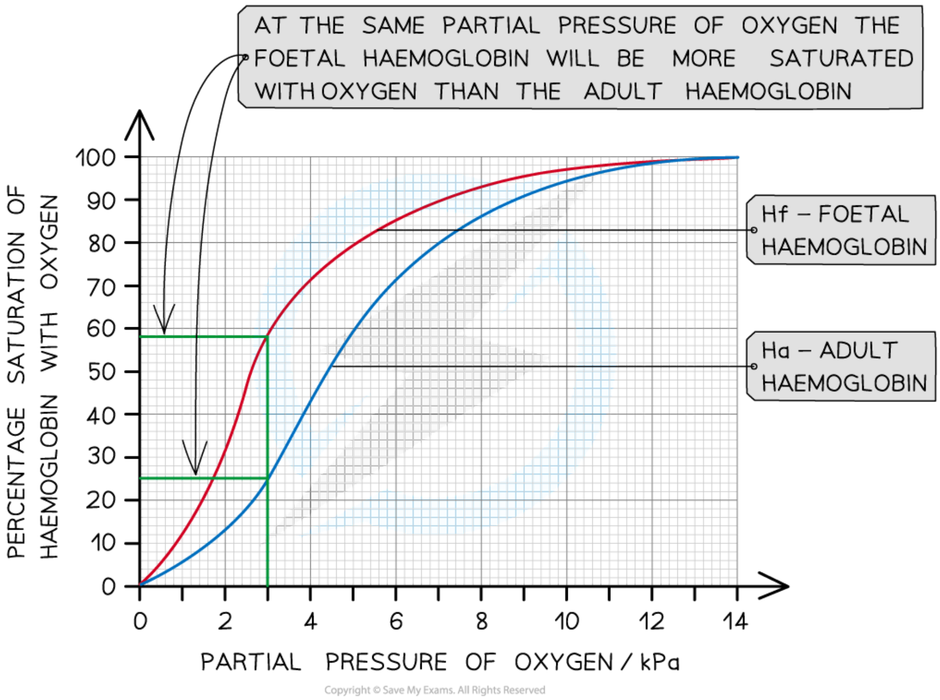
- Changes in the oxygen dissociation curve **as a result of carbon dioxide levels** are known as the **Bohr effect**, or Bohr shift
- When the **partial pressure of carbon dioxide in the blood is high, haemoglobin's affinity for oxygen is reduced**
  - This is the case in **respiring tissues**, where cells are producing carbon dioxide as a waste product of respiration
  - This occurs because **CO_2 lowers the pH of the blood**
    - CO_2 combines with water to form carbonic acid
    - Carbonic acid dissociates into hydrogen carbonate ions and hydrogen ions
    - Hydrogen ions bind to haemoglobin, causing the release of oxygen
- This is a helpful change because it means that **haemoglobin gives up its oxygen more readily** in the respiring tissues where it is needed
- On a graph showing the dissociation curve, the curve **shifts to the right** when CO_2 levels increase
  - This means that **at any given partial pressure of oxygen, the percentage saturation of haemoglobin is lower at higher levels of CO_2**



The dissociation curve shifts to the right as a result of the Bohr effect. This means that at any given partial pressure of oxygen, the percentage saturation of haemoglobin is lower at higher CO_2 levels

Foetal haemoglobin

- The haemoglobin of a developing foetus has a **higher affinity for oxygen than adult haemoglobin**
- This is vital as it allows a foetus to **obtain oxygen from its mother's blood** at the placenta
  - Foetal haemoglobin can **bind to oxygen at low pO_2**
  - At this low pO_2 the mother's haemoglobin is **dissociating with oxygen**
- On a dissociation curve graph, the curve for foetal haemoglobin **shifts to the left** of that for adult haemoglobin
  - This means that **at any given partial pressure of oxygen, foetal haemoglobin has a higher percentage saturation than adult haemoglobin**
- After birth, a baby begins to produce adult haemoglobin which **gradually replaces** foetal haemoglobin
  - This is important for the **easy release of oxygen in the respiring tissues** of a more metabolically active individual



Foetal haemoglobin has a higher affinity for oxygen than adult haemoglobin. This means that at any given pO_2, foetal haemoglobin will have a higher percentage saturation than adult haemoglobin

Atherosclerosis

- There are a number of diseases of the heart, or cardiovascular diseases, that can affect blood vessels in different ways
- **Atherosclerosis,** also known as hardening of the arteries, is caused primarily by damage to the delicate endothelium of an artery followed by an **inflammatory response**
  - It is a progressive disease, meaning that it can worsen over time
- In a healthy artery the **endothelium** is smooth and unbroken to reduce friction between blood and the inside of the artery
- The steps involved in atherosclerosis are
  - **Damage**, e.g. by high blood pressure, is caused to the **endothelium**
    - Damage can also occur as a result of high levels of certain types of cholesterol, smoking, diabetes, obesity, and old age
  - An **inflammatory response** occurs and white blood cells, such as macrophages, accumulate in the damaged area
  - **Lipids** and **cholesterol** clump together with the macrophages **under the endothelium** and form **fatty streaks**
    - This is one of the first signs of atherosclerosis
  - **Platelets** can also add to the fatty deposit
    - Platelets are fragments of red blood cells involved in the blood clotting process
  - The collection of cholesterol, lipids, macrophages and platelets accumulate under the endothelium
    - The structure forms a **plaque** known as an **atheroma**
  - The atheroma narrows the lumen of the artery, reducing and restricting blood flow and thereby **raising blood pressure**
  - Over time the plaque can **calcify and harden**, reducing elasticity of the artery wall and further increasing blood pressure

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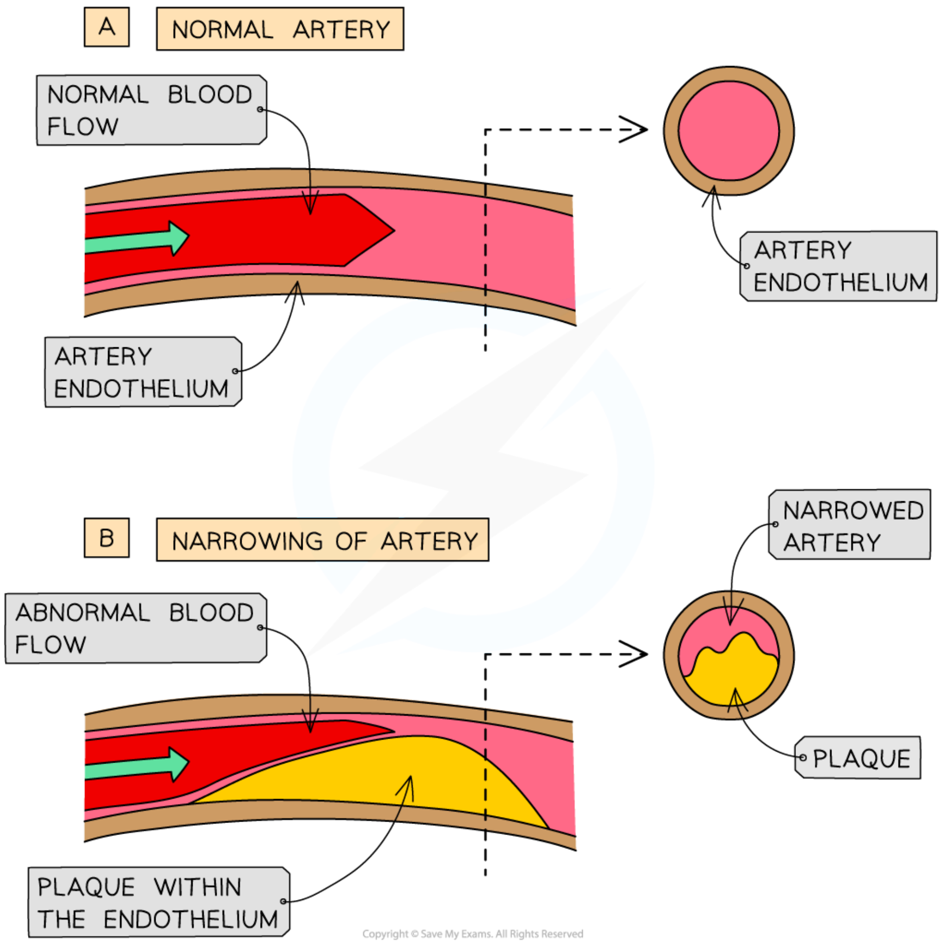

Atherosclerosis is the process by which atheroma plaques form in the endothelium of arteries

Your notes

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Blood Clotting

- Blood clotting is an important process; it prevents excess blood loss, the entry of pathogens, and provides a barrier, or scab, under which wound healing can occur
- A break in the mucous membranes or skin membranes causes the release of molecules that trigger a **chemical cascade,** which results in blood clotting
- The chemical cascade involves a large number of steps and several plasma proteins
- The process of blood clotting involves
  - Platelets release **thromboplastin**, which acts as an enzyme
  - **Calcium ions** from the plasma, along with thromboplastin, trigger the conversion of soluble **prothrombin** protein into the enzyme **thrombin**
  - Thrombin catalyses the conversion of the **soluble protein fibrinogen** to the **insoluble protein fibrin**
  - Fibrin fibres mesh and tangle together, **trapping platelets and red blood cells**
  - A blood clot is formed

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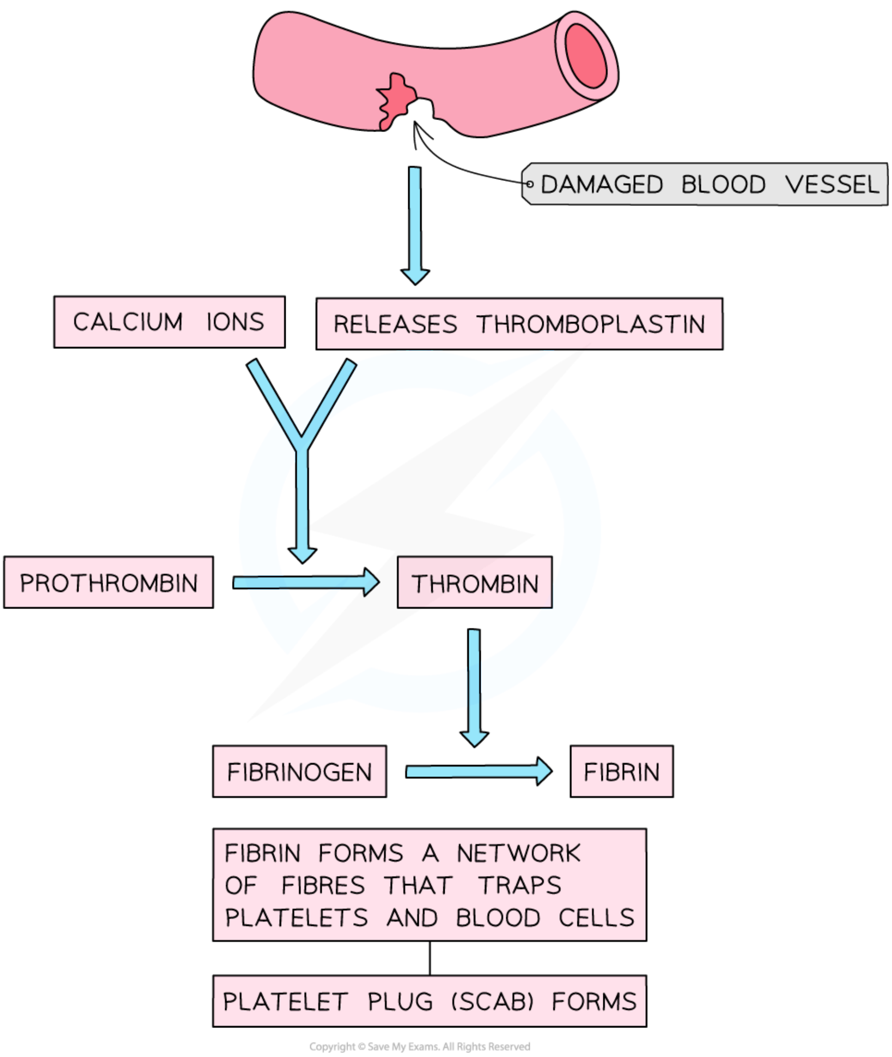

Blood clotting is brought about by a cascade of chemical reactions

Blood clots and atheromas

- **Atheromas** can **increase the risk** of blood clotting
  - The **plaque deposit** of an atheroma can **rupture through the endothelium** of the artery, damaging the endothelium and forming a rough surface
  - The damage to the endothelium triggers the process of blood clotting
- The combination of atheromas and blood clotting can be dangerous to an individual
  - The blood clot that forms can **completely block the artery**
    - Blood clots reduce blood flow, which **restricts the movement of oxygen** in the blood, therefore **reducing the respiration** of the surrounding cells, tissues and organs
    - The blood clots can dislodge and travel to different blood vessels in the body; if they reach the brain, this can cause a **stroke** to occur

- A blood clot that forms within a blood vessel, obstructing blood flow, is called a **thrombus**

Your notes

- Blood clotting can also lead to
  - **Heart attack**
  - **Deep vein thrombosis**

Stroke

- A stroke is a **sudden loss of brain function** in a localised area due to **disruption of blood flow** to the brain
  - A blood clot leads to a **blockage of the arteries** supplying the brain
  - This leads to **reduced blood flow and delivery of oxygen** to the cells of the brain, reducing respiration
  - Cells in the affected part of the brain cannot produce ATP and their function is reduced
- A stroke caused by a blood clot is called an **ischemic stroke**

Heart attack

- **Coronary heart disease (CHD)** is caused by the formation of atheromas and blood clots in the **coronary arteries**
  - The coronary arteries flow over the surface of the heart, supplying the heart muscle itself with blood
- **Blood flow to certain areas of the heart is restricted** and delivery of oxygen to the affected cells decreases, thereby **reducing respiration** in these cells
  - The cells can no longer produce ATP
  - The cells can no longer contract, **reducing the force generated by the heart** when it beats
  - The cells can die, causing permanent damage to heart tissue
- This leads to a **myocardial infarction,** also known as a heart attack
- **Complete heart failure** may occur if large areas of the heart are affected by blood clots; this can be fatal
- **Symptoms** of a heat attack include
  - Chest pain
  - Shortness of breath
  - Sweating

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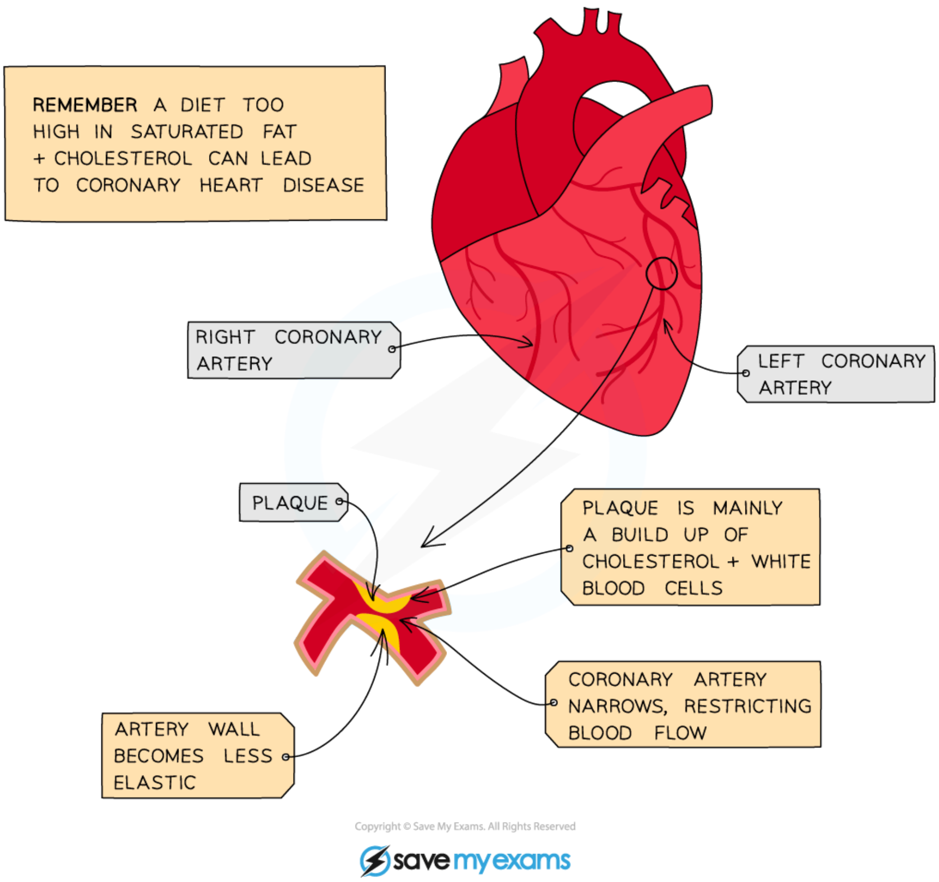

Atheroma and blood clots in the coronary arteries can restrict blood flow to the heart muscle, leading to a heart attack

Deep vein thrombosis

- If a blood clot forms in a vein deep inside the body, it is known as **deep vein thrombosis (DVT)**
- This is most common in the **veins of the legs**
- Causes include
  - prolonged inactivity
  - old age
  - some medications