DP IB Biology: SL

Your notes

6.2 The Blood System

Contents

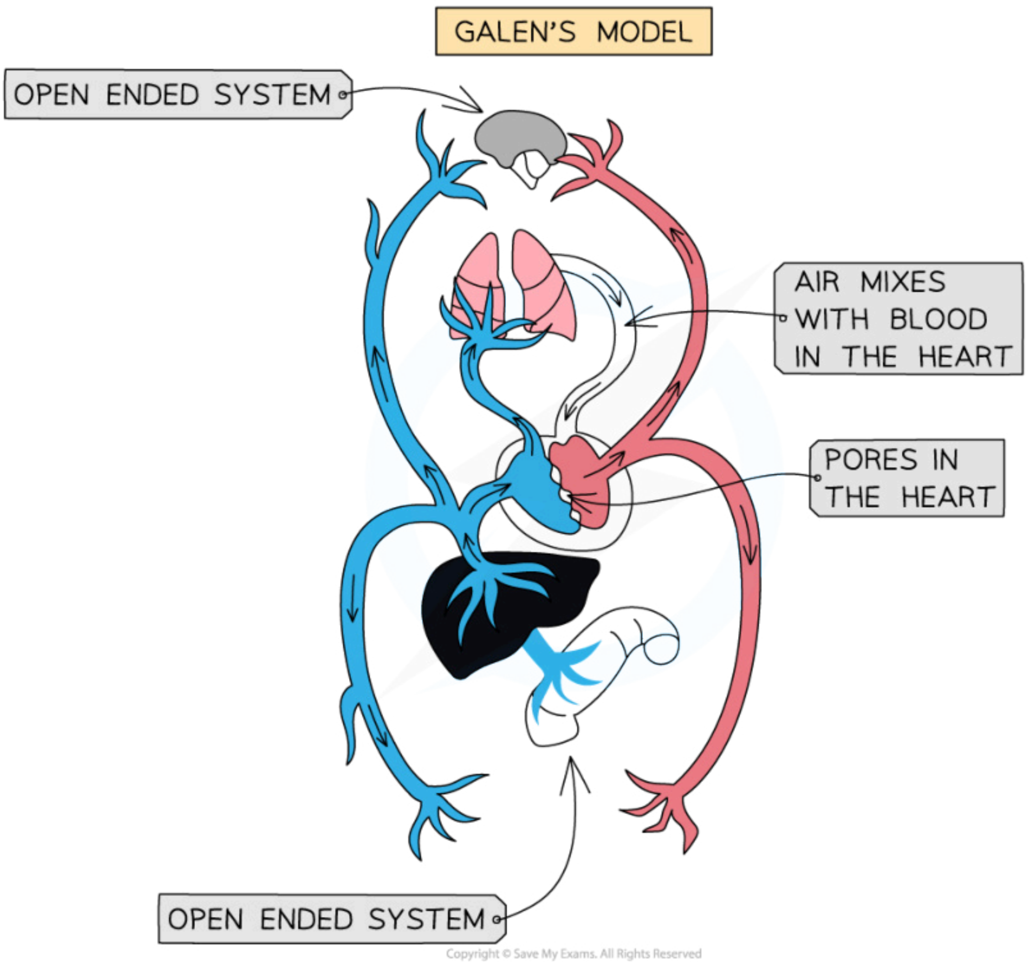
6.2.1 The Blood System: History

Your notes

Discovery of the Circulation of Blood

NOS: Theories are regarded as uncertain; William Harvey overturned theories developed by the ancient Greek philosopher Galen on movement of blood in the body

- A theory can be defined as:
  - **A carefully thought-out idea, with accompanying evidence, that explains observations of the natural world**
- Theories are often **constructed using the scientific method** which involves bringing together many facts and hypotheses
  - There is always a level of **uncertainty** when using scientific methods
  - Uncertainty can be due to
    - Natural **variability of individual organisms**
    - **Accuracy** of measurements taken
- Theories can therefore be regarded as **uncertain** due to the **uncertainties in the methods used**
- New technology or the discovery of new evidence often results in theories being falsified or overturned
- An example of the **falsification of a set of theories** is that of Galen's theories about the blood and circulation
  - **Galen** was an **ancient Greek philosopher** and surgeon who developed the following theories
    - Blood is formed in the **liver from ingested food**
    - Blood is pumped backwards and forwards between the **liver** and the **right ventricle** in the heart
    - Some blood moves into the **left ventricle** through invisible **pores** and mixes with **air from the lungs**
    - This mixing of air with blood produces **spirits** which are distributed to the body via the **brain**
    - Blood is **consumed by the tissues** so that new blood must be continuously made
  - Galen **failed to present any evidence** for his theories
- Galen's theories were **overturned** by English physician **William Harvey** through a series of **experiments and observations**
  - Harvey developed the following theories, which were ridiculed at the time
    - Blood is pumped to the **brain and body by the heart**
    - Blood circulates through the **pulmonary** and **systemic circulation systems**
    - **Capillaries exist** which link arteries to veins
    - Blood flow is too fast for blood to be consumed by the tissues; it would run out too quickly to be replaced. Instead, blood **returns to the heart** and **re-circulates**
  - Harvey refused to accept Galen's theories without **direct evidence** and he toured Europe to **demonstrate evidence** for his own theories to others, eventually leading to acceptance of his new theories


GALEN'S MODEL
OPEN ENDED SYSTEM
AIR MIXES WITH BLOOD IN THE HEART
PORES IN THE HEART
OPEN ENDED SYSTEM
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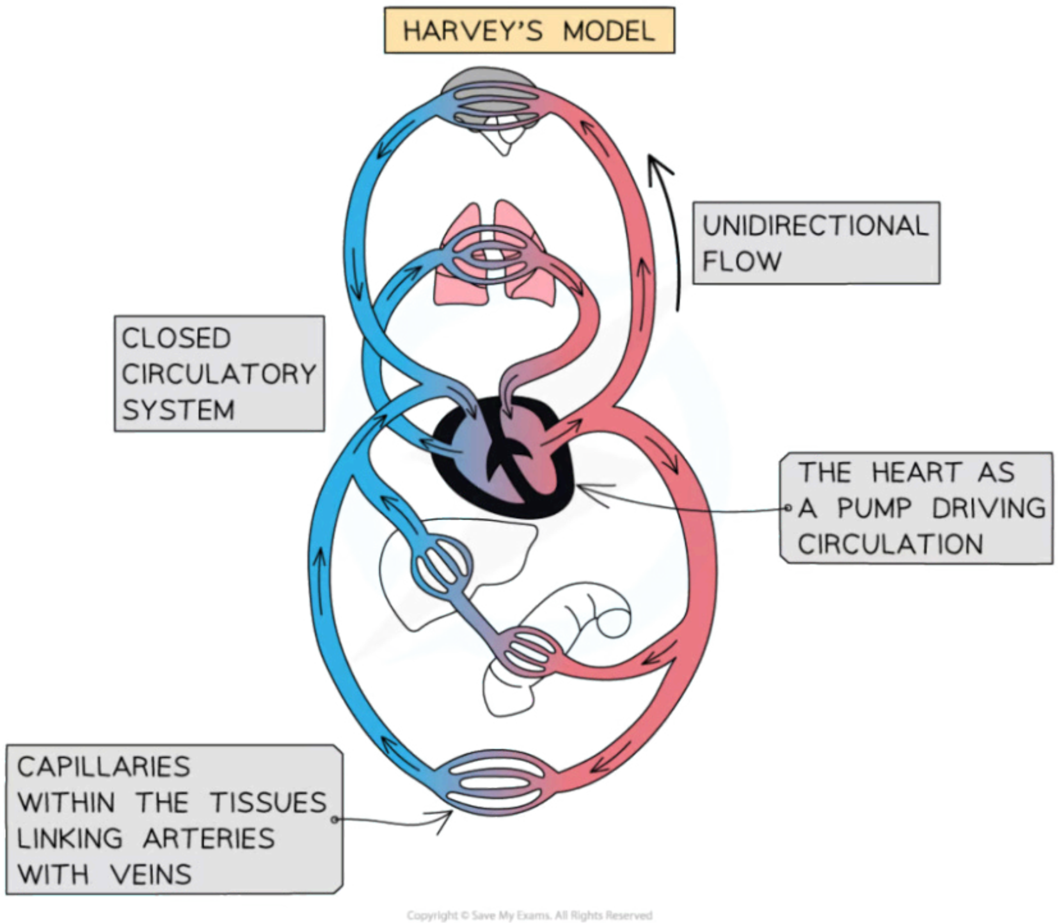
Your notes



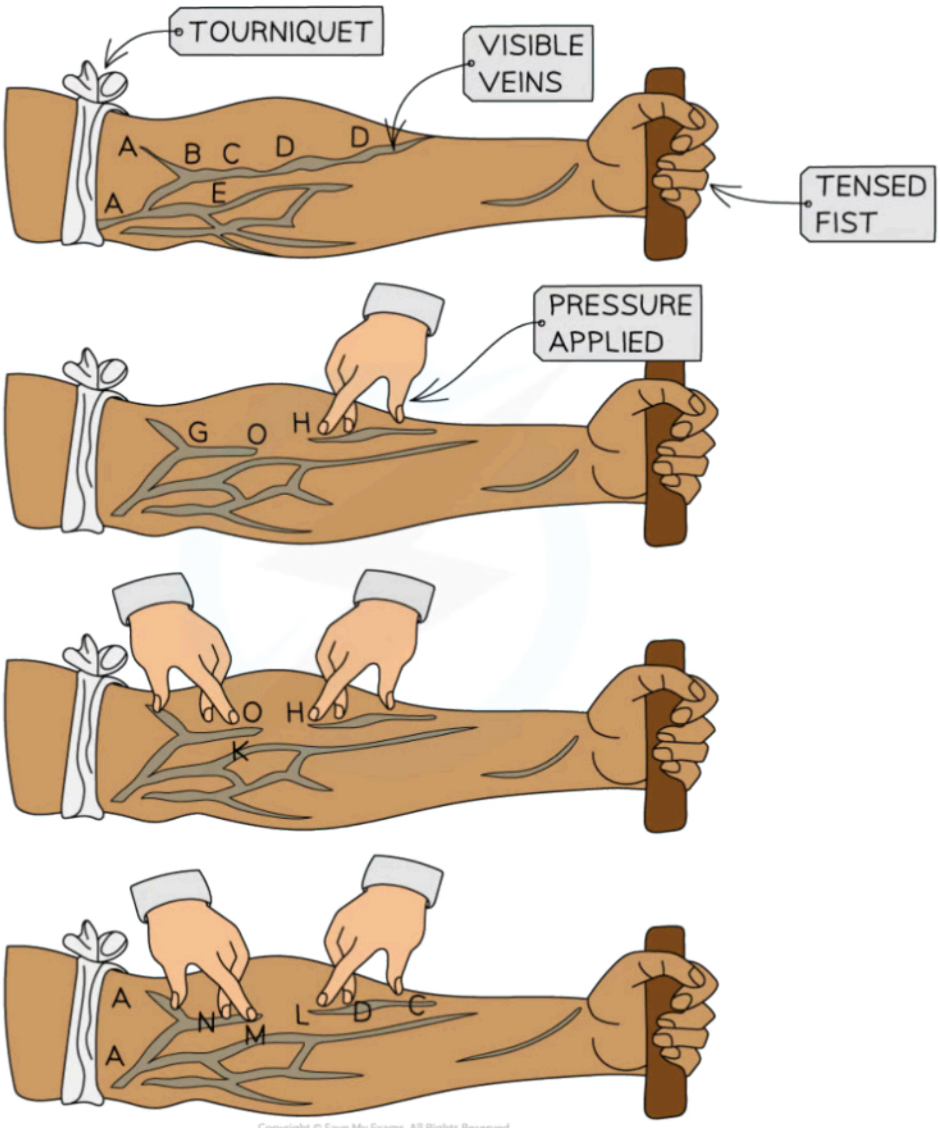
Galen proposed a model which was later disproved by William Harvey

Discovery of the Heart as a Pump

Your notes

- Harvey used a **series of experiments** to show that blood flow is **unidirectional** and that the presence of **valves prevents backflow** in veins
  - Harvey attached a tourniquet to a person's upper arm and instructed them to grip tightly onto a pole
    - A tourniquet is a band applied to a limb to limit blood flow to the lower part of that limb
  - Once the veins became visible, Harvey proceeded to **apply pressure to the veins systematically** to show how blood flow was affected
  - He used this method to demonstrate how **blood moves unidirectionally** through the veins in the arm

Your notes



William Harvey showed the movement of blood into the veins of the arms in this simple experiment

- He then demonstrated how the **heart acts as a pump** which forces blood out through the arteries; it then **circulates** around the body before it **returns to the heart** through the veins
- He also showed that the blood being pumped out of the heart was **travelling too quickly** to be constantly used up by the tissues, as described by Galen
- Despite not having powerful enough microscopes to see the capillaries, Harvey **predicted** their presence as small vessels which link the arteries to the veins

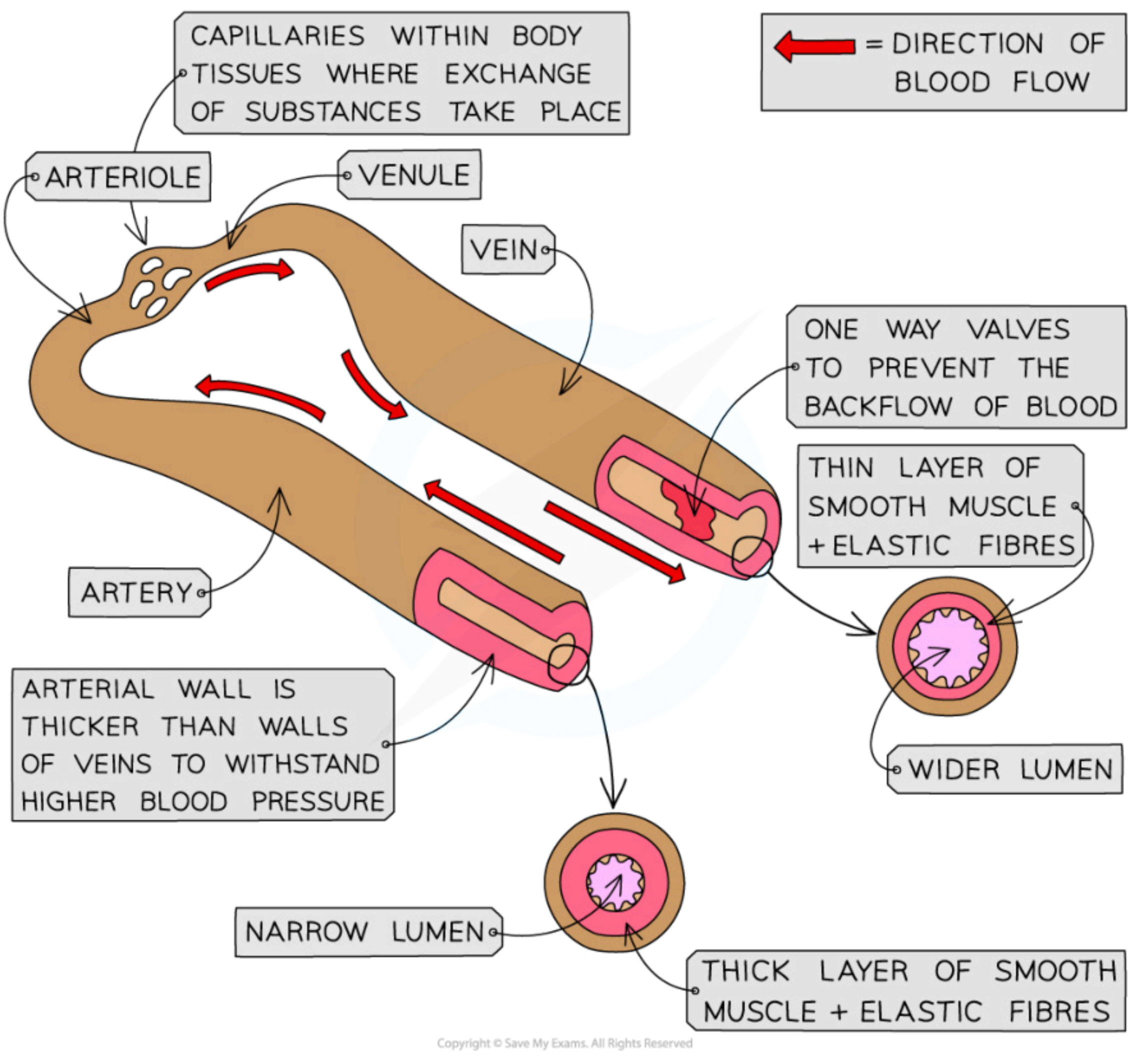
6.2.2 The Blood System: Vessels

Your notes

Arteries

Introduction to blood vessels

- The **circulatory system** of the human body contains several different types of **blood vessel**:
  - Arteries
  - Arterioles
  - Capillaries
  - Venules
  - Veins
- Each type of blood vessel has a **specialised structure** that relates to the function of that vessel



The circulatory system includes several blood vessels, each specialised to carry out its function

Your notes

Structure and function of arteries

- **Arteries** transport blood away from the heart at high pressure
  - Blood travels from the ventricles to the tissues of the body
  - Remember; **a**rteries carry blood **a**way from the heart

- Artery walls consist of **three layers**:
  - The **tunica intima** is the innermost layer and is made up of **an endothelial layer, a layer of connective tissue** and **a layer of elastic fibres**
    - 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

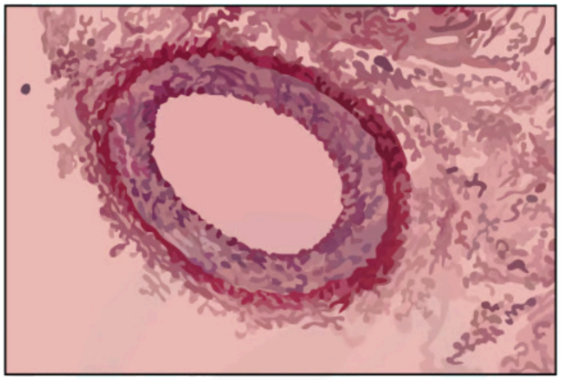
  - The **tunica media** is made up of **smooth muscle cells** and a **thick layer of elastic tissue**
    - Arteries have a **thick** tunica media
    - The layer of muscle cells strengthen the arteries so they can **withstand high pressure**
      - Blood leaves the heart under high pressure

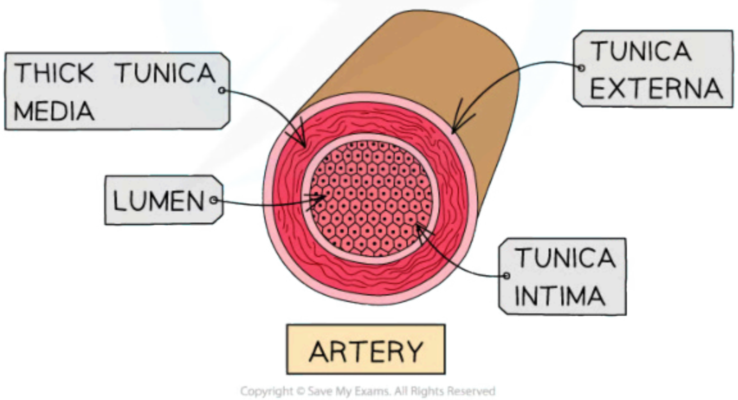
    - Muscles cells can also **contract or relax** to control the diameter of the lumen and **regulate blood pressure**
    - The elastic tissue helps to **maintain blood pressure** in the arteries. It **stretches** and **recoils** to even out fluctuations in pressure

  - The **tunica externa** covers the exterior of the artery and is mostly made up of **collagen**
    - Collagen is a strong protein and 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 due to blood leaving the heart under high pressure

Your notes





Arteries have thick muscular walls made up of three layers of tissue and a narrow lumen

Structure and function of arterioles

- **Arterioles** branch off from arteries forming narrower blood vessels which transport blood into capillaries
- Arterioles are similar in structure to arteries, but they have a **lower proportion of elastic fibres** and a **large number of muscle cells**
- The presence of muscle cells allows them to **contract** and close their lumen to **regulate blood flow** to specific organs
  - Eg. during exercise blood flow to the stomach and intestine is reduced while blood flow to the muscles increases

Arterial blood pressure

- Arteries, and to a slightly lesser extent arterioles, must be able to **withstand high pressure** generated by the contracting heart, and both must **maintain this pressure** when the heart is relaxed
- **Muscle** and **elastic fibres** in the arteries help to maintain the **blood pressure** as the heart contracts and relaxes
  - **Systolic pressure** is the peak pressure point reached in the arteries as the blood is forced out of the ventricles at high pressure

Your notes

    - At this point, the walls of the arteries are forced outwards, enabled by the **stretching** of elastic fibres
  - **Diastolic pressure** is the lowest pressure point reached within the artery as the heart relaxes
    - At this point, the stretched elastic fibres **recoil** and force the blood onward through the lumen of the arteries
  - This maintains high pressure throughout the heart beat cycle
- Vasoconstriction of the circular muscles of the arteries can increase blood pressure by **decreasing the diameter of the lumen**
- Vasodilation of the circular muscles causes blood pressure to decrease by **increasing the diameter of the lumen**

Examiner Tip

Be careful with the language you use to describe the roles of muscle and elastic tissue; muscle can **contract** and **relax**, while elastic tissue can **stretch** and **recoil**.

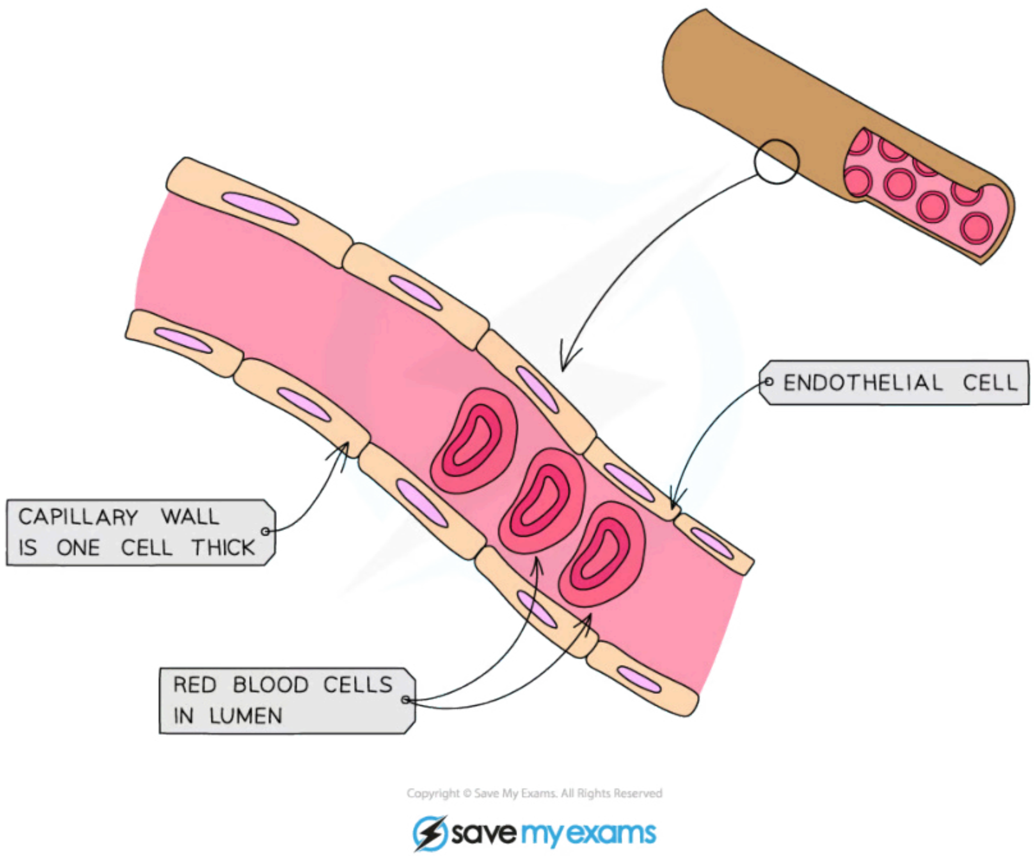
Capillaries

Your notes

Structure and function of capillaries

- **Capillaries** provide the **exchange surface** in the tissues of the body through a network of vessels called capillary beds
  - The wall of a capillary is made from a **single layer of endothelial cells** (this layer is also found lining the lumen in arteries and veins)
    - Being just **one cell thick** reduces the **diffusion distance** for **oxygen** and **carbon dioxide** between the blood and the tissues of the body
  - The thin endothelium cells also have gaps between them called **pores** which allow blood plasma to leak out and form **tissue fluid**
    - Tissue fluid contains **oxygen, glucose** and other small molecules from the blood plasma
    - Large molecules such as proteins usually can't fit through the pores into the tissue fluid
    - Tissue fluid surrounds the cells, enabling **exchange** of substances such as oxygen, glucose, and carbon dioxide
    - The **permeability** of capillaries can vary depending on the requirements of a tissue
  - Capillaries have a lumen with a **small diameter**
    - Red blood cells squeeze through capillaries in single-file
    - This forces the blood to travel slowly which provides more opportunity for diffusion to occur
  - Capillaries form **branches in between the cells;** this is the capillary bed
    - These branches increase the **surface area** for diffusion of substances to and from the cells
    - Being so close to the cells also reduces the **diffusion distance**

Your notes



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

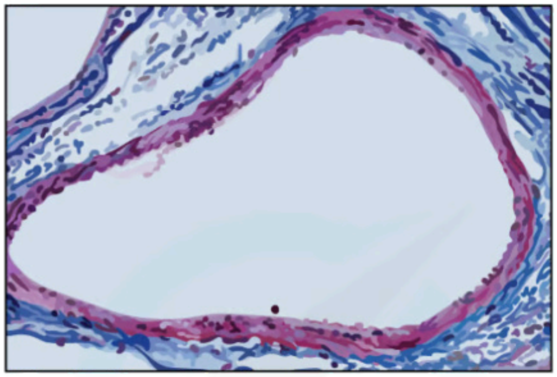
Veins

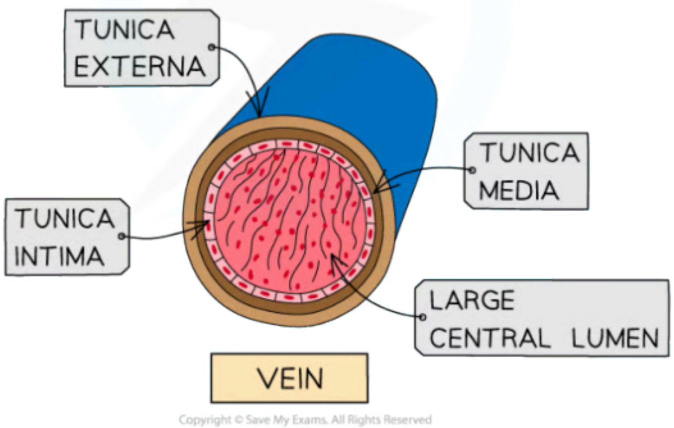
Structure and function of veins

Your notes

- **Veins** transport blood to the heart at **low pressure**
  - Remember; ve**in**s carry blood **in**to the heart
- They receive blood that has passed through capillary networks, across which **pressure has dropped** due to the slow flow of blood
- The structure of veins differs from arteries:
  - The **tunica media** is much **thinner** in veins
    - There is no need for a thick muscular and elastic layer as veins don't have to maintain or withstand high pressure
  - The **lumen** of veins is much **wider in diameter** than that of arteries
    - 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 endothelial layer 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
  - Veins contain **valves**
    - These **prevent the back flow** of blood that can result under low pressure, helping return blood to the heart
    - Movement of the skeletal muscles pushes the blood through the veins, and any blood that gets pushed backwards gets caught in the valves; this blood can then be moved forwards by the next skeletal muscle movement
- A pulse is **absent** in veins; the pressure changes taking place due to the beating of the heart are no longer present

Your notes





Veins have a structure similar to arteries with three layers of tissue and a large lumen

Structure and function of venules

- Venules connect the **capillaries to the veins**
- They have **few** or **no elastic fibres** and a **large lumen**
  - As the blood is at low pressure after passing through the capillaries there is no need for a muscular layer to maintain pressure
  - The large lumen enables a large volume of blood to be transported

> **Examiner Tip**
>
> 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, "Capillaries have walls that are one-cell thick, enabling quick and efficient diffusion of substances due to a short diffusion distance."

6.2.3 The Blood System: Double Circulation

Your notes

Double Circulation

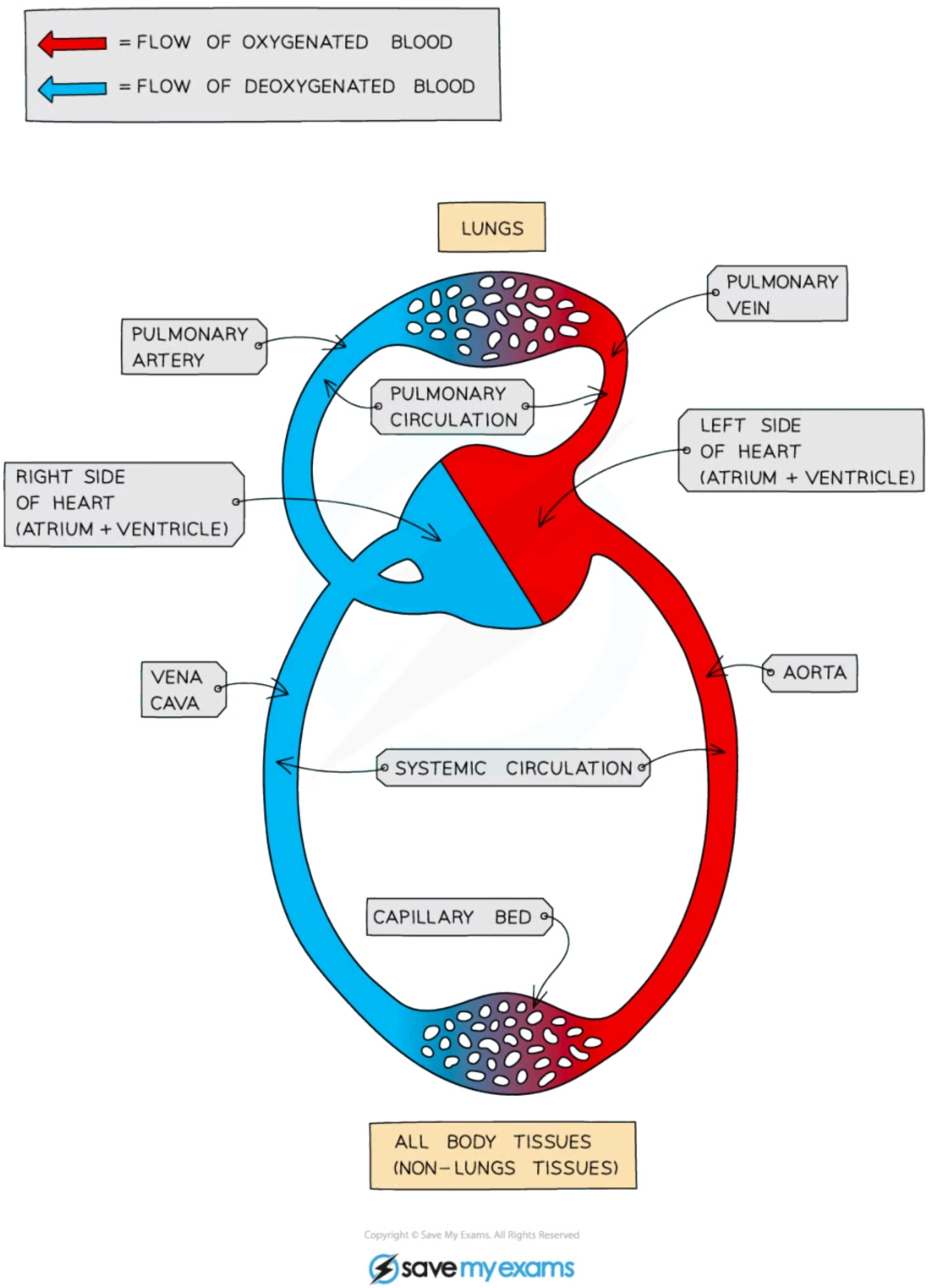
The need for a circulatory system

- All organisms need to **transport** materials to where they are needed inside their tissues
  - **Small organisms** (or relatively inactive animals like jellyfish) can rely on **diffusion** alone to transport oxygen, carbon dioxide and nutrients around their bodies
  - **Larger organisms** have more layers of cells, so diffusion alone is insufficient for transport of materials between cells further from the exchange surface of the organism
- **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 ensure that fluids containing these substances reach all of the cells in an organism **quickly enough** to supply their needs and remove waste

Humans have a closed, double circulatory system

- A **closed** circulatory system is one in which blood is **contained within a network of blood vessels**
  - As opposed to an open circulatory system in which the fluid fills the body cavity e.g. as in insects
- A **double** circulatory system passes through the heart **twice** for every **one** complete circuit of the body, with blood passing through **two separate circuits** known as **pulmonary** and **systemic** circulation
  - In the **pulmonary circulatory system**
    - The right side of the heart pumps **deoxygenated** blood to the **lungs** for gas exchange
    - **Blood pressure is lower** in the pulmonary system; this prevents damage to the lungs
  - In the **systemic circulatory system**
    - **Oxygenated** blood returns to the left side of the heart from the lungs
    - The left ventricle then pumps the oxygenated blood at **high pressure** around the **body**

Your notes


= FLOW OF OXYGENATED BLOOD
= FLOW OF DEOXYGENATED BLOOD
LUNGS
PULMONARY ARTERY
PULMONARY VEIN
PULMONARY CIRCULATION
LEFT SIDE OF HEART (ATRIUM + VENTRICLE)
RIGHT SIDE OF HEART (ATRIUM + VENTRICLE)
VENA CAVA
AORTA
SYSTEMIC CIRCULATION
CAPILLARY BED
ALL BODY TISSUES (NON–LUNGS TISSUES)
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The double circulatory system in mammals

Your notes

Main Circulatory System Structures Table

Structure	Function
Heart	A hollow, muscular organ located in the chest cavity which pumps blood. Cardiac muscle tissue is specialised for repeated involuntary contraction without rest.
Arteries	Blood vessels which carry blood away from the heart. The walls of the arteries contain lots of muscle and elastic tissue and a narrow lumen, to maintain high blood pressure. Arteries range from 0.4 – 2.5cm in diameter.
Arterioles	Small arteries which branch from larger arteries and connect to capillaries. These are around 30 μm in diameter.
Capillaries	Tiny blood vessels (5–10 μm in diameter) which connect arterioles and venules. Their size means they pass directly past cells and tissues and perform gas exchange and exchange of substances such as glucose.
Venules	Small veins which join capillaries to larger veins. They have a diameter of 7 μm – 1mm.
Veins	Blood vessels which carry blood back towards the heart. The walls of veins are thin in comparison to arteries, having less muscle and elastic tissue but a wider lumen. Valves help maintain blood flow back towards the heart.

6.2.4 The Blood System: Cardiac Cycle

Your notes

Introduction to the Heart

Mammalian heart structure

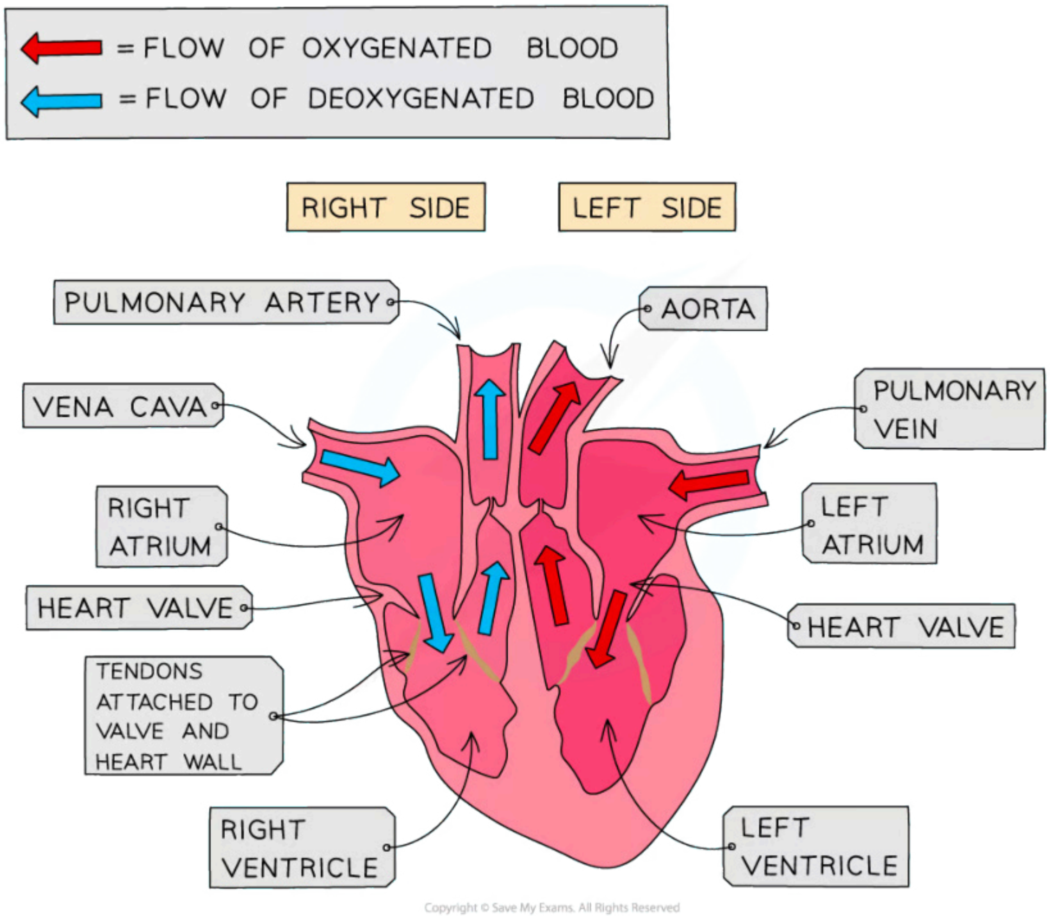
- The heart is a hollow, **muscular organ** located in the chest cavity
- The heart is divided into **four chambers**
  - The two top chambers are **atria**
  - The bottom two chambers are **ventricles**

- 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

- **Valves** are important for keeping blood flowing **forward** in the right direction and stopping it flowing backwards. They are also important for maintaining the correct pressure in the chambers of the heart
  - The atria and ventricles are separated by the **atrioventricular valves**
  - The ventricles and the arteries that leave the heart are separated by **semi-lunar valves**
    - The right ventricle and the pulmonary artery are separated by the **pulmonary valve**
    - The left ventricle and aorta are separated by the **aortic valve**

- There are two blood vessels bringing blood to the heart; the **vena cava** and **pulmonary vein**
- There are two blood vessels taking blood away from the heart; the **pulmonary artery** and **aorta**

Your notes



The human heart has four chambers and is separated into two halves by the septum

Your notes

Sinoatrial Node

Contraction of the heart muscle

- The contraction of the heart is called **systole**, while the relaxation of the heart is called **diastole**
- **Atrial systole** is the period when the atria are contracting and **ventricular systole** is when the ventricles are contracting
- Atrial systole happens around 0.13 seconds after ventricular systole
- Atrial systole forces blood **from the atria into the ventricles**
- During ventricular systole, blood is forced **from the ventricles into the pulmonary artery** and **aorta**
- One systole and diastole makes a heartbeat and lasts around 0.8 seconds in humans.
- This is the **cardiac cycle**

Initiation of the heartbeat by the sinoatrial node

- The heart muscle is **myogenic**, meaning that the heart will beat without any external stimulus from other organs or the nervous system
  - This intrinsic control causes the heart to beat at around 60 beats per minute
- The heart beat is initiated by a **group of cells** in the wall of the **right atrium** called the **sinoatrial node** (**SAN**)
- The cells of the sinoatrial node **depolarise**, reversing the charge across their membranes
  - This triggers a **wave of depolarisation** that spreads across the rest of the heart
- The sinoatrial node is considered to be the **pacemaker** of the heart because it **initiates** the heart beat and so controls the **speed at which the heart beats**
  - Note that **artificial pacemakers** are electronic devices implanted just underneath the skin. They can be used to replace or regulate the sinoatrial node if it becomes defective

Cardiac Cycle

Your notes

Electrical control of the cardiac cycle

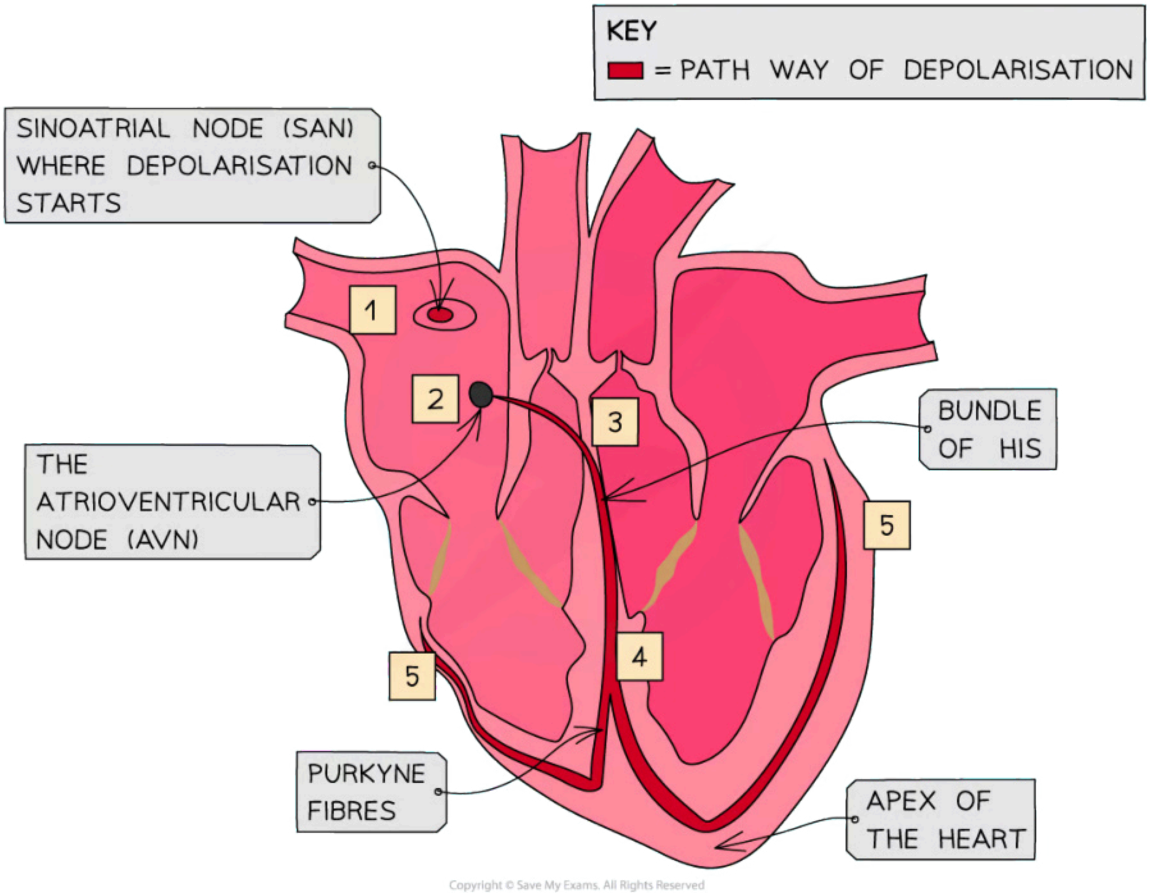
- The **cardiac cycle** is the series of events that take place in **one heart beat**, including **atrial** and **ventricular systole**
- The cardiac cycle is controlled by **electrical signals** that are initiated in the **sinoatrial node**
  - Depolarisation of the cells in the **sinoatrial node** sends an electrical signal over the **atria**, causing them to contract in **atrial systole**
  - The electrical signal then reaches a region of **non-conducting** tissue which prevents it from spreading straight to the ventricles; this causes the signal to pause for around 0.1 s
    - This delay means that the atria can **complete their contraction** before the ventricles begin to contract
  - The electrical signal is carried to the ventricles via the **atrioventricular node** (**AVN**)
    - This is a region of conducting tissue between atria and ventricles
  - The signal then travels to the base of the heart via **conductive fibres** in the septum known as the bundle of His
  - The electrical signal is then carried through another set of conductive fibres called Purkyne fibres which spread around the sides of the ventricles, causing **contraction of the ventricles** from the apex, or base, of the heart upwards
    - This is called **ventricular systole**
    - Blood is forced out of the heart into the **pulmonary artery** and **aorta**

Electrical Control of the Cardiac Cycle Table

Your notes

Stage in sequence	Event
1	Sinoatrial node sends out a wave of excitation
2	Atria contract
3	Atrioventricular node sends out a wave of excitation
4	Purkyne tissue conducts the wave of excitation
5	Ventricles contract

Your notes



The wave of depolarisation spreads across the heart in a coordinated manner

Worked example

Explain the roles of the sinoatrial node, the atrioventricular node and the conductive fibres in a heartbeat.

The cells of the sinoatrial node depolarise and send out an electrical signal which spreads across both atria, causing atrial systole. Non-conducting tissue between the atria and ventricles prevents depolarisation from spreading to the ventricles, ensuring that the atria finish contracting before the ventricles begin. The atrioventricular node then sends the electrical signal to the apex of the ventricles via conductive fibres in the septum known as the bundle of His. The electrical signal is then carried upwards around the walls of the ventricles by conductive tissues called Purkyne fibres. This means that during ventricular systole, the blood contracts from its base and blood is pushed upwards and outwards.

Your notes

Cardiac Cycle Pressure Changes

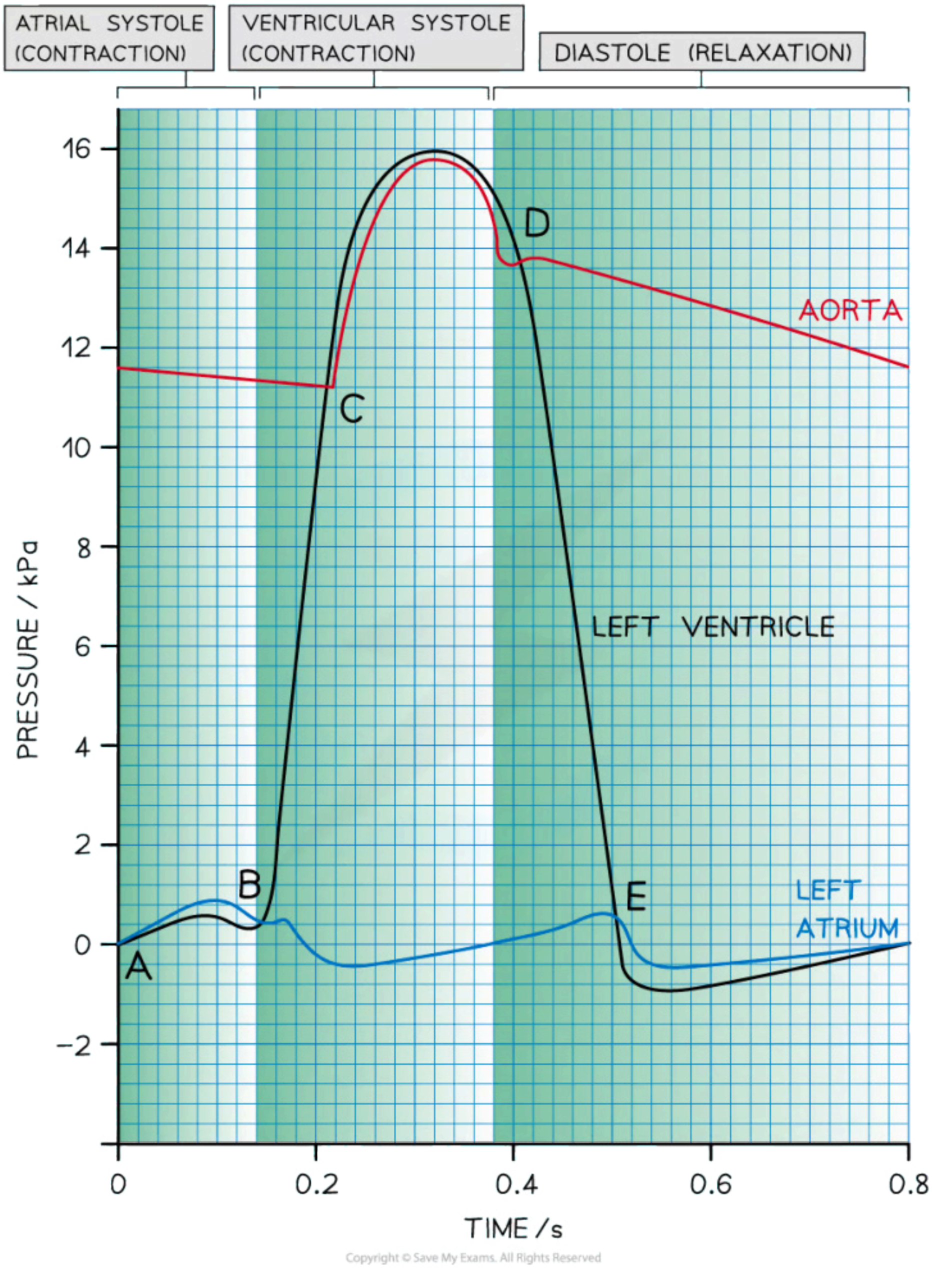
- **Contraction** of the heart muscle causes an **increase in pressure** in the corresponding chamber if the heart, which then **decreases** again when the muscle **relaxes**
- Throughout the cardiac cycle, **heart valves open and close** as a result of **pressure changes** in different regions of the heart:
  - Valves **open** when the pressure of blood **behind them is greater than the pressure in front of them**
  - 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**
- The pressure changes of the cardiac cycle can be represented in a graph

Pressure changes during diastole

- During **diastole**, the heart muscle is **relaxing**
  - During this period, blood begins to flow into the atria from the veins, **increasing the atrial pressure**
- Relaxed muscle in the heart walls **recoils**, **increasing the volume** of the chambers of the heart:
  - The **atrioventricular valves open** as the pressure in the atria is higher than the pressure in the ventricles
  - The **semilunar valves close** as the pressure in the pulmonary artery and aorta is higher than the pressure in the ventricles

Pressure changes during systole

- During **systole**, the heart **contracts** and pushes blood out of the heart
- The **contraction of the muscles** in the wall of the heart **reduces the volume** of the heart chambers and **increases the pressure** within that chamber
- In **atrial systole**, the atria contract
  - The **atrioventricular valves are open** as the pressure in the atria exceeds the pressure in the ventricles
  - The **semilunar valves are closed** as the pressure in the ventricles is less than the pressure in the aorta and pulmonary artery
- In **ventricular systole**, the ventricles contract
  - The **atrioventricular valves are closed** as the pressure in the ventricles exceeds the pressure in the atria
  - The **semilunar valves are open** as the pressure in the ventricles exceeds the pressure in the aorta and pulmonary artery



Graph showing the pressure changes within the aorta, left atrium and left ventricle during the cardiac cycle. The atrioventricular valves open at E and close at B, while the semilunar valves open at C and close at D.

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**

Your notes

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

Examiner Tip

When looking at the heart, remember the right side of the heart will appear on the page as being on the left. This is because the heart is labelled as if it were in your body and flipped around. Remember that the heart muscle is **myogenic**, which means that the heart will generate a heartbeat by itself and without any other stimulation. Instead, the electrical activity of the heart regulates the heart rate.The maximum pressure in the ventricles is substantially higher than in the atria. This is because there is much **more muscle** in the thick walls of the ventricles which can **exert more force** when they contract.

Your notes

6.2.5 The Heart Rate

Heart Rate: Alteration by Nervous System

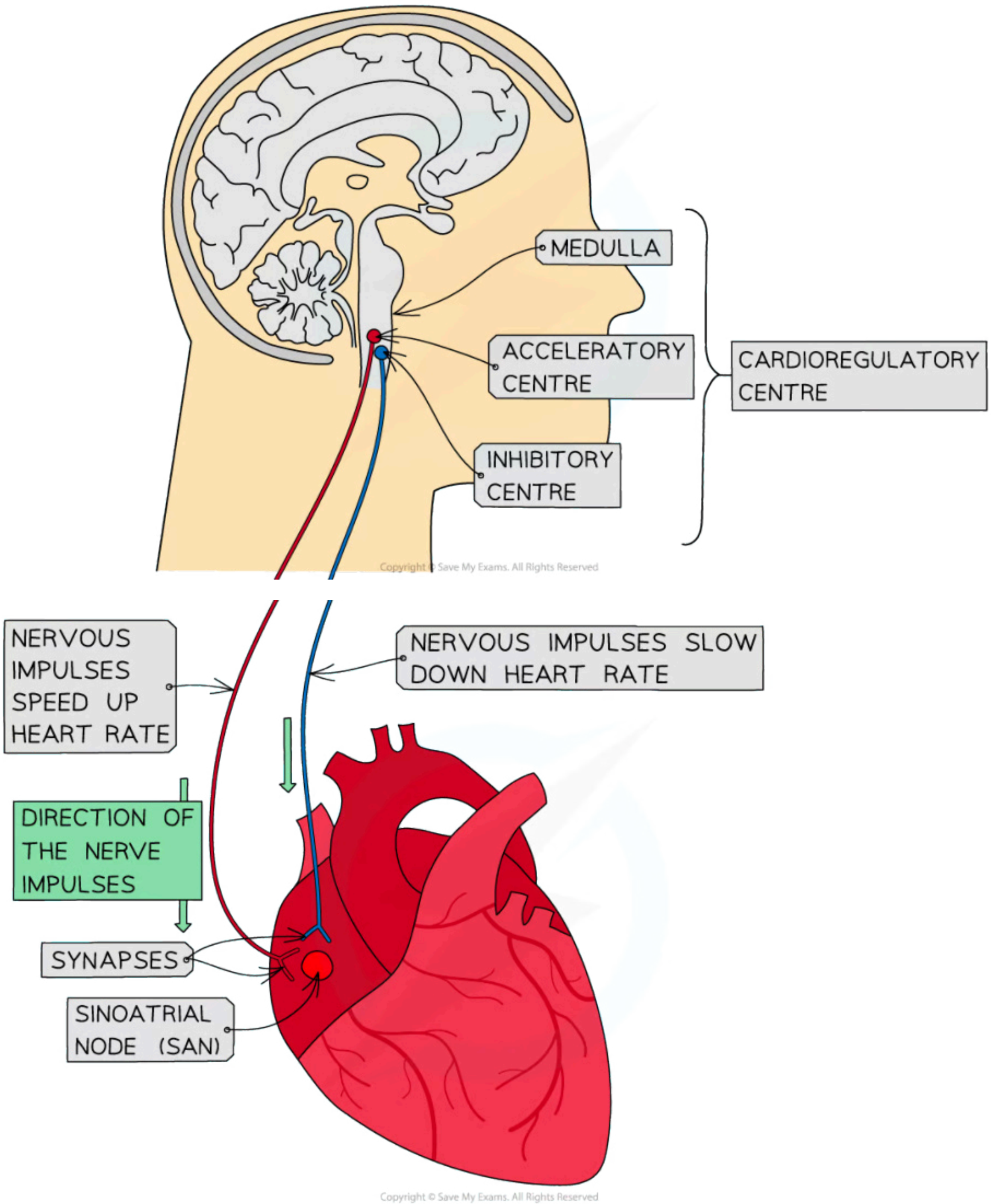
- Although the heart muscle maintains a base heart rate via myogenic stimulation, there are several circumstances that can cause an individual's heart rate to change, e.g.
  - Exercise
  - Stress
  - Relaxation

- The **brain** is involved in the regulation of heart rate, though it does not require conscious thought
  - The branch of the nervous system that does not require conscious thought is known as the **autonomic nervous system**

- The area of the brain that controls heart rate is the **cardiovascular centre,** located in a region of the brain called the **medulla**
- The medulla is found at the base of the brain near the top of the **spinal cord**
- Two nerves connect the medulla with **the sinoatrial node** (SAN):
  - One nerve connects to the **acceleratory centre**, which causes the heart to **speed up**
    - This happens in response to **low blood pressure, low oxygen concentrations** and **low pH**
    - These changes might occur during **exercise**
    - The blood vessels dilate, causing a decrease in blood pressure
    - The muscle cells are using up oxygen at a faster rate, causing blood oxygen levels to drop
    - The production of carbon dioxide by respiring cells causes blood pH to decrease

  - The other nerve connects to the **inhibitory centre**, which causes the heart to **slow down**
    - This happens in response to **high blood pressure, high oxygen concentrations and high pH**
    - These changes are likely to occur when the body is at rest

Your notes



The heart rate is controlled by the cardiovascular centre in the medulla

Heart Rate: Alteration by Hormonal System

Your notes

- **Epinephrine,** also called **adrenaline,** is produced by the **adrenal glands**, located above the kidneys, in times of fear, stress, or excitement
- The **brain** controls the release of epinephrine from the adrenal glands
- Epinephrine **increases** the **heart rate** and **boosts** the delivery of **oxygen** and **glucose** to the **brain** and **muscles**, preparing the body for 'flight or fight'
  - Increased glucose and oxygen are needed by the cells for **aerobic respiration** to **release** energy, e.g. to fuel the muscles to move/run away!

6.2.6 Skills: The Blood System

Your notes

The Structure of the Heart

Heart structure

- The heart has **two sides**:
  - The **left** side pumps **oxygenated** blood around the body in the **systemic circulation**
  - The **right** side pumps **deoxygenated** blood to the lungs in the **pulmonary circulation**

- 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

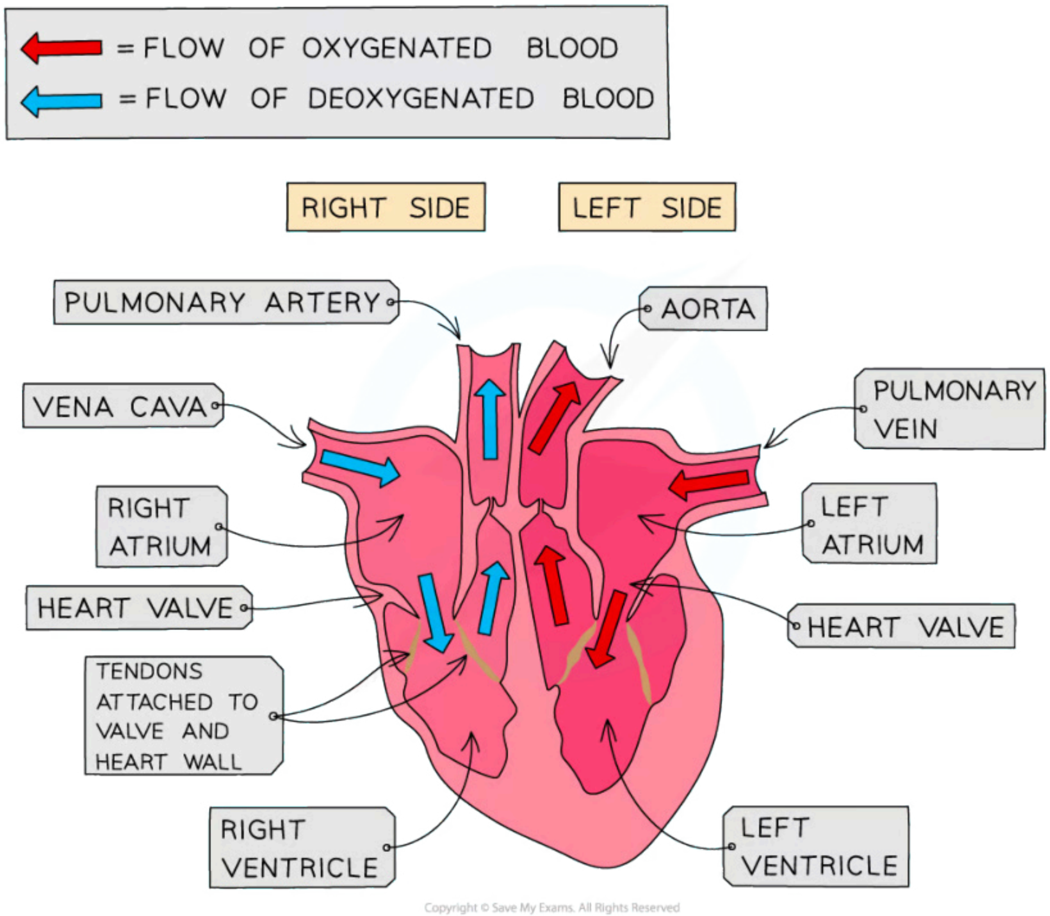
- The heart is divided into **four chambers**
  - The two top chambers are **atria** (singular atrium) - they receive blood from the veins and pump it through to the ventricles
  - The bottom two chambers are **ventricles –** they receive blood from the atria and pump it out into the arteries

- **Valves** are important for keeping blood flowing forward in the right direction and stopping it flowing backwards. They are also important for maintaining the **correct pressure** in the chambers of the heart
  - The atria and ventricles are separated by the **atrioventricular valves**
    - The right atrium and ventricle are separated by the tricuspid valve
    - The left atrium and ventricle are separated by the bicuspid valve

  - The ventricles and the arteries that leave the heart are separated by **semi-lunar valves**
    - The right ventricle and the pulmonary artery are separated by the **pulmonary valve**
    - The left ventricle and aorta are separated by the **aortic valve**

- There are two blood vessels bringing blood into the heart; the **vena cava** and **pulmonary vein**
- There are two blood vessels taking blood out of the heart; the **pulmonary artery** and **aorta**

Your notes



The human heart has four chambers and is separated into two halves by the septum

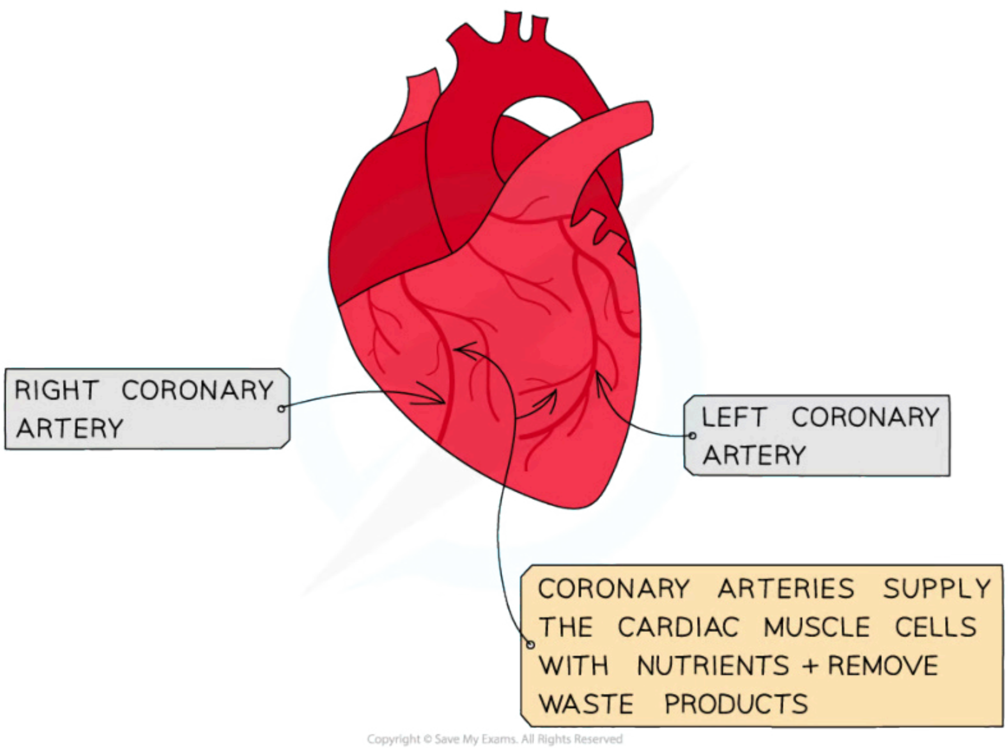
The pathway of blood through the heart

- **Deoxygenated blood** coming from the body flows through the **vena cava** and into the **right atrium**
- The **atrium contracts** and the blood is forced through the **atrioventricular** (tricuspid) **valve** into the **right ventricle**
- The ventricle **contracts** and the blood is pushed through the **semilunar valve** into the **pulmonary artery**
- The blood travels to the **lungs** and moves through the capillaries past the alveoli where **gas exchange** takes place
  - **Low pressure** blood flow on this side of the heart prevents damage to the capillaries in the lungs

- **Oxygenated blood** returns via the **pulmonary vein** to the **left atrium**
- The **atrium contracts** and forces the blood through the **atrioventricular** (bicuspid) **valve** into the **left ventricle**
- The ventricle **contracts** and the blood is forced through the **semilunar valve** and out through the **aorta**
  - Thicker muscle walls of the left ventricle produce a **high enough pressure** for the blood to travel around the whole body

Coronary arteries

- The heart is a muscle and so requires its own blood supply to enable its cells to carry out **aerobic respiration**
- The heart receives blood through arteries on its surface called **coronary arteries**
- It's important that these arteries remain clear of blockages called plaques, as this could lead to angina or a heart attack (myocardial infarction)



The coronary arteries cover the outside of the heart, supplying it with oxygenated blood

Dissection of a mammalian heart

- Dissections are a vital part of scientific research
- They allow for the internal structures of organs to be examined so that theories can be made about how they function

Apparatus

- Scissors
- Scalpel
- Tweezers / Forceps
- Dissection board
- Paper towels
- Biological specimen

Your notes

Your notes

- Pins
- Gloves
- Goggles

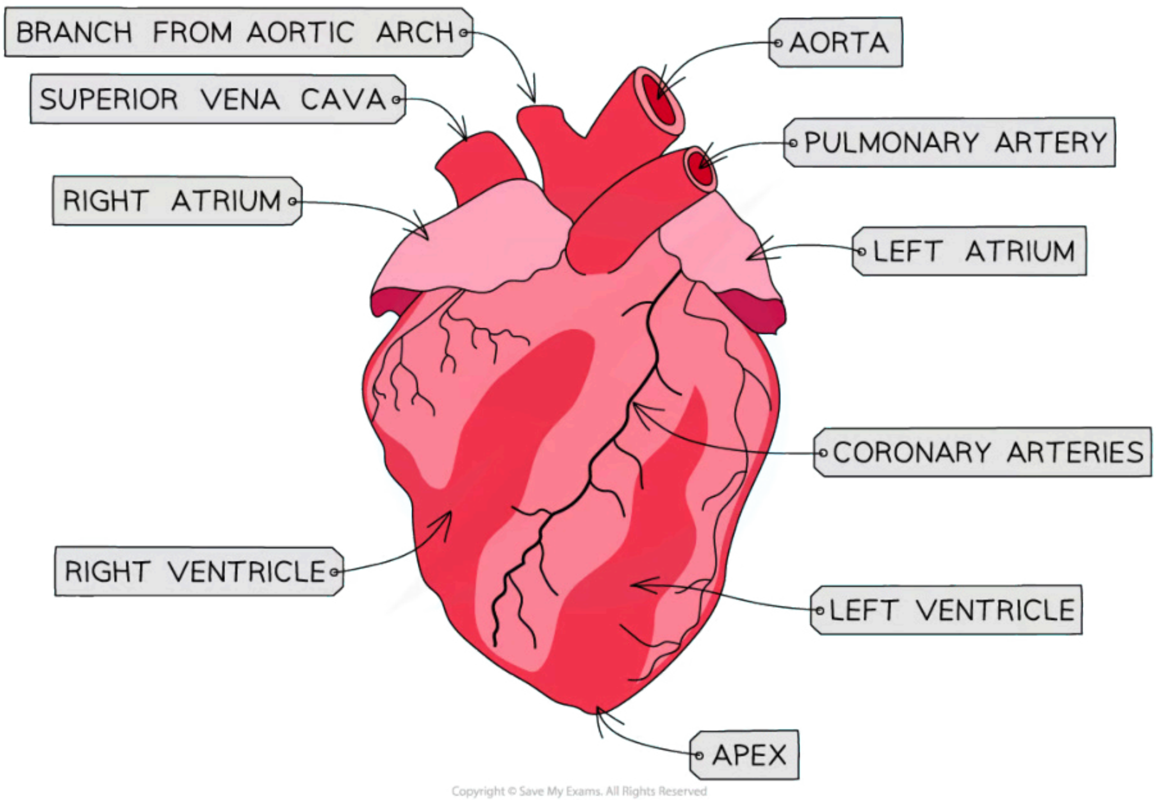
Method

- A lab coat, gloves and eye protection should be worn
  - This is done to avoid contamination with biological material which could cause an allergic reaction or contain harmful microorganisms
- Place the specimen on the dissecting board
- Use the tools to access the desired structure
  - When using the scalpel cut **away** from your body and keep your fingers **far from the blade** to reduce the chance of cutting yourself
  - Scissors can be used for cutting large sections of tissue (cuts do not need to be precise)
  - Scalpel enables finer, more precise cutting and needs to be sharp to ensure this
- Use pins to move the other sections of the specimen aside to leave the desired structure exposed

Identifying structures during the dissection

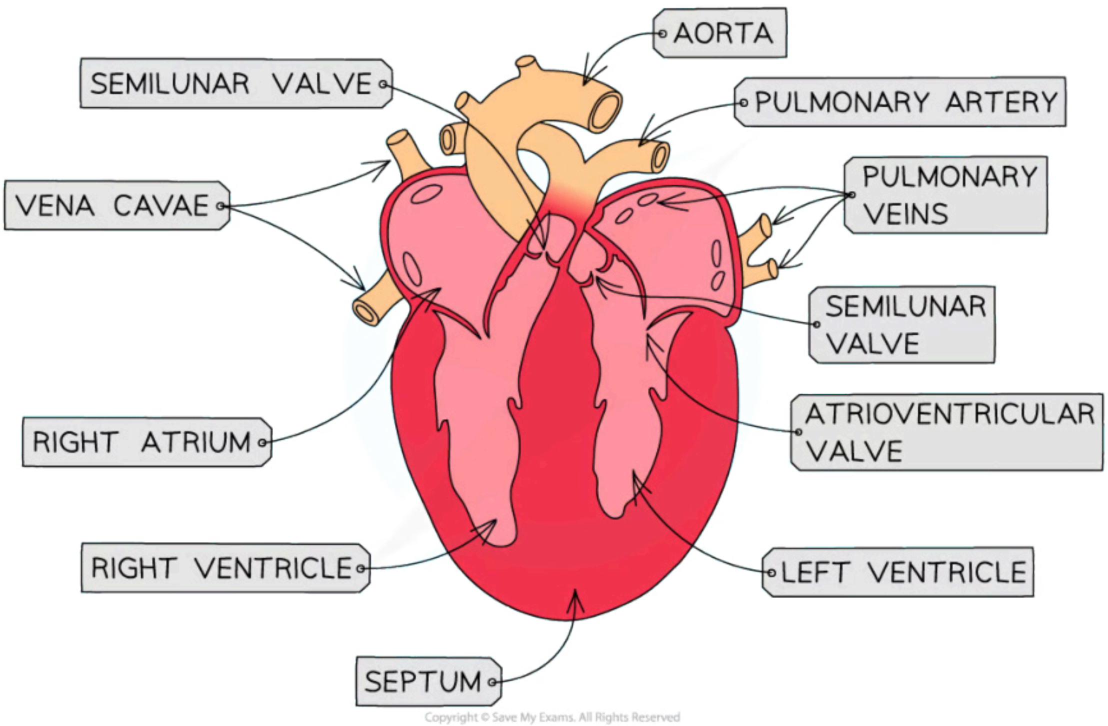
- Observe the outside of the heart to identify the **coronary arteries** supplying the cardiac muscle with a oxygenated blood and nutrients
  - The coronary arteries branch off the **aorta** near to the **semilunar valves**
  - The coronary arteries are often surrounded by white, fatty tissue
- Position the heart and study it from the top, you should be able to identify
  - **Arteries** leaving the heart - these can be identified by the thicker walls
    - Poke a glass rod through the **aorta** to feel the thicker walls of the left ventricle and through the **pulmonary artery** to feel the thinner walls of the right ventricle
  - **Veins** entering the heart - these can be identified by their thinner walls
    - Poking a glass rod through the **pulmonary vein** will lead to the left atrium and poking a glass rod through the superior or inferior **vena cava** will lead to the right atrium.
- Lay the heart down on its flatter side, this is the **dorsal side**.
  - Dorsal refers to the back of an organism
- The **ventral side** is now closest to you with the pulmonary artery facing outwards and in front of the aorta
  - Ventral refers to the front of an organism
- Make an incision from the Aorta, underneath the pulmonary artery and around the **apex** of the heart to cut the heart into halves
- This should open up the heart to show the **ventricles** so that you can compare the thickness of the walls
- The **atrioventricular valves** should also be visible as a white flap of connective tissue attached by tendinous cords which prevent inversion of the valve
  - The tendinous cords are stringy in appearance and are sometimes referred to as the heartstrings

- The **atria** are wrinkled in appearance and can be tricky to see compared with the ventricles.
  - They sit just above the atrioventricular valves and are the entry point for the veins (the pulmonary vein and the vena cava)
  - They are significantly smaller than the ventricles
  - It is possible that the atria and blood vessels may be sliced off some specimens
- Observe the **septum** of the heart which separates the left and right-hand sides. The septum contains the **conductive fibres** which stimulate contraction, however, these are not visible to the eye



Your notes

Your notes



Following a careful method during a heart dissection will allow you to identify the different structures

Examiner Tip

Remember:

- **A**rteries carry blood **a**way from the heart
- Ve**in**s carry blood **in**to the heart

When explaining the route through the heart we usually describe it as one continuous pathway with only one atrium or ventricle being discussed at a time, but remember that in reality, both atria contract at the same time and both ventricles contract at the same time

Also, the heart is **labelled as if it was in the chest** so the left side of a diagram is actually the right hand side and vice versa

Your notes

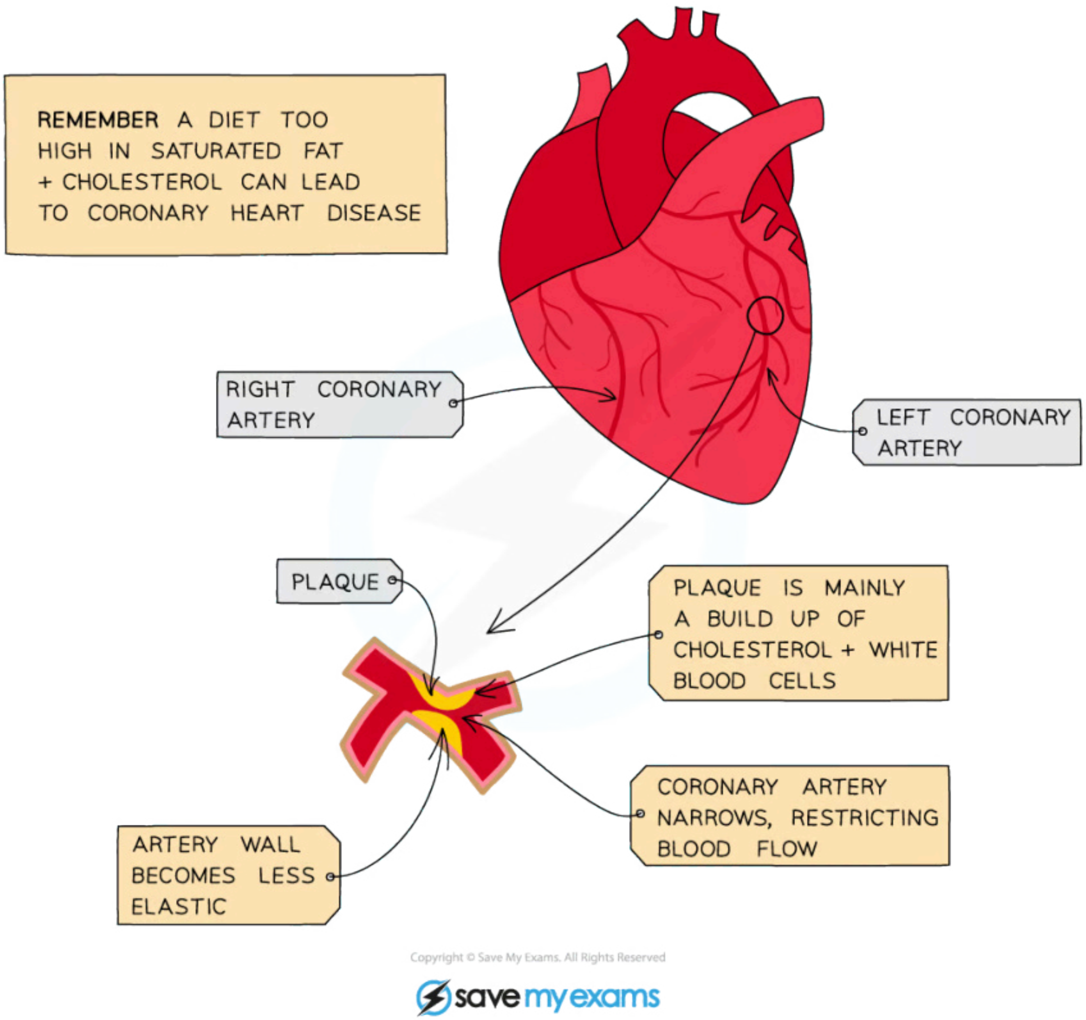
Atherosclerosis

- **Occlusion** can be defined as
  - **The narrowing of the arteries due to a blockage**
- The arteries can be blocked by the process of **atherosclerosis**
- **Atherosclerosis** results in a build-up of layers of fatty material known as plaque inside **arteries**
- The main cause of atheroma development is the presence of low-density **lipoprotein** (**LDL**) which forms from saturated fats and cholesterol
- LDL builds up in regions of the arteries and **phagocytes** move to these areas, engulfing the LDL by **endocytosis**
- The enlarged phagocyte cells are then covered by **smooth muscle cells** which cause a bulging of the **endothelium** in the artery
- Deposition of **calcium ions** can worsen the situation by hardening the endothelium
- This **narrows the lumen** of the artery, reducing the space for blood flow

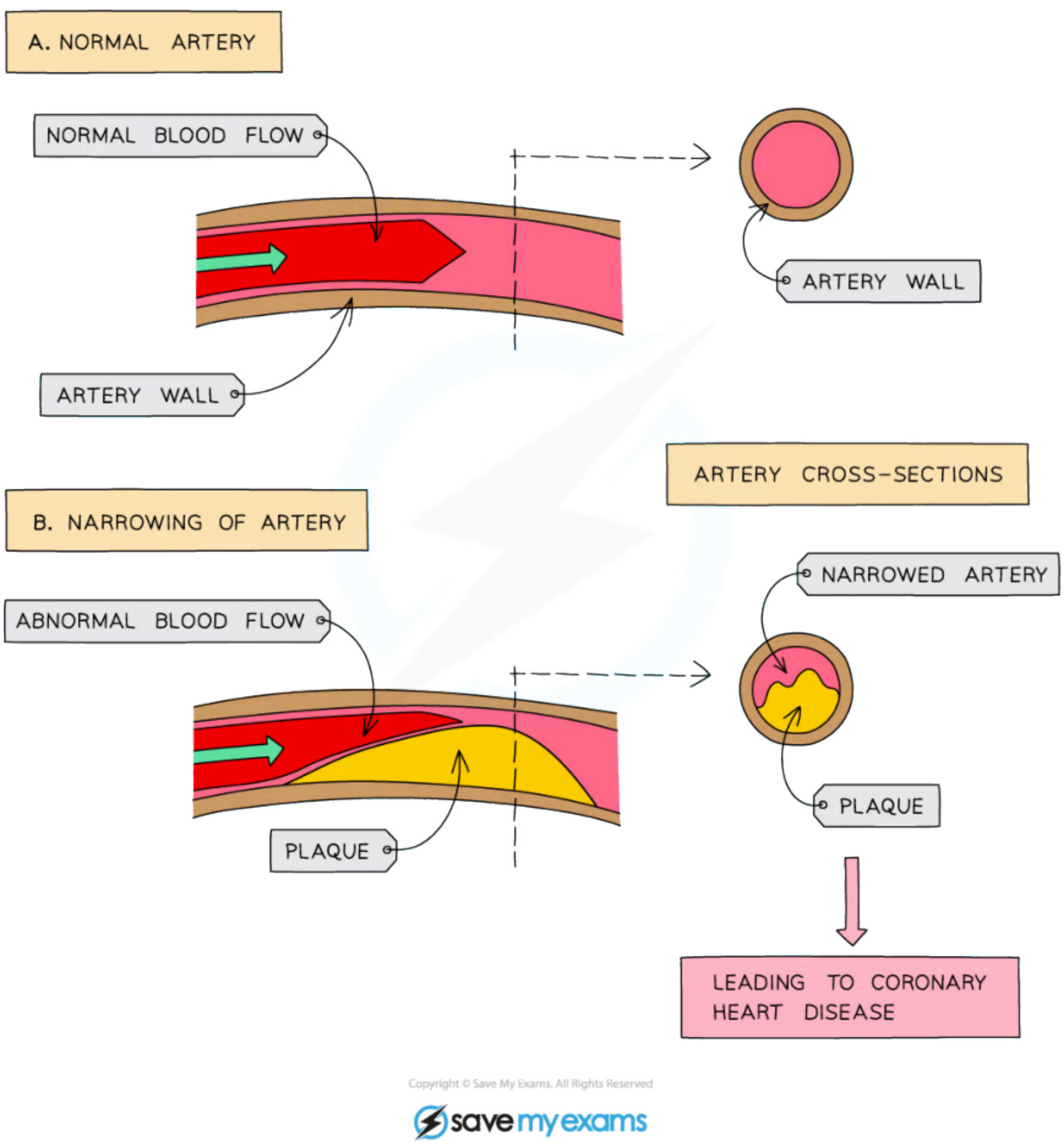
Consequences of occlusion of the arteries

- When an atheroma builds up enough to cause impeded blood flow, tissues do not receive the required level of **oxygen** and **nutrients**
  - This can **inhibit cell functions**
- **Occlusion** of the **coronary arteries** in particular can lead to significant health issues such as **coronary heart disease**
  - The flow of blood through the coronary arteries is reduced, resulting in a lack of oxygen and nutrients for the heart muscle
  - **Partial blockage** of the coronary arteries creates a restricted blood flow to the cardiac muscle cells and results in severe chest pains called **angina** as the heart muscle beats faster to try to increase blood supply
  - **Complete blockage** means cells in the area of the heart not receiving blood will not be able to respire aerobically; these cells will be unable to contract, leading to a heart attack
  - Atheromas can sometimes rupture, leading to the development of a **blood clot**
    - Blood clots can worsen existing blockages, or break off and travel into smaller blood vessels
      - Blood clots that travel to the coronary arteries can cause a heart attack
      - Blood clots that travel to the brain can lead to a stroke

Your notes



Buildup of plaque in the coronary arteries narrows the lumen



The effect of a narrowed lumen in a coronary artery is reduced blood flow to the heart

Risk factors for atherosclerosis

- There are several **risk factors** which will increase the chances of coronary heart disease:
  - **Consumption of *trans*-fats**
    - These damage the endothelium of the artery initiating formation of an atheroma
  - **Constant high blood sugar**
    - This is usually the result of consumption of foods high in carbohydrate

- **High blood pressure**
  - This increases the force of the blood against the artery walls and consequently leads to damage of the vessels
  - Blood pressure can increase due to smoking or stress
- **High blood concentrations of LDL**
  - Speeds up the build up of fatty plaques in the arteries, leading to blockages
- **Smoking**
  - Chemicals in smoke cause an increase in plaque build up and an **increase in blood pressure**
  - Carbon monoxide also reduces the oxygen carrying capacity of the red blood cells
- **Infection by certain microbes**
  - *Chlamydia pneumoniae* can infect the arterial wall and trigger **inflammation** which promotes atherosclerosis
  - Microbes of the small intestine produce the **chemical** trimethylamine N-oxide which promotes atherosclerosis

Your notes

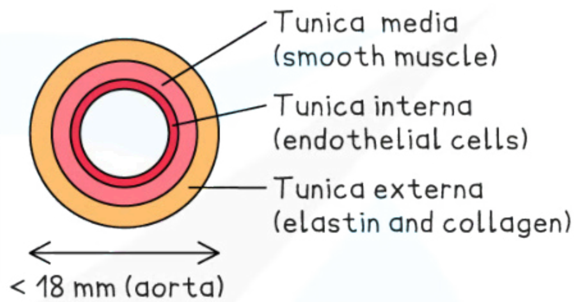
Structure of the Blood Vessels

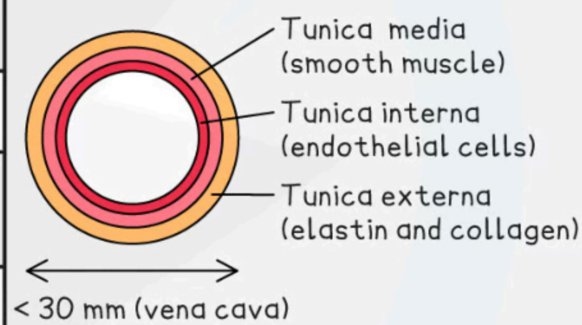
Your notes

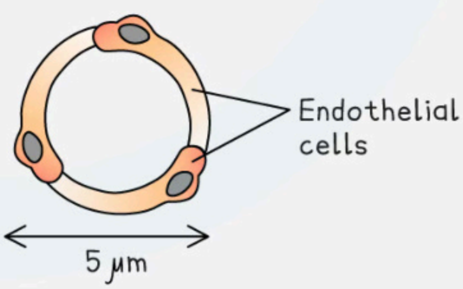
- The body contains several different types of blood vessel
- The walls of each type of blood vessel have a structure that relates to the function of the vessel
  - **Arteries** transport blood **a**way from the heart (usually at high pressure). They are structured as follows:
    - Three thick layers in their walls
    - A high proportion of muscle and elastic fibres
    - Narrow lumen
    - No valves
  - **Capillaries** transport blood from arteries to veins, and are located between the cells in the tissues. They are structured as follows:
    - Walls are only one cell thick (endothelial layer only)
    - No muscle or elastic fibres
    - No valves
  - **Veins** transport blood **in**to the heart (usually at low pressure). They are structured as follows:
    - Thin walls with three layers
    - Low proportion of muscle and elastic fibres compared to arteries
    - Large lumen
    - Valves (usually) present

Your notes

Vessel	Features
Artery	Thicker tunica externa with a high proportion of elastin and collagen Thicker tunica media with a high proportion of muscle fibres Narrow lumen
Vein	One−way valves Wide lumen Less smooth muscle and elastin Lots of collagen
Capillary	Very small diameter Capillaries branch between cells Thin walls, no elstic, smooth muscle or collagen







The three main categories of blood vessel can be identified by comparing their structures

Examiner Tip

For "explain" questions relating to blood vessel structure, remember to pair a description of a structural feature to an explanation of exactly how it helps the blood vessel to function. For example "capillary walls are one-cell thick, which enables quick and efficient diffusion of substances such as oxygen and glucose to the cells"