HL IB Biology

Your notes

Transport

Contents

Blood Vessels

Your notes

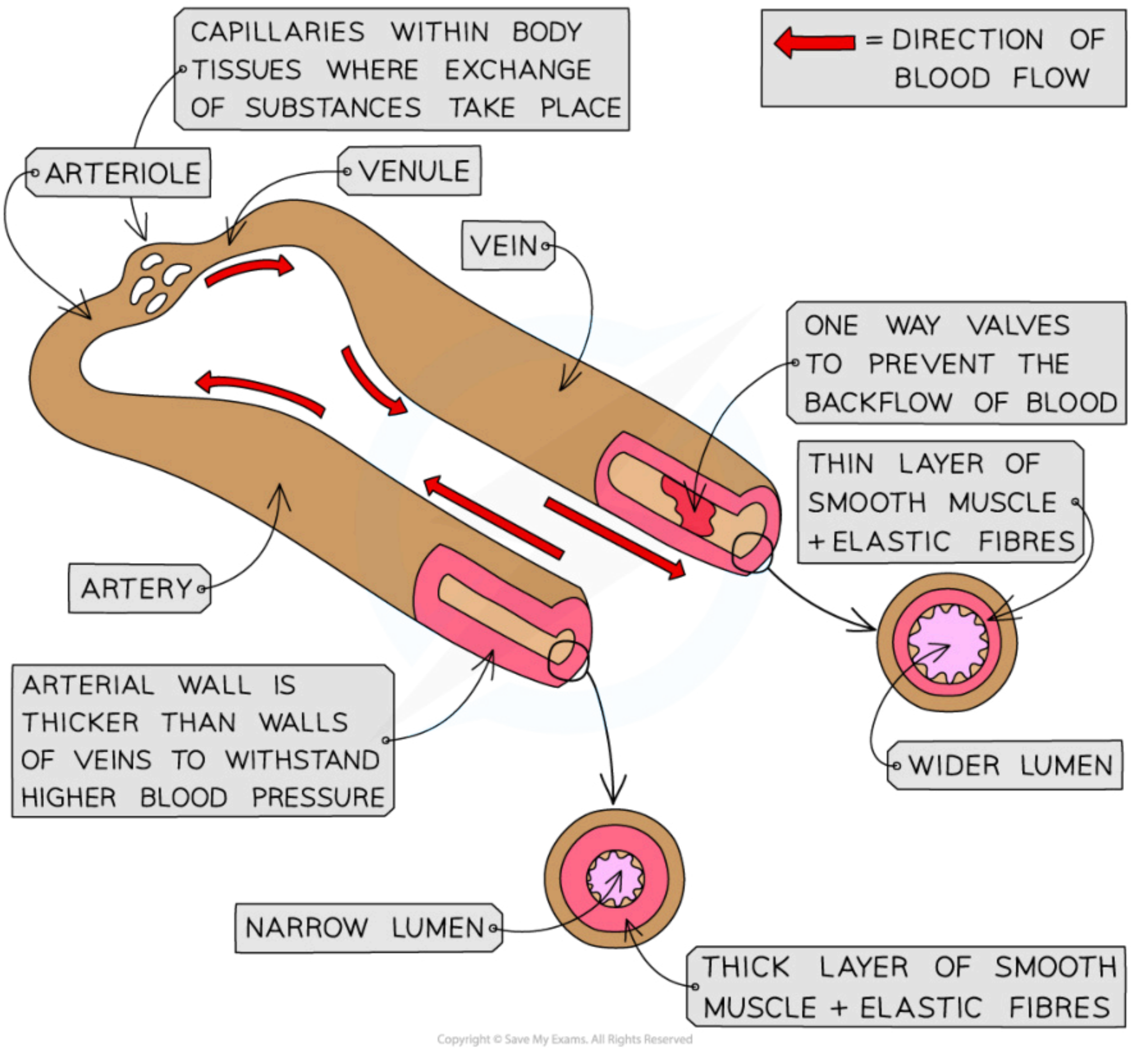
Capillaries

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

Blood vessels diagram

Your notes



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

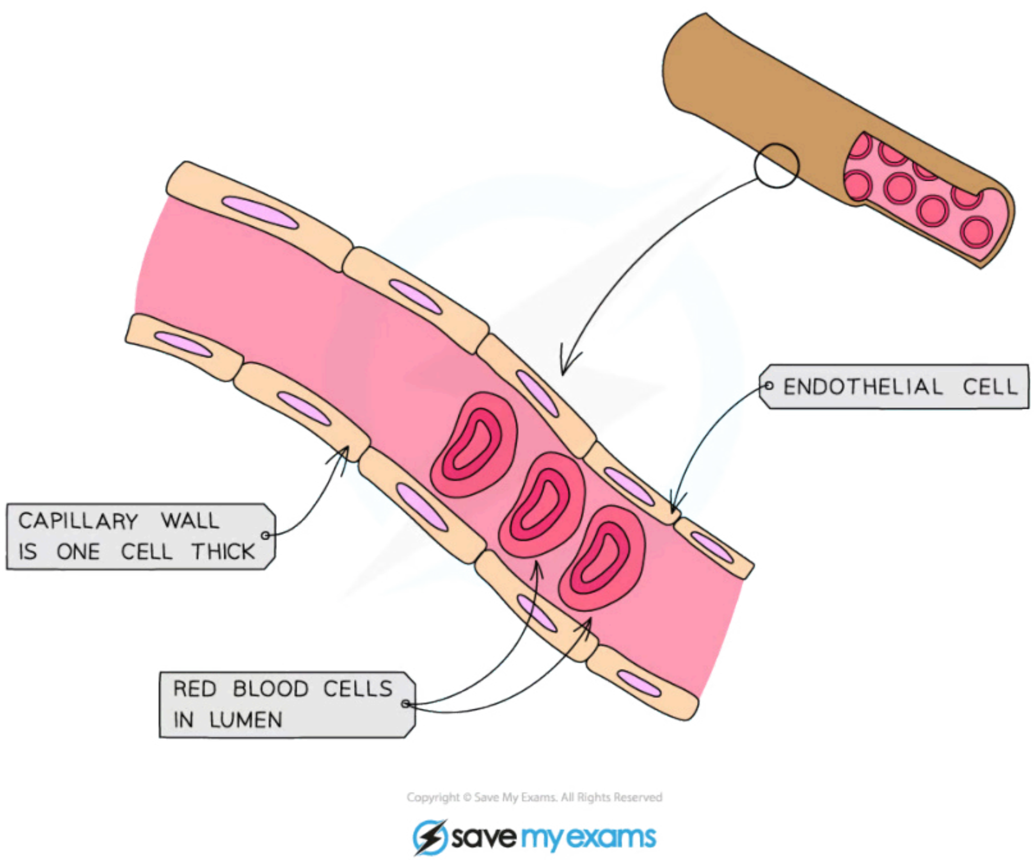
Adaptations of capillaries for exchange of materials

- **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**
    - 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 of some capillaries have gaps between them called **fenestrations** which allow blood plasma to leak out and form **tissue fluid**
    - Tissue fluid surrounds the cells, enabling **exchange** of substances such as oxygen, glucose, and carbon dioxide
    - Tissue fluid contains **oxygen, glucose** and other small molecules from the blood plasma

- Large molecules such as proteins usually can't fit through the fenestrations into the tissue fluid
- The **permeability** of capillaries can vary depending on the requirements of a tissue
- 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**
- 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
  - It also **reduces** the diffusion distance as red blood cells are brought in close contact with the capillary wall

Your notes

Capillary structure diagram



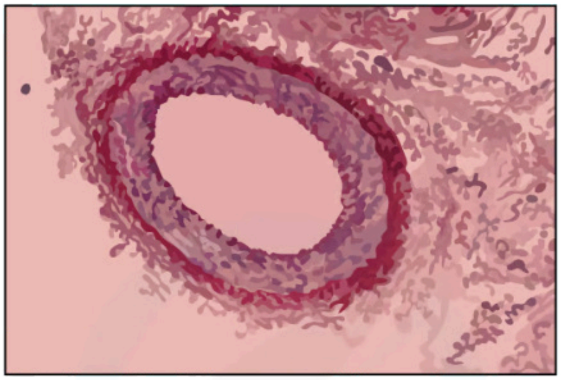
Capillaries have a narrow lumen and walls that are one cell thick to increase the rate of diffusion between the blood and cells

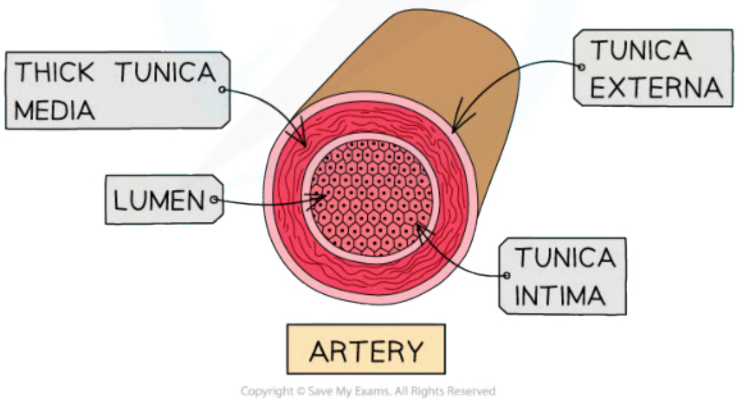
Arteries

Adaptations 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 innermost layer is an endothelial layer, consisting of squamous epithelium
    - 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 middle layer contains **smooth muscle cells** and a **thick layer of elastic tissue**
    - This layer is very **thick** in the walls of arteries
    - The layer of **muscle**:
      - **Strengthen** the arteries so they can **withstand high pressure**
      - Can **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 when the heart beats
    - Further from the heart there is more smooth muscle and less elastic tissue due to smaller fluctuations in blood pressure
  - The outer layer covers the exterior of the artery and is mostly made up of **collagen** and **elastic fibres**
    - Collagen is a strong protein and protects blood vessels from damage by over-stretching
    - Along with elastic fibres, it prevents the arterial wall from rupturing as blood surges from the ventricles
- Arteries have a **narrow lumen** which helps to maintain high blood pressure

Artery structure diagram





Arteries have thick muscular walls and a narrow lumen

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
    - 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

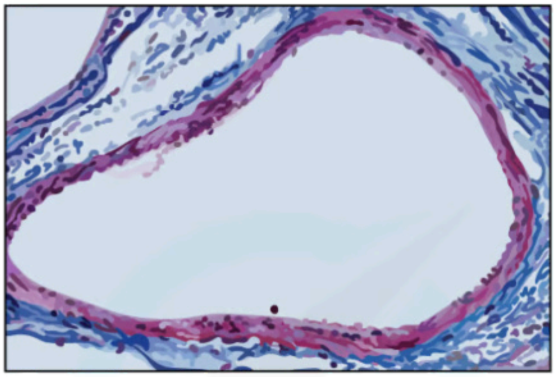
Be careful with the language you use to describe the roles of muscle and elastic tissue; muscle can **contract** and **relax**, while elastic tissue can **stretch** and **recoil**.

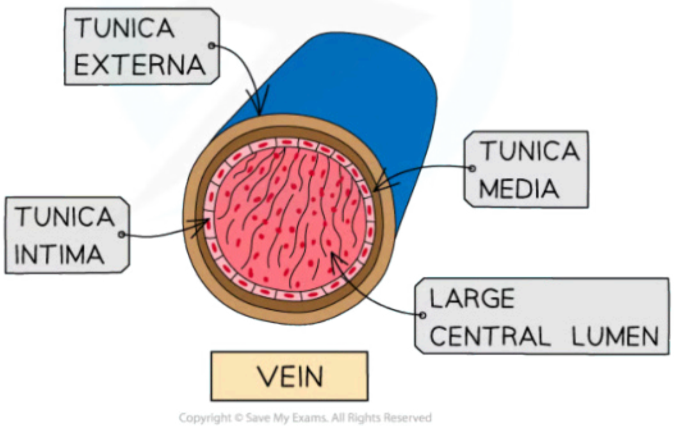
Veins

Adaptations of veins

- **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 capillaries converge to form **venules**, which deliver blood to veins
- The structure of veins differs from arteries:
  - The middle layer 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 walls of veins are **flexible**, allowing surrounding muscles and tissues to compress them
    - This facilitates the movement of blood back to the heart
  - 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
  - Veins have a **wide lumen**
    - This **maximises the volume** of blood that can flow at any one time

Vein structure diagram





Veins have thin walls and a wide lumen

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."

Identify Blood Vessels: Skills

Your notes

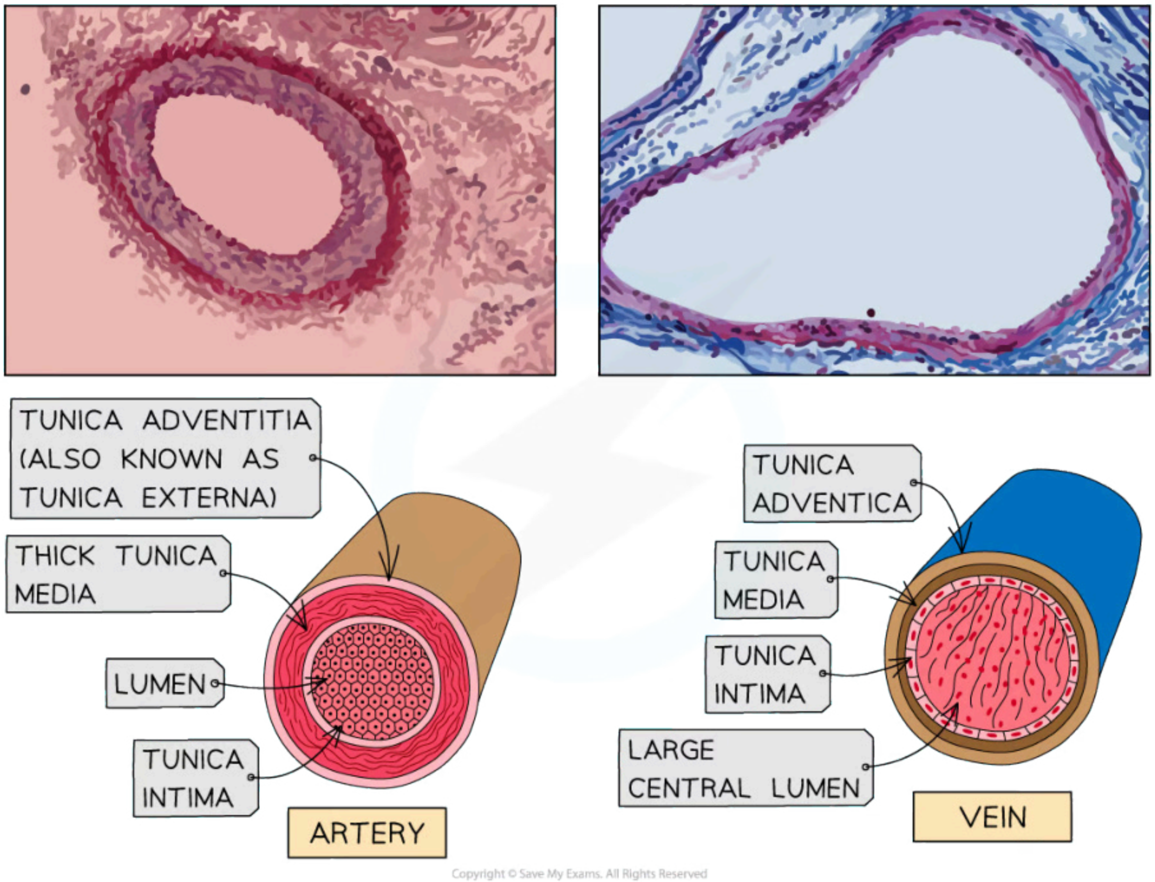
Structure of Arteries & Veins

Distinguishing arteries and veins in micrographs

- Arteries
  - The arterial walls are **much thicker and stronger** than those of veins
    - This is due to the presence of more collagen and elastic fibres, as well as a thicker layer of smooth muscle
  - The **lumen** of arteries is relatively **narrow** compared to the thickness of the wall
    - This maintains the blood pressure inside the arteries
- Veins
  - The walls of veins are **much thinner** than those of arteries
    - They do not need to withstand the high pressure present in arteries
  - The **lumen** of veins is much **wider in diameter** compared to the thickness of the wall
    - 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**
- These characteristics can be used to distinguish arteries and veins in micrographs

Artery and vein micrograph diagrams

Your notes



Arteries and veins can be distinguished from each other by the thickness of their walls and the diameter of the lumen; arteries (left) have thick walls and a narrow lumen while veins (right) have thin walls and a wide lumen

Note that you do not need to know the scientific names for the different tissue layers in the walls of the blood vessels

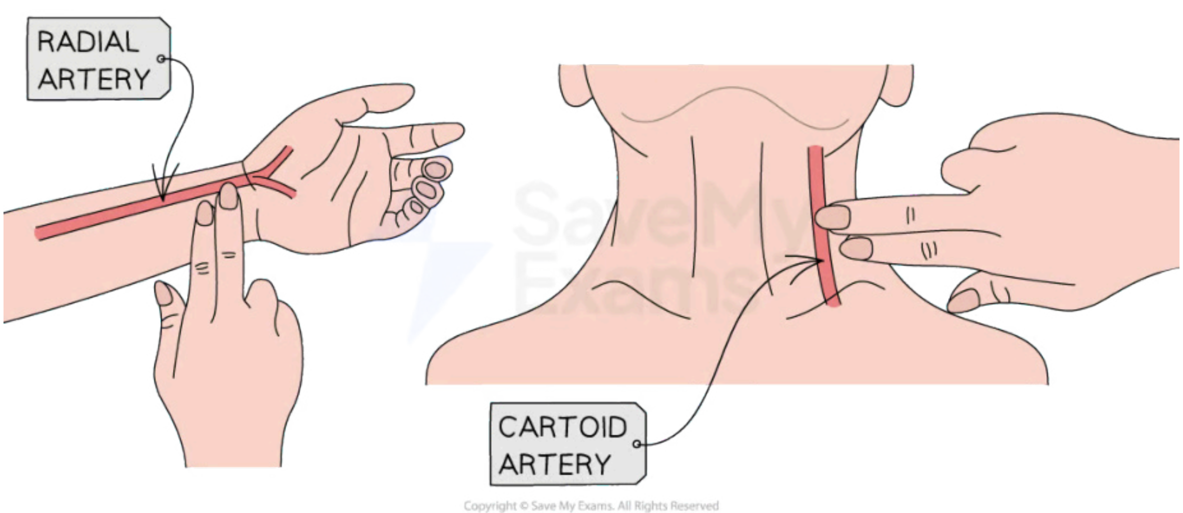
Measuring Pulse Rate: Skills

Your notes

Measuring Pulse Rate

- The contraction of the ventricles forces a large volume of blood through the arteries, which **expand** to accommodate this
- This can be felt as a **pulse**, especially in places where an artery is close to the skin surface or passes over a bone
  - For this reason, the **carotid artery** or **radial artery** can be used to measure pulse rate
    - The carotid artery runs down the side of the neck and a pulse can be felt just below the jaw
    - The radial artery passes over the wrist bones where a pulse can be felt just below the base of the thumb
- A pulse can be taken as follows:
  - Place **two fingers** on the radial or carotid artery and **gently compress** the blood vessel
  - **Count** the number of pulses felt for **60 seconds**
    - Alternatively, you could count for 30 seconds and multiply by 2
- Do not use your thumb when taking a pulse, since it also has a pulse that can lead to inaccurate results
- There are many **digital devices** that can also be used to determine pulse rate
  - These include data loggers, smartwatches or fitness bands
  - They scan the blood flow through the radial artery to measure pulse rate

Measuring pulse diagram



The radial or carotid artery can be used to measure the pulse rate

Your notes

Coronary Heart Disease: Skills

Coronary Heart Disease

- **Occlusion** of the arteries can be defined as

The narrowing of the arteries due to a blockage

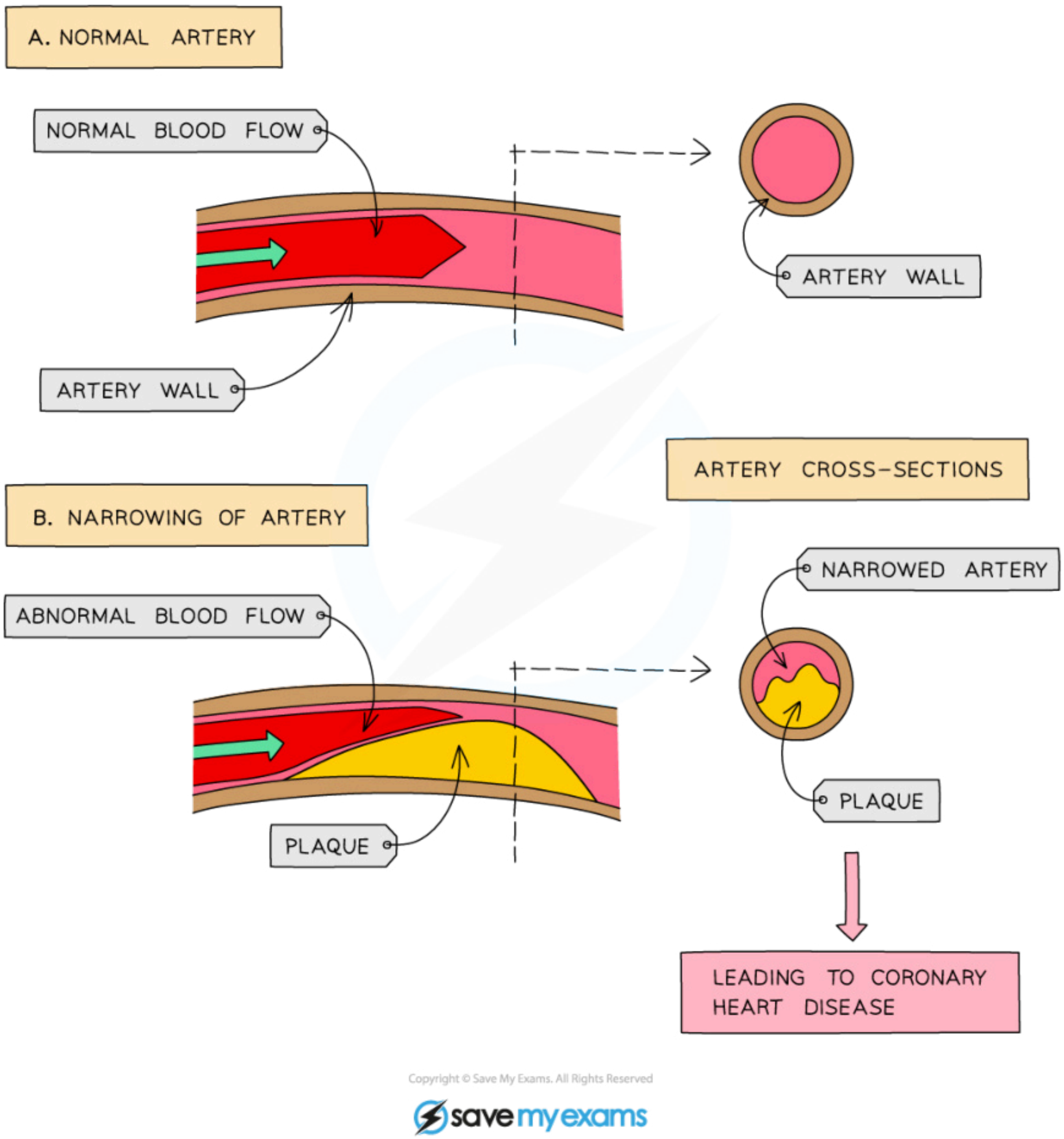
- The arteries can be blocked by the process of **atherosclerosis**
  - **Atherosclerosis** begins when there is damage to the walls of the arteries due to high blood pressure
  - This damage can lead to the build-up of fatty deposits known as **atheromas** under the endothelium
  - These fatty deposits narrow the lumen of the artery, reducing the space for blood flow
- Atherosclerosis can lead to an **increase in blood pressure** within the artery, which causes further damage to the artery wall
  - **Fibrous tissue** is produced to repair the damage to the artery wall
    - This type of tissue is not elastic, so the overall elasticity of the artery wall is reduced
  - The smooth lining of the arteries breaks down and forms lesions called **plaques**
- This further damage can lead to the rupturing of blood vessel walls, which results in **blood clotting**
  - Clots formed within a blood vessel are called a **thrombus**
  - Once it circulates in the blood clots are known as an **embolus**

Consequences of atherosclerosis of the arteries

- When an embolus blocks a small artery or arteriole, tissues further down from the blockage do not receive the required level of **oxygen** and **nutrients**
  - This can **inhibit cell functions** and cause the cells to **die**
- If this happens in the **coronary arteries** then parts of the heart muscle die
  - This may stop the heart from pumping blood and lead to a **myocardial infarction**, or heart attack
- Blockages in the coronary arteries may be bypassed by undergoing **heart bypass surgery**
  - Blood vessels from the patient's leg are removed and used to create an alternative route for blood to flow past the blockage

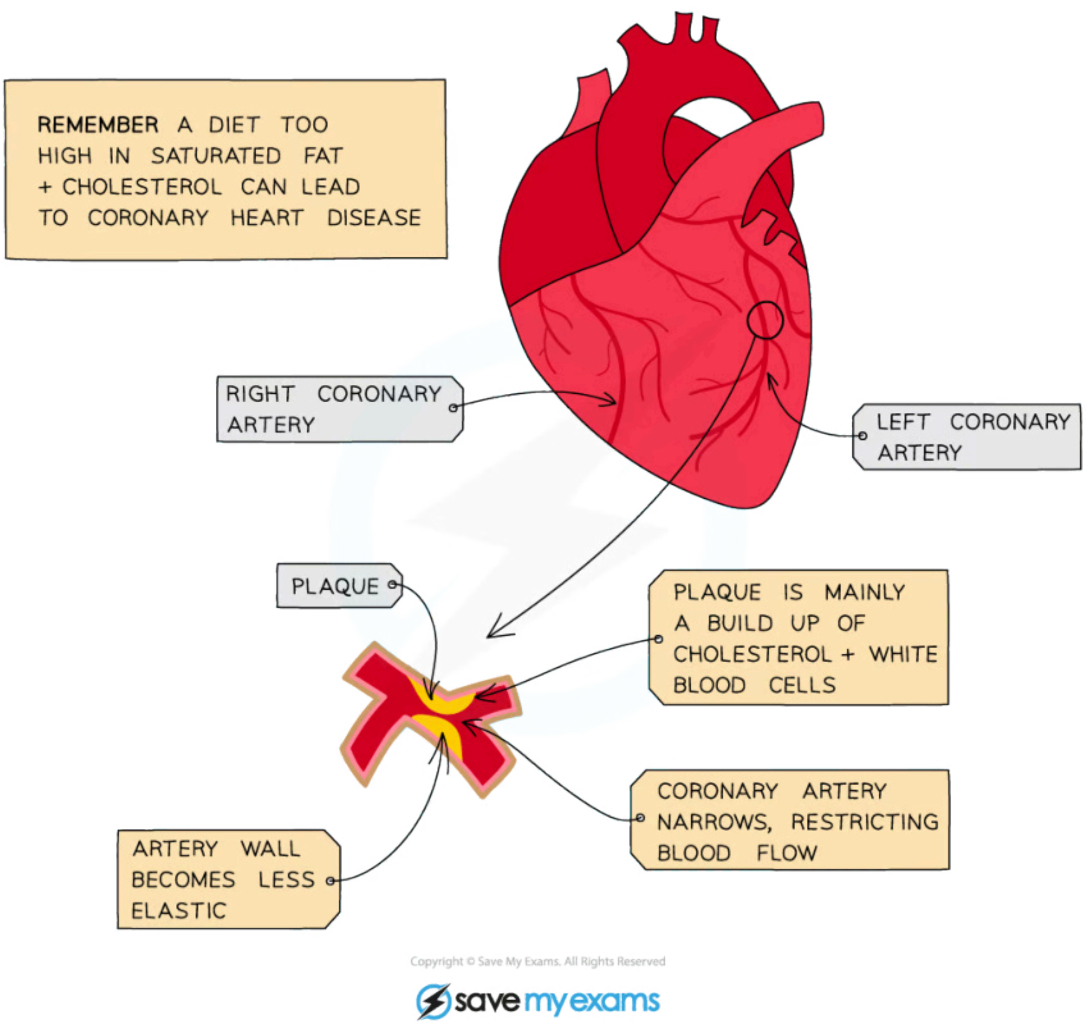
Atherosclerosis & coronary heart disease diagram

Your notes



Atherosclerosis leads to narrowing of the arteries; this can lead to coronary heart disease

Your notes



Buildup of plaque in the coronary arteries narrows the lumen, and can lead to a heart attack

Evaluating epidemiological data relating to the incidence of coronary heart disease

- Claims about the importance of different risk factors and coronary heart disease, e.g. a diet high in saturated fats, are based on:
  - **Epidemiological studies** on human populations
    - The evidence provide **correlation** data and so **do not** provide a definite causal link between coronary heart disease and risk factors such as saturated fat intake
  - **Clinical studies** of individual patients
    - Such studies are **small**, e.g. they may focus on just a few individuals, so they may not provide representative data
    - Studies will **not include a suitable controlled experiment** so it is not possible to make a definite causal link from the results

Your notes

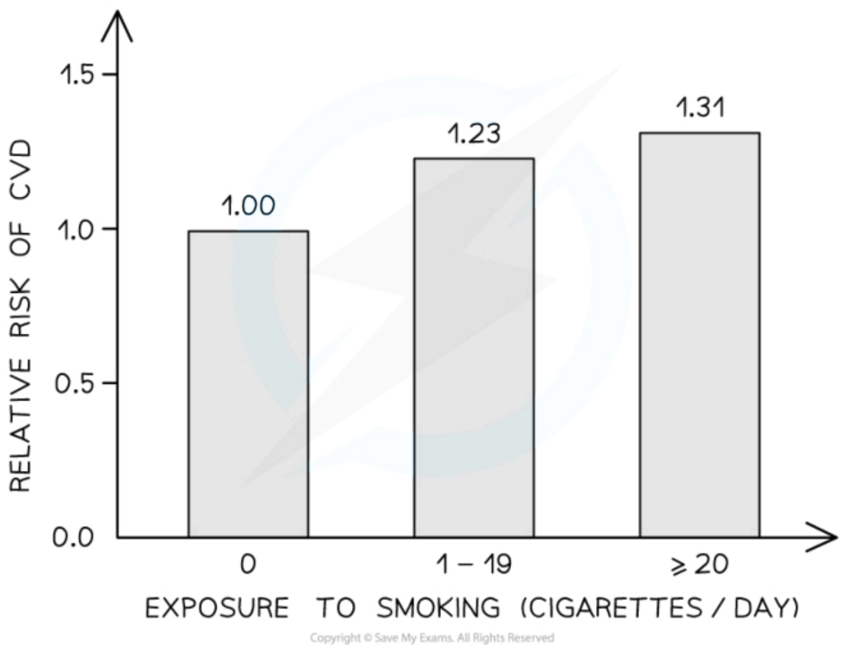
        - A controlled experiment would involve. e.g. one group of participants eating a normal diet while another group eats a diet high in saturated fat
        - Ethical considerations would prevent such controlled experiments from being carried out, due to the risk of harm to a group consuming a high fat diet over a long period
- When **evaluating** data from studies on coronary heart disease you could consider the following:
    - The sample group used must be **representative** of the population
        - **Larger sample sizes** are more likely to be representative as they cover a larger cross-section of the population
        - Samples must **not all come from the same demographic group**, e.g. not all white men who are over 60 and live in London
        - Samples must be **human**; results from animal trials do not perfectly represent human physiology
    - Statistical analysis should be used to check that any **differences between results are statistically significant**
        - E.g. the use of error bars in graphical data or the comparison of mean values from different trial groups
    - Some studies need to have a **control** with which to compare the results
        - E.g. when testing a drug to treat heart disease, a control group that is not given the drug should be included in the study to ensure that any effect shown is due to the drug and not any other factor
    - Studies should be **repeated**, or there should be **many studies that show the same result**, before conclusions can be drawn
    - The study should be designed to **control any variable that is not being tested**; this increases the **validity** of the results
        - Controlled factors might include, e.g. prior health of participants, other lifestyle factors of participants such as exercise and stress levels, age of participants, and biological sex of participants
        - Results are considered to be valid if they **measure what they set out to measure**, i.e. they are not influenced by external variables or poor experimental design, and have been analysed correctly
    - Researchers should **not be biased**, i.e. looking for a particular outcome
        - This could be a problem if someone is being paid to come up with a particular result
    - **Data collection methods** must be accurate, e.g. participants may not tell the truth in a questionnaire about diet or exercise

Your notes

Worked example

A study was carried out into the relative risk of heart disease (CVD) in non-smoking adults exposed to a range of levels of cigarette smoke from a smoking partner. The study looked at 523 non-smoking partners of smokers.

The results are shown in the graph below



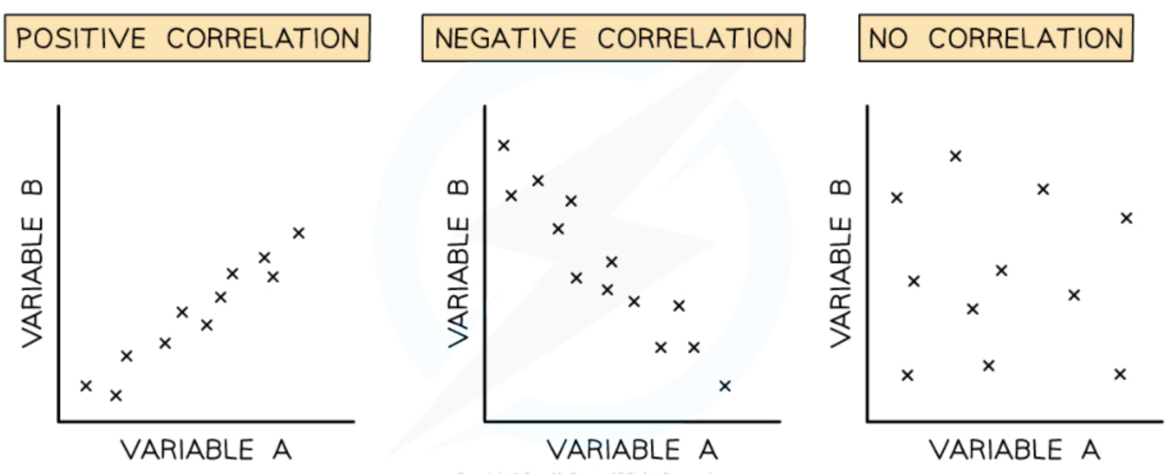
Evaluate the validity of the data

- A commentary on the **validity** of the data could include
  - The study included 523 people; this is a fairly **small sample size** and may not represent an entire population
  - This is only one study; **more studies would need to be carried out** to back up these results
    - Being able to replicate the results of a study shows that the results are reliable
  - There is no information on **how other risk factors might be interacting with smoking** to influence the risk of CVD
    - Risk factors such as age, diet, biological sex, or exercise levels may be playing a role, as these factors may be interacting with the smoking variable e.g.
      - Smokers are often older
      - More men may smoke than women
      - Smokers may be less likely to exercise
  - The data doesn't comment on the **use of any statistical tests** so we cannot state the significance of the differences between the different levels of smoke exposure

NOS: Correlation coefficients quantify correlations between variables and allow the strength of the relationship to be assessed

Your notes

- Sometimes **correlation** between two variables can appear in the data
  - **Correlation** is an association, or relationship, between variables
  - There is a clear distinction between **correlation** and **causation**: a correlation does not necessarily imply a causative relationship
    - **Causation** occurs when one variable has an influence on, or is influenced by, another
- In order to get a broad overview of the correlation between two variables the data points for both variables can be plotted on a **scatter graph**
- Correlation can be **positive or negative**
  - Positive correlation: as variable A increases, variable B increases
  - Negative correlation: as variable A increases, variable B decreases
- The correlation coefficient (r) can be calculated; this indicates the **strength of the relationship** between variables
  - Perfect correlation occurs when **all of the data points lie on a straight line** with a **correlation coefficient of 1** or **–1**
    - Remember that even strong correlations do not imply a causal relationship between the variables
  - The closer the correlation coefficient is to 1 or -1, the stronger the relationship
  - If there is **no correlation** between variables the **correlation coefficient will be 0**
- **Low** correlation coefficients or **no** correlation between variables may provide evidence **against** a hypothesis



Scatter graphs can be used to show the correlation between variables

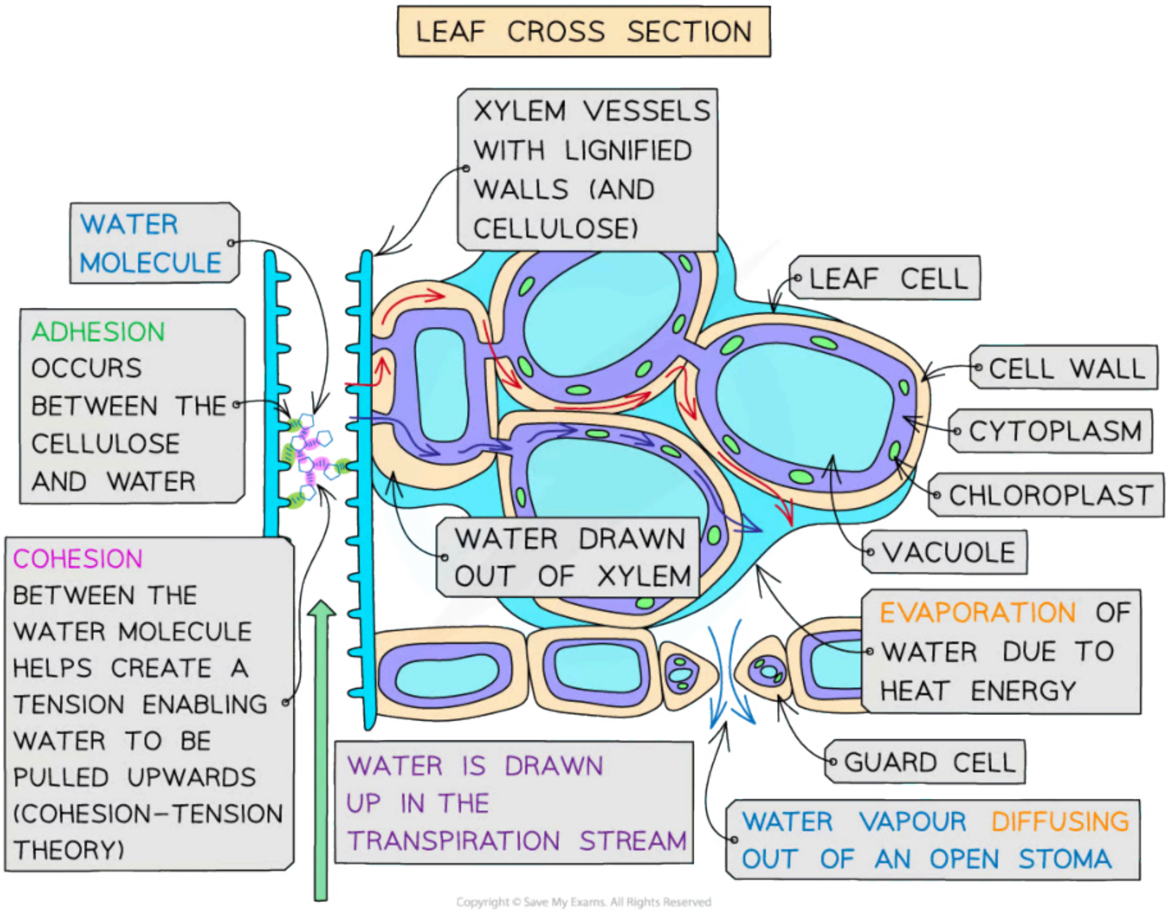
The Transpiration Stream

Your notes

The Transpiration Stream

- When water **evaporates** from the surfaces of cells inside a leaf during transpiration, more water is **drawn from the nearest xylem vessels** to **replace the water lost** by evaporation
  - Water molecules adhere **to the cell walls of plant cells** in the leaf, enabling water to move through the cell walls
    - Here the water moves through the cell walls of the xylem into other cells of the leaf
  - This movement of water that occurs due to adhesion to the walls of a narrow tube is **capillary action**
- The loss of water from the xylem vessels **generates tension** (negative pressure) within the xylem
- The tension generated in the xylem when water moves into the cells in the leaves creates a **pulling force** throughout the xylem vessels that is transmitted, via cohesion **between water molecules**, all the way down the stem of the plant and to the ends of the xylem in the roots
  - This is known as **transpiration pull** and it allows water to be moved upwards through the plant, against the force of gravity
- This is sometimes known as the cohesion-tension theory of transpiration
- This continuous upwards flow of water in the xylem vessels of plants is known as the **transpiration stream**

Water transport in plants diagram



The movement of water through xylem vessels is due to the evaporation of water vapour from the leaves and the cohesive and adhesive properties exhibited by water molecules

- Transpiration is important to the plant in the following ways
  - It provides a means of **cooling** the plant via evaporative cooling
  - The transpiration stream is helpful in the **uptake of mineral ions**
  - The turgor pressure of the cells (due to the presence of water as it moves up the plant) provides **support** to leaves (enabling an increased surface area of the leaf blade) and the stem of non-woody plants

Your notes

Adaptations of Xylem Vessels

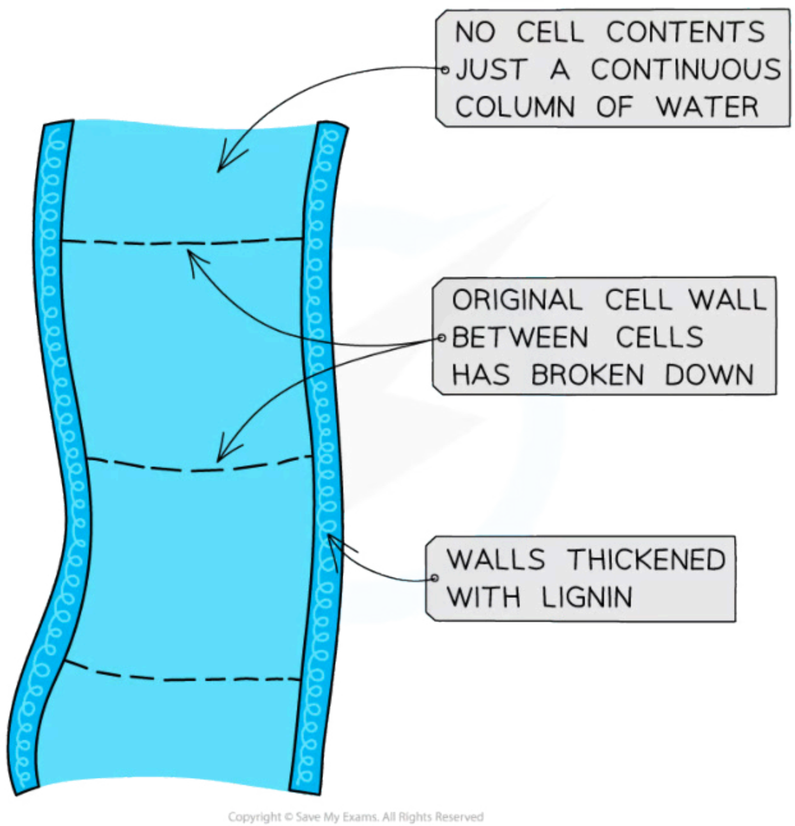
Adaptations of Xylem Vessels

- The transport of water occurs in xylem vessels, one of the vascular tissues found within plants
  - Along with water, xylem vessels are also responsible for the transport of mineral ions from the roots
- The cohesive property of water, together with the structure of the xylem vessels, allows water to be transported under tension from the soil to the leaves

Xylem vessel adaptations

- Xylem vessels are formed from **long lines of cells** that are connected at each end
  - Mature xylem vessels are **non-living** cells
- As the xylem cells develop the **cell walls between the connected cells degrade** and the **cell contents are broken down**
  - This forms **mature xylem vessels** that are **long, continuous, hollow tubes** that lack cell content and end walls
  - This allows for **unimpeded flow** through the xylem vessels
- The walls of xylem vessels are **thickened with cellulose** and **strengthened with a polymer called lignin**
  - This means xylem vessels are extremely tough and can **withstand very low internal pressures**, i.e. negative pressure (tension), **without collapsing** in on themselves
- Xylem vessel walls contain tiny pores called **pits** which allow water to enter and move sideways between vessels
  - This means that if a vessel is damaged, the water can flow into another vessel and still reach the leaves

Xylem structure diagram



Xylem vessels are adapted to transport water from the roots to the leaves in plants

Your notes

Your notes

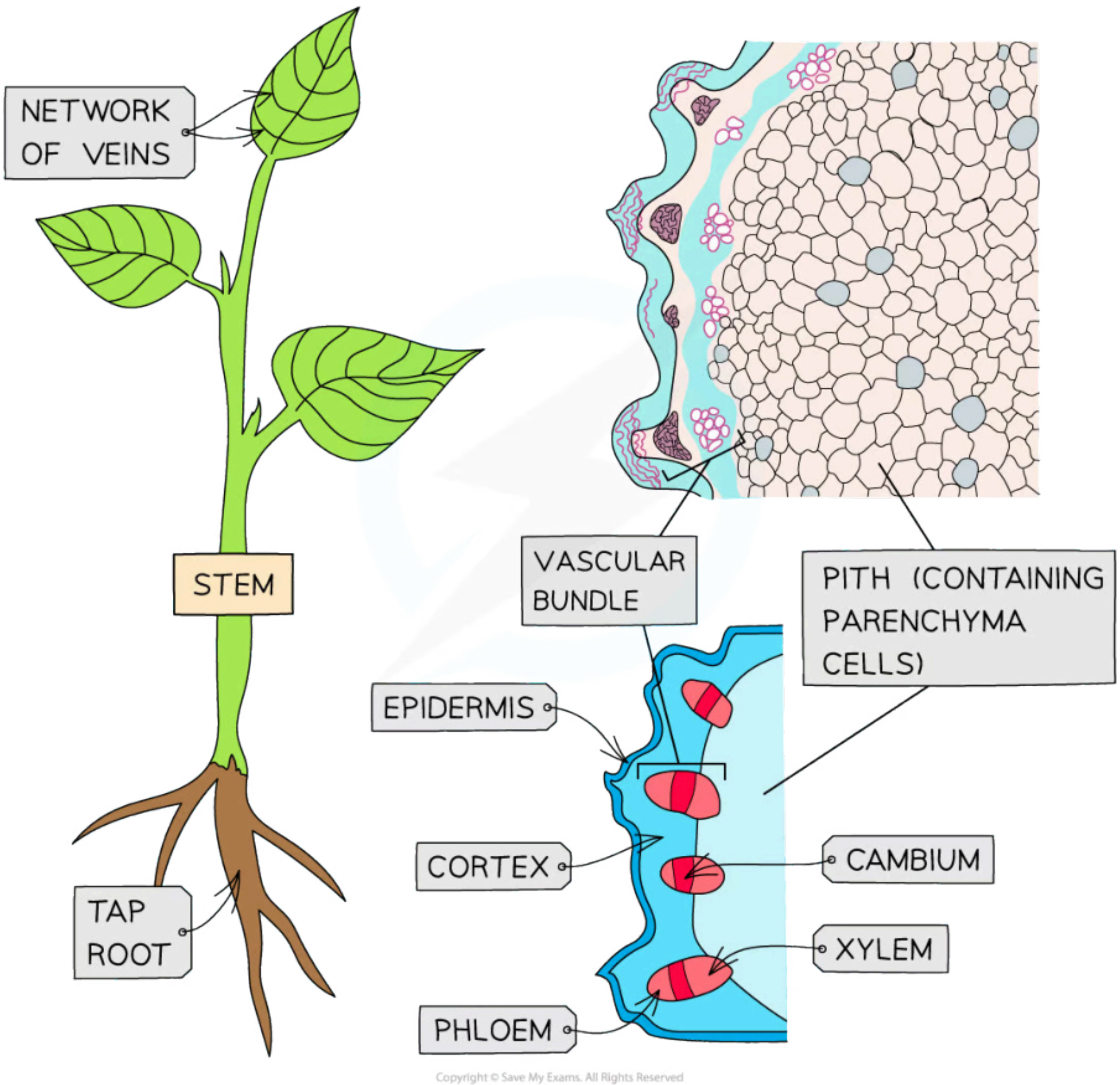
Drawing Root & Stem Structure: Skills

Dicotyledonous Stem Structure

Distribution of tissues in a transverse section of a dicotyledonous stem

- The stem in a dicotyledonous plant contains several different types of tissues, which include:
  - The **epidermis** which forms the outer layer of the stem
    - This prevents water loss and provides protection from herbivores
  - **Parenchyma** which forms the **cortex** and **pith** of the stem
    - These cells act as **storage structures** for starch and other substances
    - The cortex is the region located directly beneath the epidermis while the pith is the central region of the stem
  - **Vascular tissue** arranged in a ring of vascular bundles
    - **Xylem** transports **water** and **dissolved mineral ions** from the roots to the leaves
    - **Phloem** transports **organic solutes** from the leaves to other parts of the plant
- The distribution of tissues in a transverse section of a dicotyledonous stem can be represented as a **plan diagram**
- There are a few things to keep in mind when drawing plan diagrams:
  - Do not draw individual cells; only the **outline** of different tissues are drawn
  - Draw **clear**, **continuous lines**; do not sketch
  - **Avoid shading** parts of your drawing
  - Pay attention to the **size and proportions** of different parts visible in a micrograph
  - Make sure the different parts are **clearly labelled**
  - Add a **scale bar** or the **estimated size** of your drawing
  - Include **annotations** that give the functions of the labelled sections

Your notes



A plan diagram (bottom right) showing the distribution of different tissues in a dicotyledonous stem

Note that a hand-drawn plan diagram should not contain shading

Examiner Tip

You are expected to **annotate** your drawing with the main functions of these structures; this is not shown above

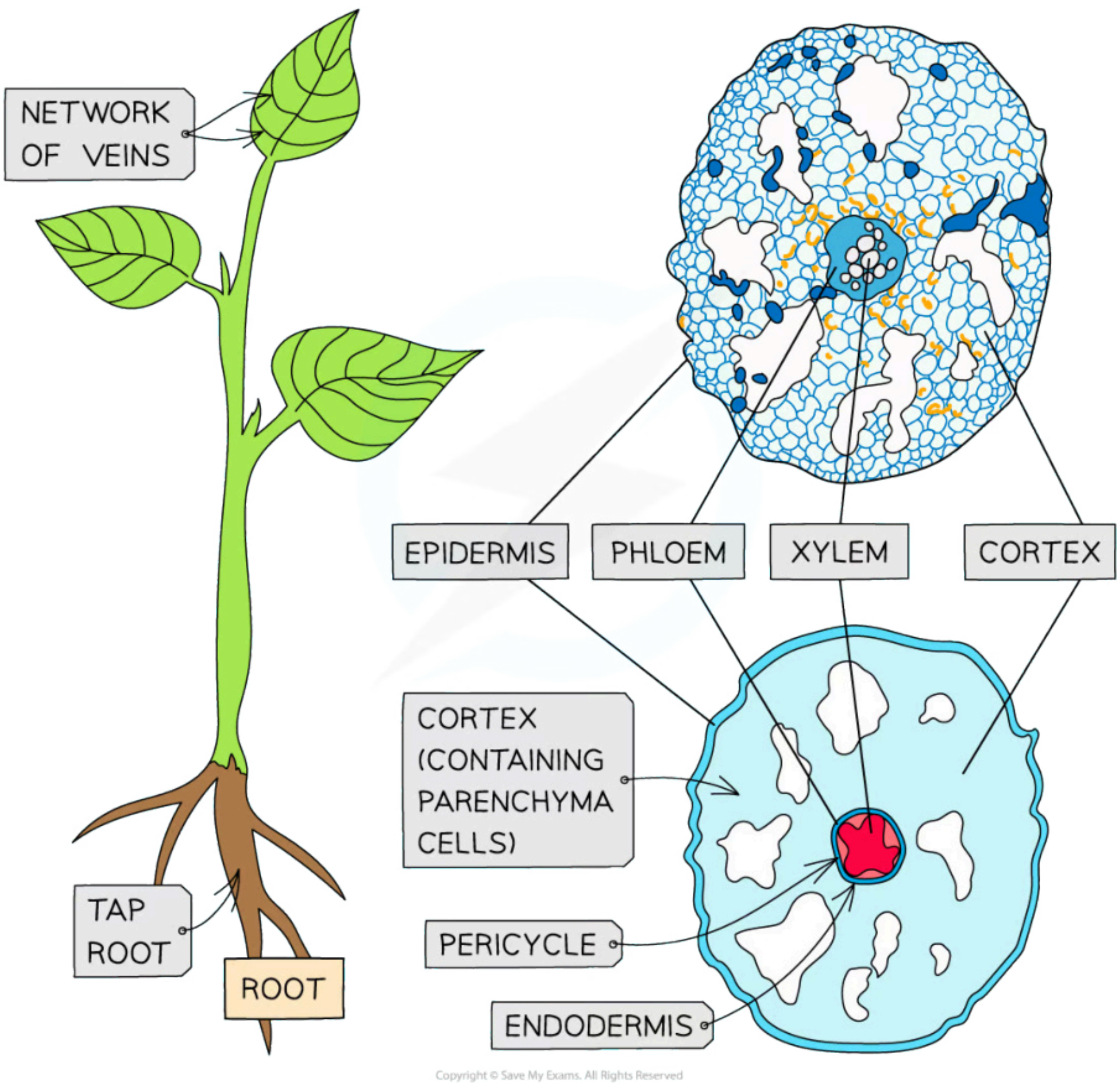
Your notes

Dicotyledonous Root Structure

Distribution of tissues in a transverse section of a dicotyledonous root

- The arrangement of the **vascular tissues** differ in a **root** compared to a stem
  - The **xylem** is centrally located in a root in a cross-shaped structure, while it forms the outer part of the ring of vascular bundles in a stem
    - Remember, x = a cross = **x**ylem
  - **Phloem** bundles are arranged between the cross "arms" of xylem in a root, while it forms the inner part of the ring of vascular bundles in a stem
- The **cortex** consists of parenchyma cells that store starch and other substances while the **epidermis** forms the outer layer of the root
  - Specialised epidermal cells called **root hairs** are present in roots to absorb water and mineral ions from the soil
- The **endodermis** forms the boundary between the vascular tissue and cortex in a root
- You should be able to **draw a plan diagram** of the tissues in a dicotyledonous root; see above for the features of a plan diagram drawing

Your notes



A plan diagram (bottom right) of a dicotyledonous root showing the distribution of different tissues

Note that hand-drawn plan diagrams should not contain any shading

Examiner Tip

Don't forget to draw your plan diagrams large enough to fill at least half of the available space on a page. Making a drawing that is too small will make it difficult to label structures accurately and may cost you marks

Your notes

Tissue Fluid (HL)

Release & Reuptake of Tissue Fluid

- **Plasma** is a straw-coloured liquid that constitutes around 55 % of the blood
- Plasma is largely composed of water (95 %) and, because **water** is a good **solvent**, many substances can dissolve in it, allowing them to be transported around the body
- As blood passes through **capillaries** some plasma is forced out through gaps in the walls of the capillary to surround the cells of the body; this results in the formation **of tissue fluid**
- The composition of plasma and tissue fluid are very similar, although **tissue fluid** contains **fewer** proteins and cells
  - Proteins are **too large to fit through gaps in the capillary walls** and so remain in the blood
  - **Red blood cells** and **platelets** are not present in the tissue fluid as they are also too large to leave the capillaries
- Tissue fluid bathes almost all the cells of the body that are outside the circulatory system
- **Exchange** of substances between cells and the blood occurs via the tissue fluid
  - For example, carbon dioxide produced in aerobic respiration will leave a cell, dissolve into the tissue fluid surrounding it, and then move back into the capillary

The effect of blood pressure on tissue fluid

Tissue fluid formation at the arterial end

- When blood is at the arterial end of a capillary the **blood pressure** is high enough to **force fluid out** of the capillary
- The process by which tissue fluid is forced out of the capillaries at high pressure is known as **pressure filtration**

Reuptake of tissue fluid at the venous end

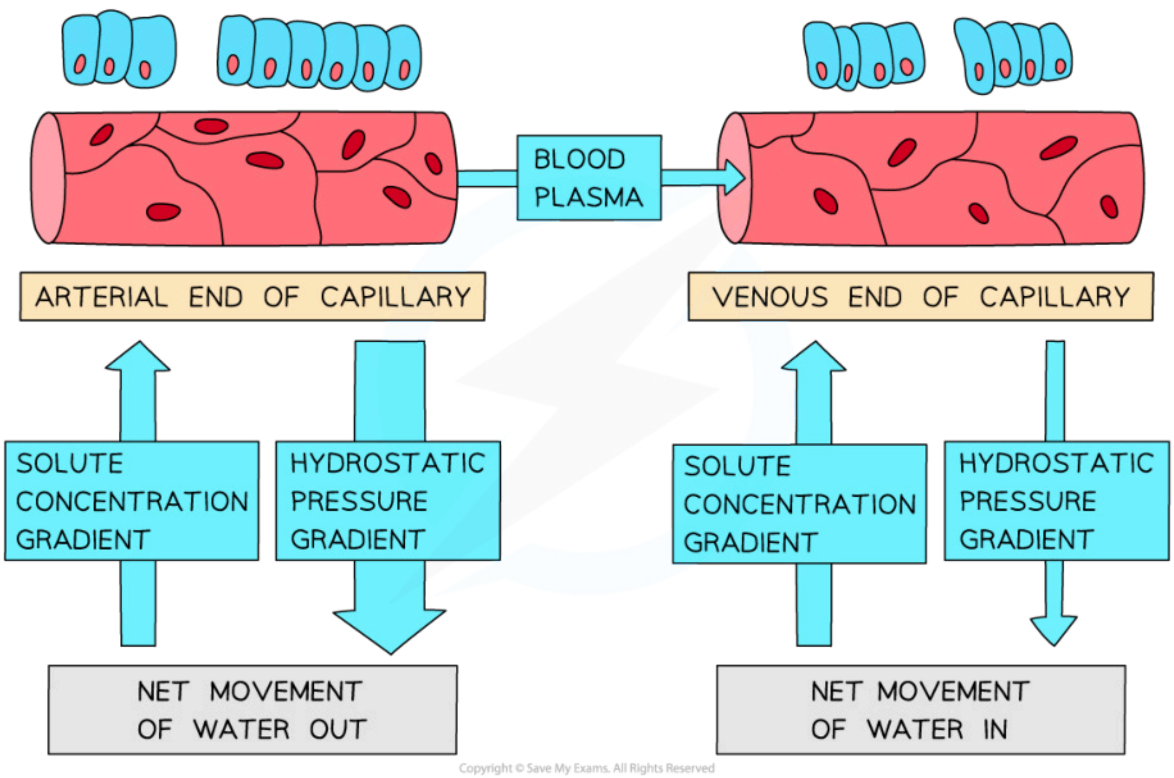
- At the venous end of the capillary the **blood pressure within the capillary is reduced** due to increased distance from the heart and the slowing of blood flow as it passes through the capillaries
- Tissue fluid drains back into the capillaries from the tissues
  - Roughly 90 % of the fluid lost at the arterial end of the capillary is reabsorbed at the venous end
  - The other 10 % remains as **tissue fluid** and is eventually collected by vessels known as lymph vessels
    - From the lymph vessels the fluid is eventually returned to the circulatory system

The effect of solute concentration on tissue fluid

- **Pressure filtration** occurs due to the outward force exerted by **high blood pressure at the arterial end** of capillaries, but high blood pressure isn't the only factor that affects tissue fluid:
  - After pressure filtration has occurred, proteins remain in the blood as they are too large to pass through the pores in the capillary wall
  - The **increased protein concentration** of the capillary creates a **solute gradient** between the capillary and the tissue fluid
    - The solutes in this case are the proteins in the blood

Your notes

- The solute gradient exerts an **inward pull** on the tissue fluid which draws water back into the capillary
  - This is due to **osmosis**, which is the movement of water from a dilute solution (the tissue fluid) to a solution with a higher solute concentration (the capillary)
- At the arterial end the outward force generated by the **high blood pressure is greater than the** inward force of the solute gradient so the net movement of water is **out of the capillaries** into the tissue fluid
- At the venous end the **inward force of the solute gradient is greater** than the outward force of the blood pressure and **fluid moves back into the capillaries**



At the arterial end the hydrostatic pressure (blood pressure) has a greater effect than the solute gradient so the tissue fluid is forced out of the capillaries

At the venous end the hydrostatic pressure has less effect than the solute gradient so most of the fluid is drawn back into the capillary

Examiner Tip

Remember that tissue fluid is formed by **pressure filtration** of plasma in capillaries, which is promoted by the higher blood pressure from arterioles. Lower pressure in venules allows tissue fluid to drain back into capillaries.

Note that the specification does not require knowledge of the effect of solute concentration on tissue fluid, but this has been included here to better explain the draining of tissue fluid at low blood pressure.

Composition of Plasma & Tissue Fluid

Your notes

- Blood plasma and tissue fluid are similar in their composition, although there are some differences between them
  - **Water** and **solutes** form an important part of both plasma and tissue fluid
  - Substances that are **too large** to filter out through the capillary wall, such as **plasma proteins** and **red blood cells** will not be found in tissue fluid
  - Some **white blood cells**, which are very flexible cells, are able to squeeze out of the capillaries, so are present in the tissue fluid
  - Substances such as **glucose**, **amino acids** and **oxygen** are absorbed by cells, so tissue fluid will contain less of these substances
    - Glucose and oxygen are requirements of **aerobic respiration** while amino acids are needed for **protein synthesis**
  - Cells produce **carbon dioxide** as a waste product during cell respiration which will diffuse into the tissue fluid

Composition of blood plasma and tissue fluid table

Substance	Blood plasma	Tissue fluid
Blood cells	Red blood cells, phagocytes, lymphocytes and platelets	Phagocytes
Proteins	Many large plasma proteins	Fewer, smaller proteins
Glucose	Higher concentration	Lower concentration
Amino acids	Higher concentration	Lower concentration
Oxygen	Higher concentration	Lower concentration
Carbon dioxide	Lower concentration	Higher concentration

Your notes

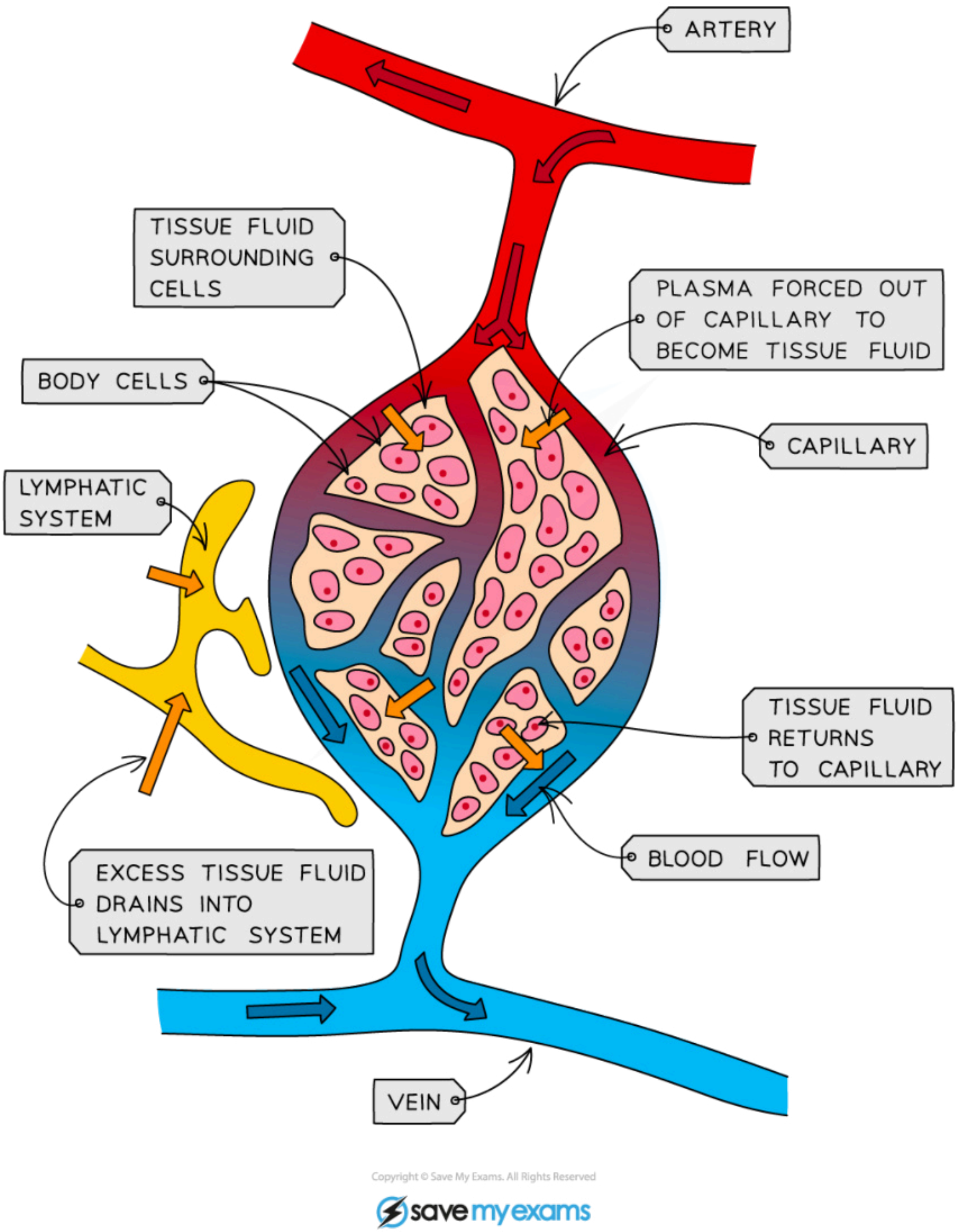
Drainage Into Lymph Ducts

Formation of lymph

- Some tissue fluid re-enters the capillaries while some enters the **lymph capillaries**
- The lymph capillaries are separate from the circulatory system and form part of the **lymphatic system**
  - They have closed ends and large pores that allow large molecules to pass through
  - They contain fluid known as lymph
- **Larger molecules** that are not able to pass through the capillary wall enter the lymphatic system
  - Small valves in the vessel walls are the entry point to the lymphatic system
- Lymph fluid moves along the larger vessels of this system by **compression caused by body movement**. Any backflow is prevented by **valves**
  - These larger vessels are known as **lymph ducts**
  - People who have been sedentary on planes may experience swollen lower limbs due to the lack of movement which causes lymph to accumulate in these parts
- **Lymph nodes** are present in the lymph ducts
  - These contain macrophages which will engulf bacteria present in the lymph
  - Other cells of the immune system can also be found in the lymph nodes
- The lymph eventually **re-enters the bloodstream** through veins located close to the heart
- Any **plasma proteins** that have escaped from the blood are returned to the blood via the lymph capillaries
  - If plasma proteins are not removed from tissue fluid they could increase the solute concentration of the tissue fluid and prevent the reabsorption of water into the blood in the capillaries
- After digestion **lipids** are transported from the intestines to the bloodstream by the lymph system, so lymph fluid contains lipids

Tissue fluid and lymph vessels diagram

Your notes



Some components of tissue fluid drain into the lymph vessels

Circulatory Systems (HL)

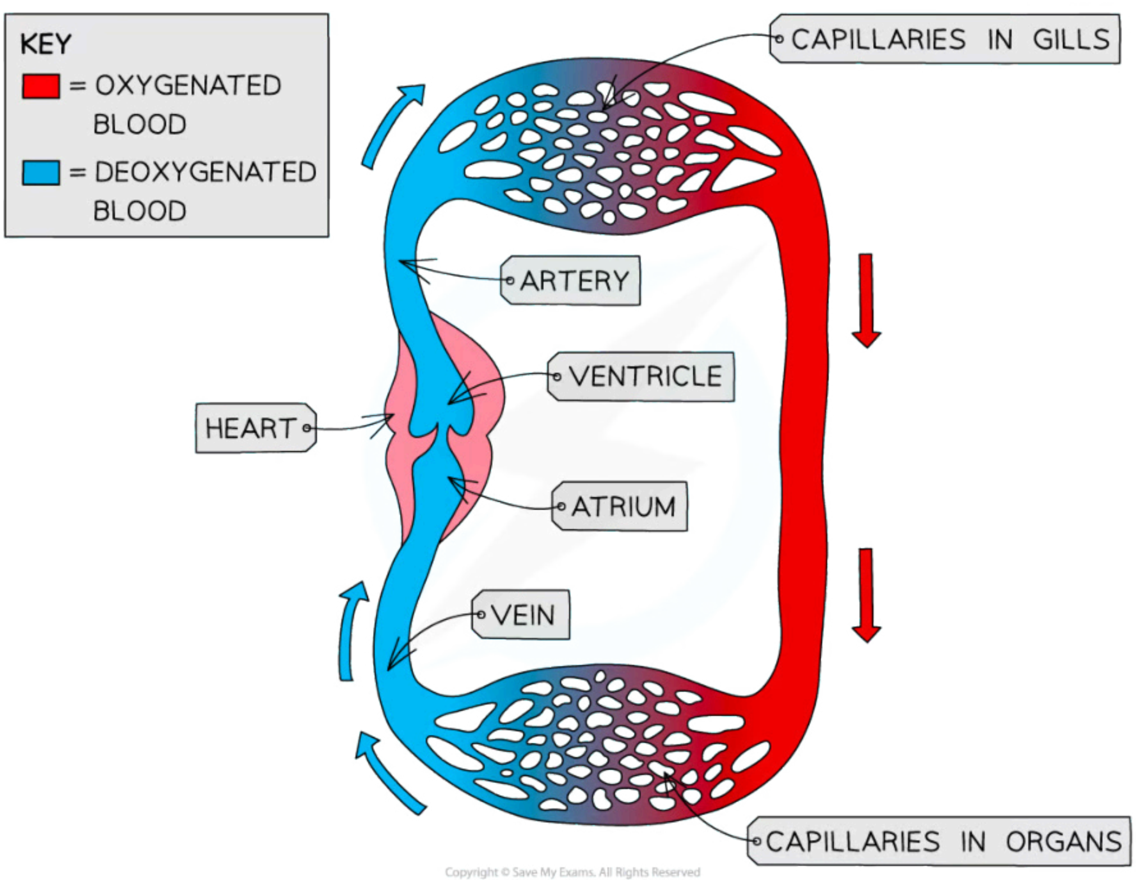
Your notes

Comparing Single & Double Circulation

Differences between single circulation in bony fish and double circulation in mammals

- Both fish and mammals have a **closed circulatory system**
  - This means blood is contained within a system of **blood vessels**
- Bony fish have **single circulation**
  - Blood moves through the heart **once** during each complete circuit
  - The heart has **two chambers**
  - It enters the heart from the body before being pumped to the **gills**
  - Here blood is **oxygenated** before moving to the rest of the **body**

Single circulation diagram

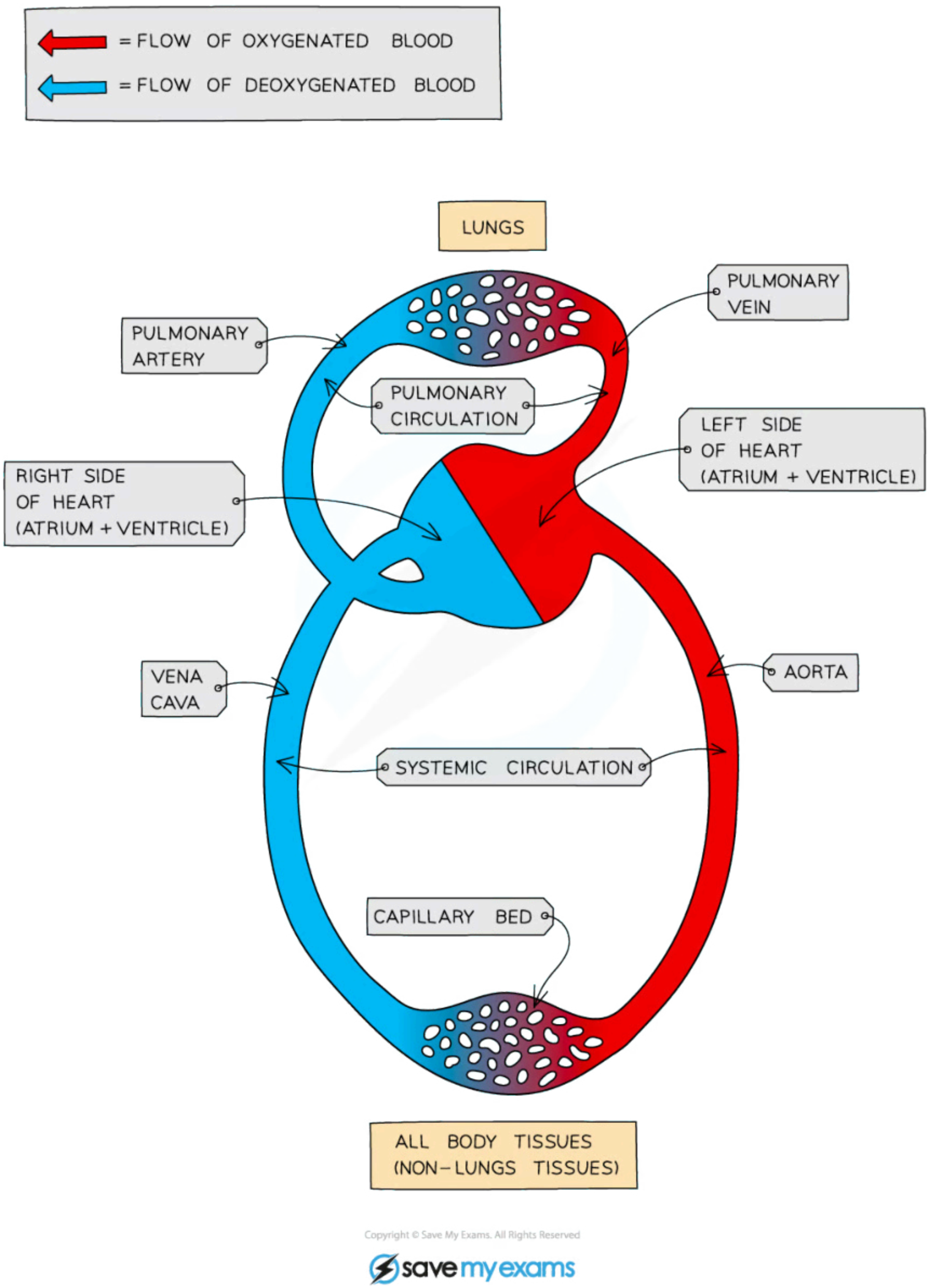


Bony fish have single circulation

- Mammals have **double circulation**
  - This means blood flows through the heart **twice** for each complete circuit of the body
  - The heart has **four chambers**; two on the right and two on the left
  - The right side of the heart pumps deoxygenated blood to the lungs for gas exchange; this is **pulmonary circulation**
  - 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 **systemic circulation**

Double circulation diagram

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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Mammals have double circulation

Your notes

- The main **advantages** of the mammalian double circulation system include:
  - Keeping **oxygenated and deoxygenated blood separate**, so that cells can receive blood with high oxygen levels for aerobic respiration
  - Maintaining a **high pressure** for the transport of oxygenated blood to every part of the body
  - Pumping blood at a **lower pressure** in the lungs so that delicate blood vessels are not damaged

Your notes

The Mammalian Heart (HL)

The Mammalian Heart

Adaptations of the mammalian heart to deliver blood to the arteries

- The heart muscle is known as **cardiac muscle**; a specialised form of muscle tissue that is able to contract repeatedly and continuously without becoming fatigued
- The heart is divided into four chambers; the two top chambers are **atria** and the bottom two chambers are **ventricles**
  - The atria
    - These chambers **receive blood from the veins** that return from the lungs and the body
    - They are surrounded by a **thin layer of muscle**, allowing them pump blood over a short distance **into the ventricles** below
  - The ventricles
    - These chambers **receive blood from the atria**
    - They have **thick muscle walls** which can generate high pressures for **pumping blood to the lungs and to the body**
    - The left ventricle has thicker muscle than the right ventricle, as it must pump blood all around the body
- 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 wall of the right atrium contain a small region of tissue known as the **pacemaker**, or sinoatrial node (SAN)
  - The pacemaker initiates the heart beat by sending a wave of excitation across the **atria**
    - This causes atrial contraction
  - The electrical impulse travels down to the **base of the ventricles**
  - From the base, it spreads **upwards** across the ventricular walls
    - This causes ventricular contraction
- 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**

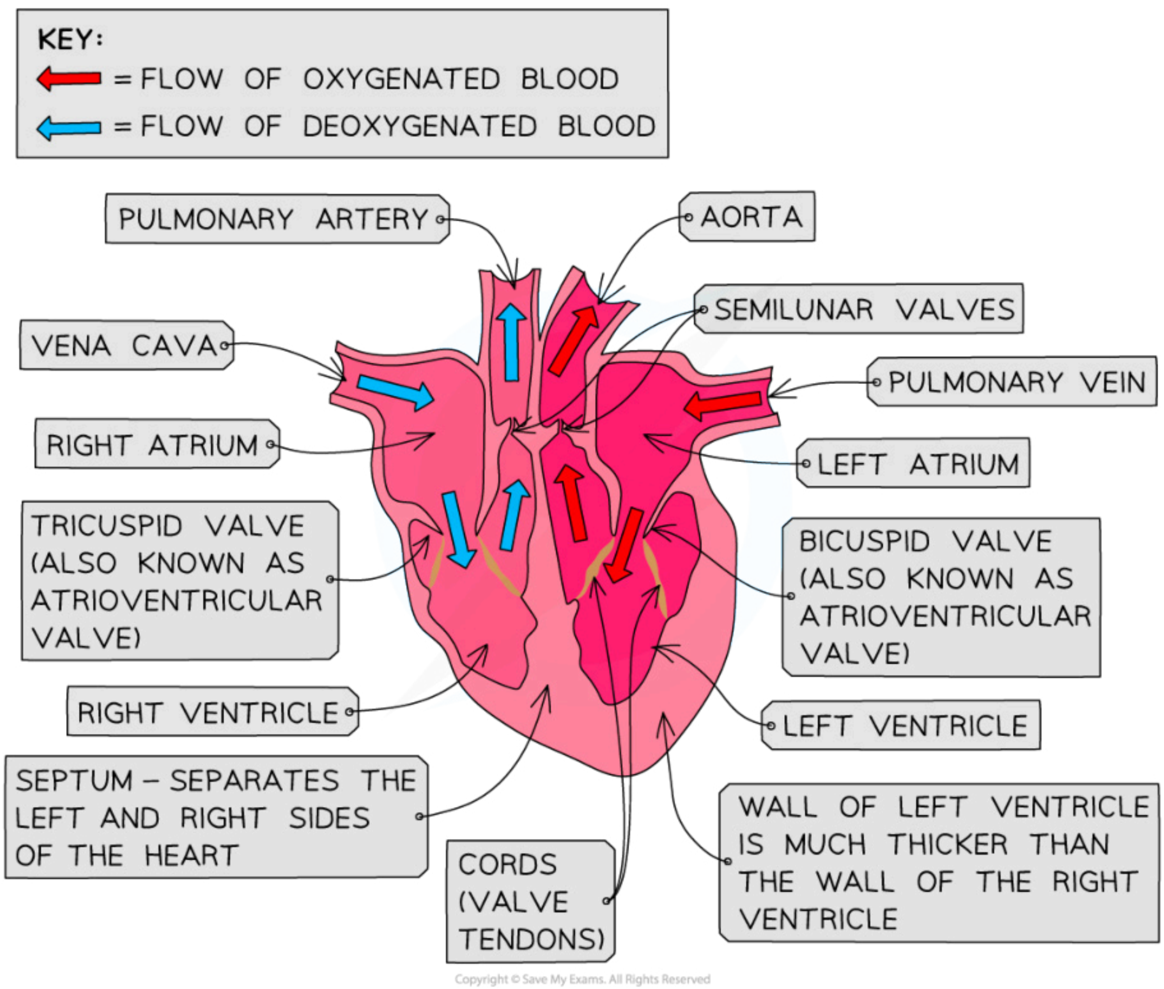
Valves in the heart

- Valves are important for keeping blood flowing forward in the **right direction** and **stopping it flowing backwards**
- 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 between the atria and the ventricles are the **atrioventricular valves**; they prevent blood from flowing back from the ventricles into the atria
  - The right atrium and right ventricle are separated by the **tricuspid valve**
  - The left atrium and left ventricle are separated by the **bicuspid valve**

Your notes

- The valves between the ventricles and the arteries are the **semilunar valves**
  - The right ventricle and the pulmonary artery are separated by the **pulmonary valve**
  - The left ventricle and aorta are separated by a valve called the **aortic valve**

Heart structure diagram



Deoxygenated blood flows into the right atrium from the body, from which it flows downwards into the right ventricle, and then upwards to the pulmonary artery which carries it to the lungs

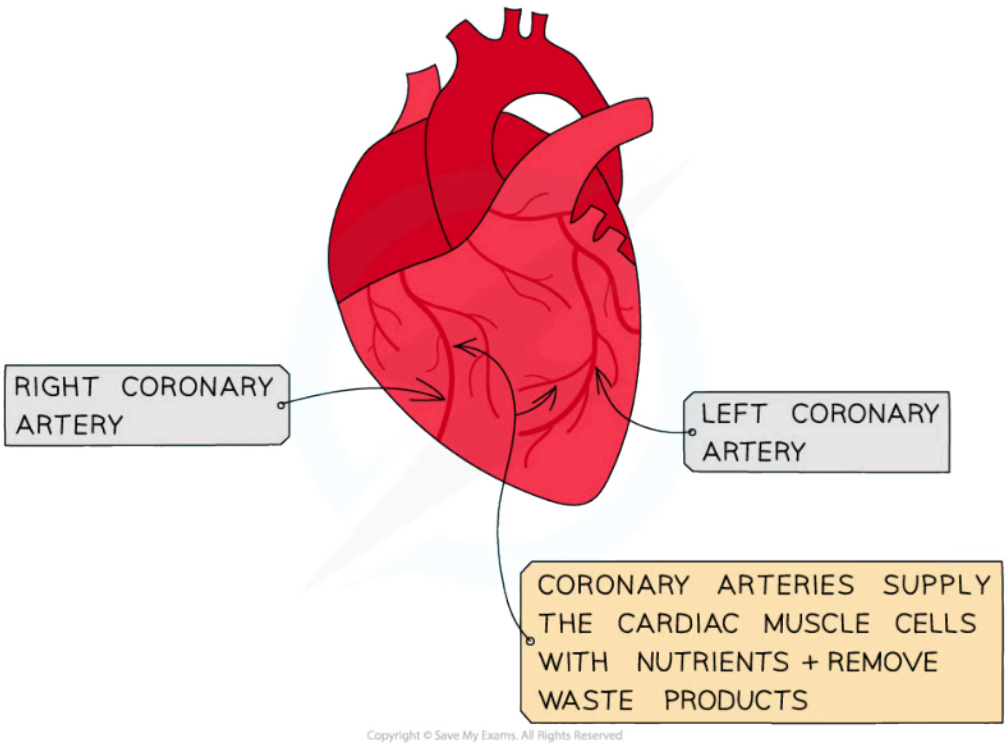
Oxygenated blood from the lungs enters the left atrium, flows down into the left ventricle, and then upwards to the aorta which carries it to the rest of the body

Coronary arteries

- The heart is a muscle and so requires its own **blood supply**; blood supplies the cells with oxygen and glucose for **aerobic respiration**
- The heart receives blood through arteries called **coronary arteries**

- These arteries are visible on the front of the heart

Coronary arteries diagram



The coronary arteries supply the heart muscle with oxygenated blood

Examiner Tip

When looking at the heart, remember that 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.

Your notes

Your notes

The Cardiac Cycle: Skills (HL)

The Cardiac Cycle

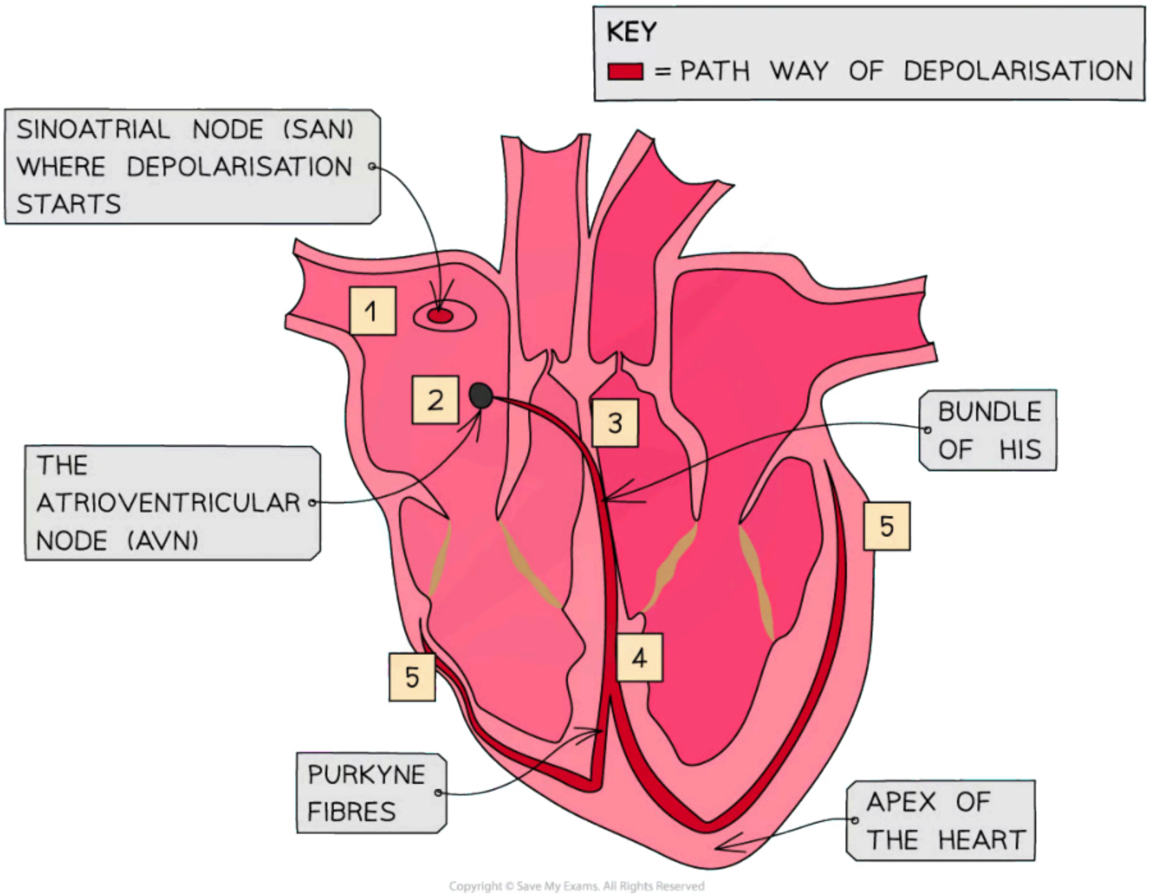
Control of the cardiac cycle

- Control of the basic heartbeat is **myogenic**, which means the heart will beat without any external stimulus from the nervous system
  - This intrinsic rhythm means the heart beats at around 60 times per minute
- The **sinoatrial node (SAN)** is a group of cells in the wall of the right atrium; it controls the cardiac cycle as follows:
  - The SAN initiates a wave of **depolarisation** that spreads across the atria and causes the **atria to contract**
  - A region of non-conducting tissue prevents the depolarisation spreading straight to the ventricles
    - This delays the wave of depolarisation for long enough to allow the atria to finish contracting
  - The depolarisation is instead carried to the **atrioventricular node (AVN)**; this is a region of conducting tissue between atria and ventricles
  - Conducting fibres carry the wave of excitation down the septum and out around the walls of the ventricles
    - The **bundle of His** is a collection of conducting tissue located in the **septum**
    - The **Purkyne fibres** spread around the ventricles
  - The ventricles depolarise from the base upwards, and the ventricles contract

Stages in the cardiac cycle table

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

Control of cardiac cycle diagram



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

The events of the cardiac cycle

- The **cardiac cycle** is the series of events that take place in **one heart beat**, 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
- The events of the cardiac cycle **occur simultaneously** in the **left and right** sides of the heart

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**
  - 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**

Your notes

Atrial systole

- The heartbeat is initiated by the **sinoatrial node**
- 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

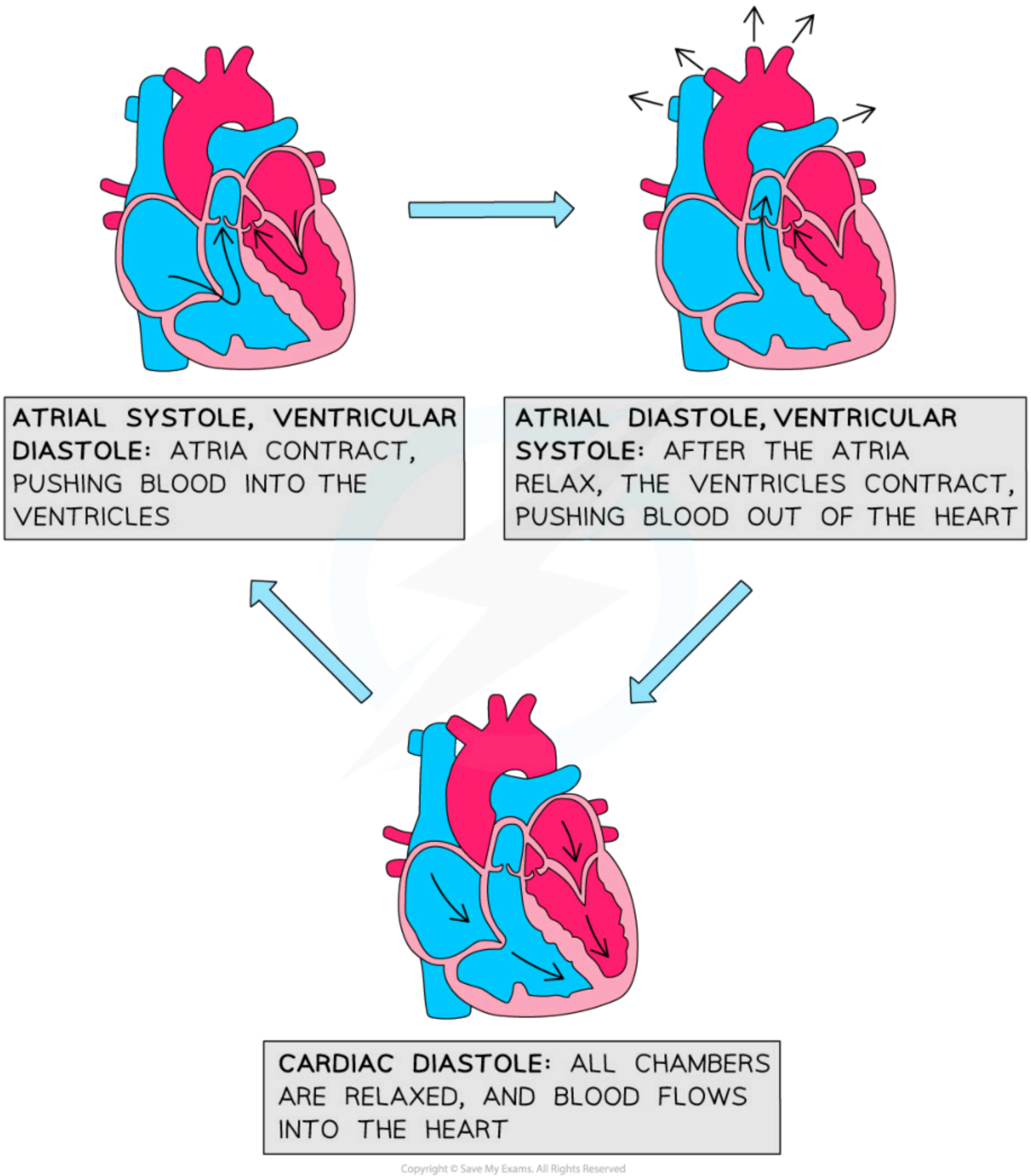
- The walls of the **ventricles contract**
  - Ventricular volume decreases
  - Ventricular pressure increases
- The pressure in the ventricles rises above that in the atria
  - This **forces the AV valves to close**, preventing back flow of blood
- The pressure in the ventricles rises above that in 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**
- The 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
- The cycle then begins again with atrial systole

Cardiac cycle diagram

Your notes

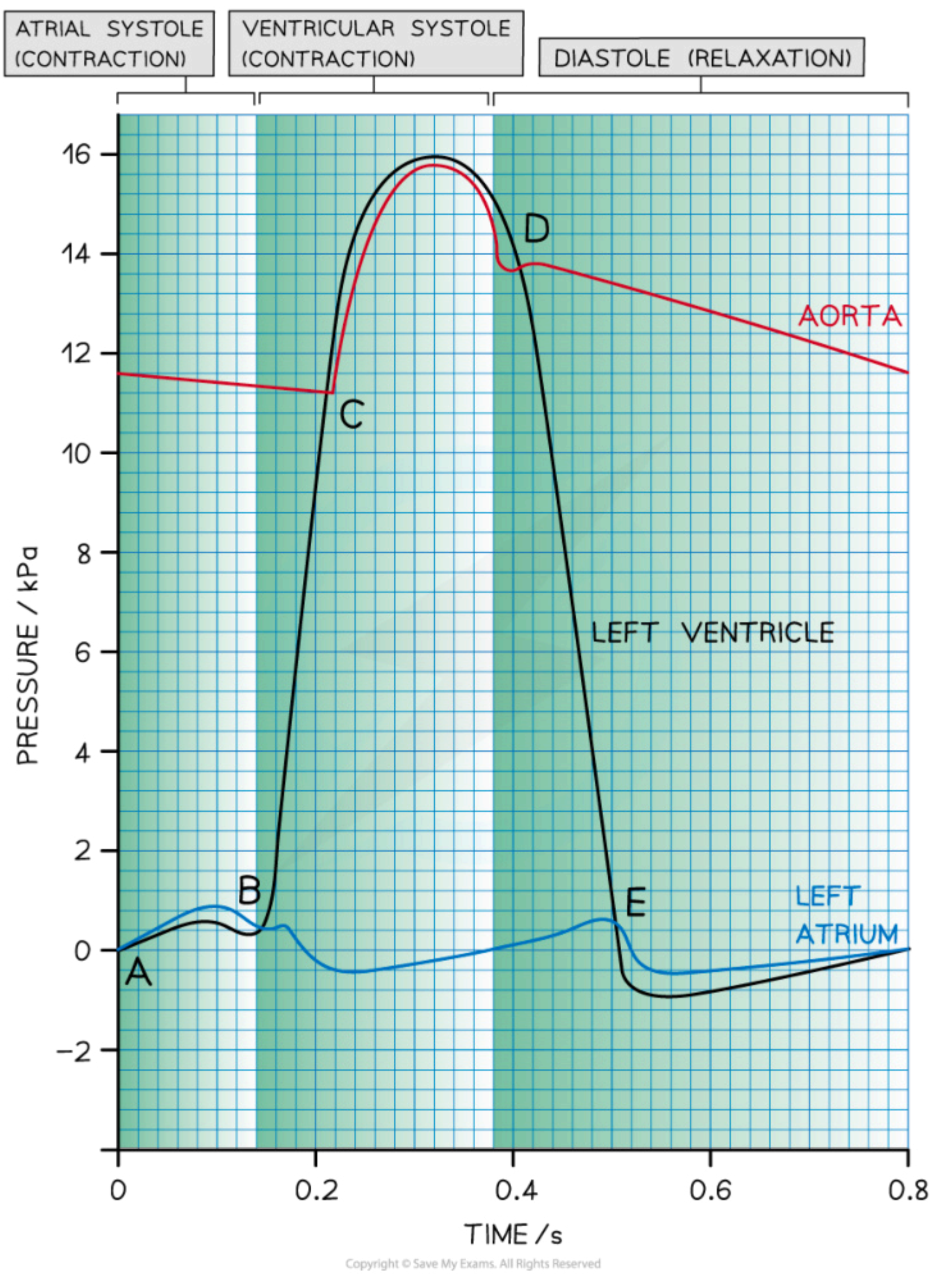


Valves during the cardiac cycle table

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

Ventricular systole	Closed	Open
Diastole	Open	Closed

Pressure changes during the cardiac cycle graph



The pressure changes during the cardiac cycle can be used to determine the events taking place

Your notes

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

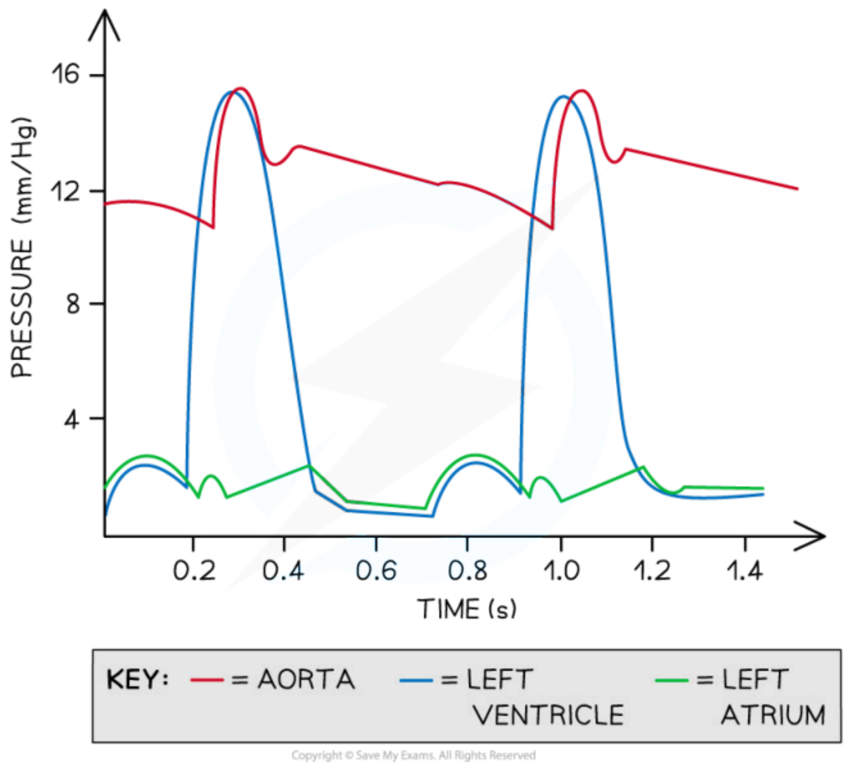
- There is a short period of time during which the **left ventricle expands** due to relaxing muscles
- This increases the internal volume of the left ventricle and **decreases the ventricular pressure**
- At the same time, blood is flowing slowly through the newly opened AV valve into the left ventricle,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

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



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**

Your notes

Examiner Tip

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 include

- Pressure and volume changes,
- Timings of valves opening and closing
- When blood starts flowing in or out of specific chambers

Note that the specification refers to events 'in the left side of the heart', while this pages does not distinguish between left and right. The events of the cardiac cycle occur simultaneously in the left and right sides of the heart, so anything on this page can be applied equally to the left or right sides.

The Roots & Water Transport (HL)

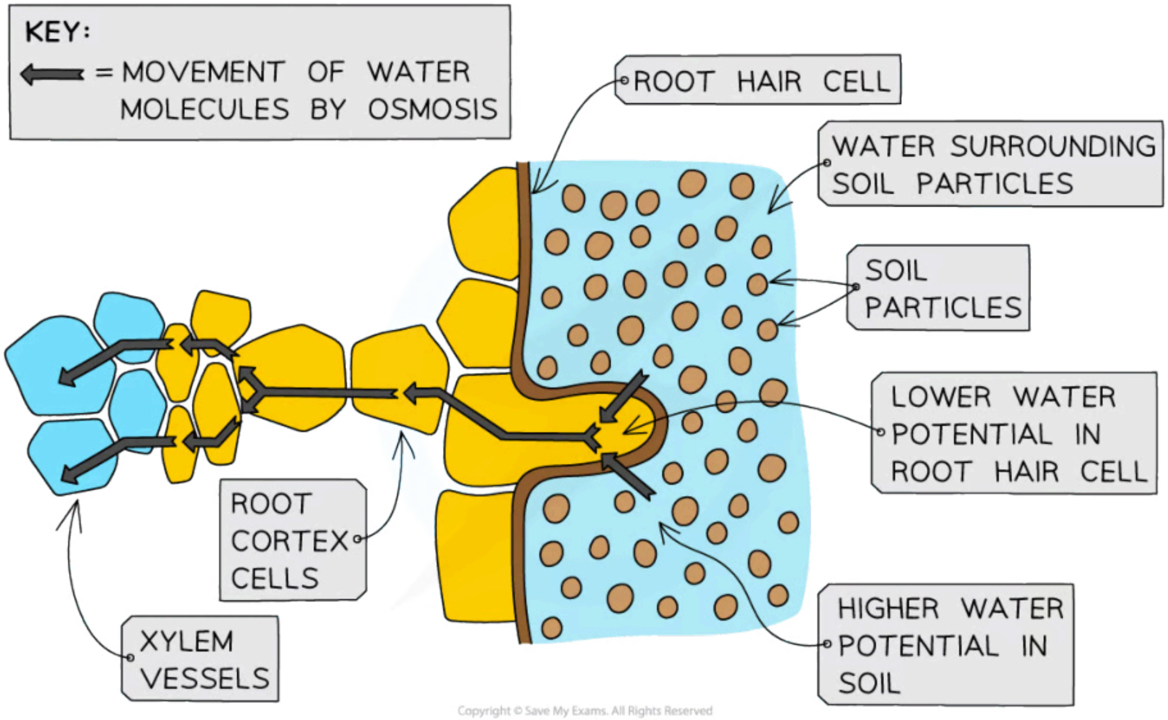
Your notes

Generation of Root Pressure

- Loss of water at the leaves by transpiration creates a negative pressure inside xylem vessels which pulls water up the stem of plants, but plants can also push water up from the roots by generating **root pressure**
- Root pressure is generated as follows:
  - Minerals are **actively transported** into the cells of the roots from the soil, **lowering the water potential** of the root cells
    - Note that a low water potential is the result of a high solute concentration
  - This creates a **water potential gradient** between the soil and the cells of the roots and **water moves into the root cells by osmosis**
  - Minerals are then actively transported from cell to cell across the root, eventually reaching the xylem
  - As minerals enter the cells and the xylem the water potential is reduced and **water follows by osmosis**
  - Water enters the xylem and generates a **positive pressure potential**; this **pushes** the column of water upwards; this is root pressure
- Root pressure is important in driving the movement of water up xylem vessels when the **rate of transpiration is low**
  - E.g. in conditions of high humidity or before the leaves of deciduous plants develop in spring

Root pressure diagram

Your notes



Water moves into the xylem by osmosis due to the water potential gradient created when minerals are actively transported into roots from the soil

Water that enters the xylem in this way generates root pressure

Your notes

Translocation in Plants (HL)

Translocation in Plants

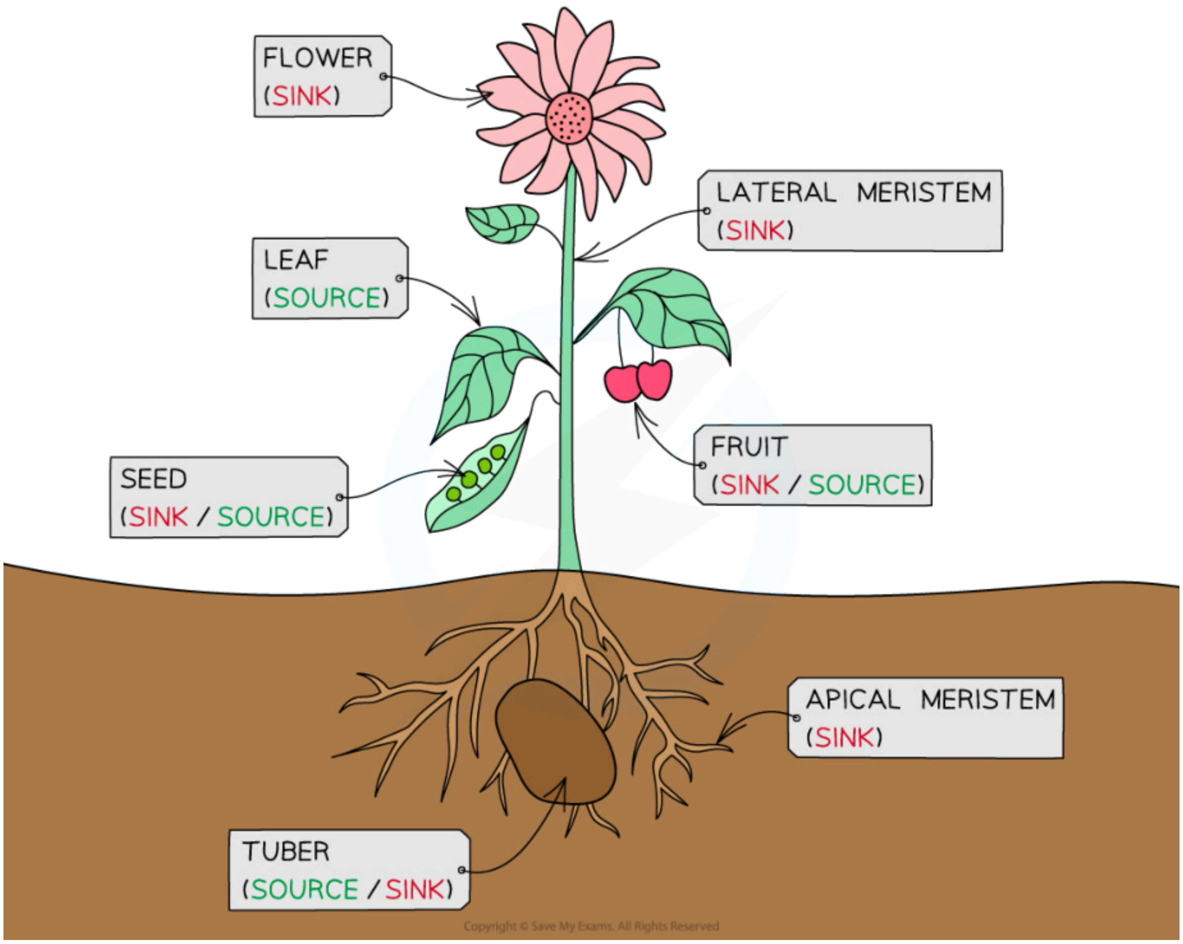
- Translocation is the biological term used to describe the **transport of organic solutes** in the **phloem tissue**
  - The liquid that is being transported within the phloem can be referred to as **phloem sap**
  - This phloem sap consists of sugars in the form of **sucrose**, along with **water** and other dissolved substances such as **amino acids**
    - These dissolved substances are sometimes referred to as assimilates
- Translocation within phloem tissue transports these organic compounds from regions known as **'sources'** to regions known as **'sinks'**

Sources and sinks

- Sources are the regions of plants in which **organic solutes originate**; they can include
  - Mature **green leaves** and **green stems**
    - **Photosynthesis** in these regions **produces glucose** which is converted into sucrose before being transported
  - **Storage organs**, e.g. tubers and tap roots, unloading their stored substances at the beginning of a growth period
  - Food stores in **seeds which are germinating**
- Sinks are the regions of plants where **organic compounds are required** for growth; they can include
  - Meristems that are actively dividing
  - **Roots** that are **growing** or actively **taking up mineral ions**
  - **Young leaves** in bud
  - Any part of the plant where **organic compounds are being stored**, e.g. developing seeds, fruits, or storage organs
- Note that **sources can become sinks and vice versa**, depending on the time of year and the processes taking place inside the plant

Sources and sinks diagram

Your notes



Organic compounds are moved through a plant, by the process of translocation, from source(s) to sink(s).

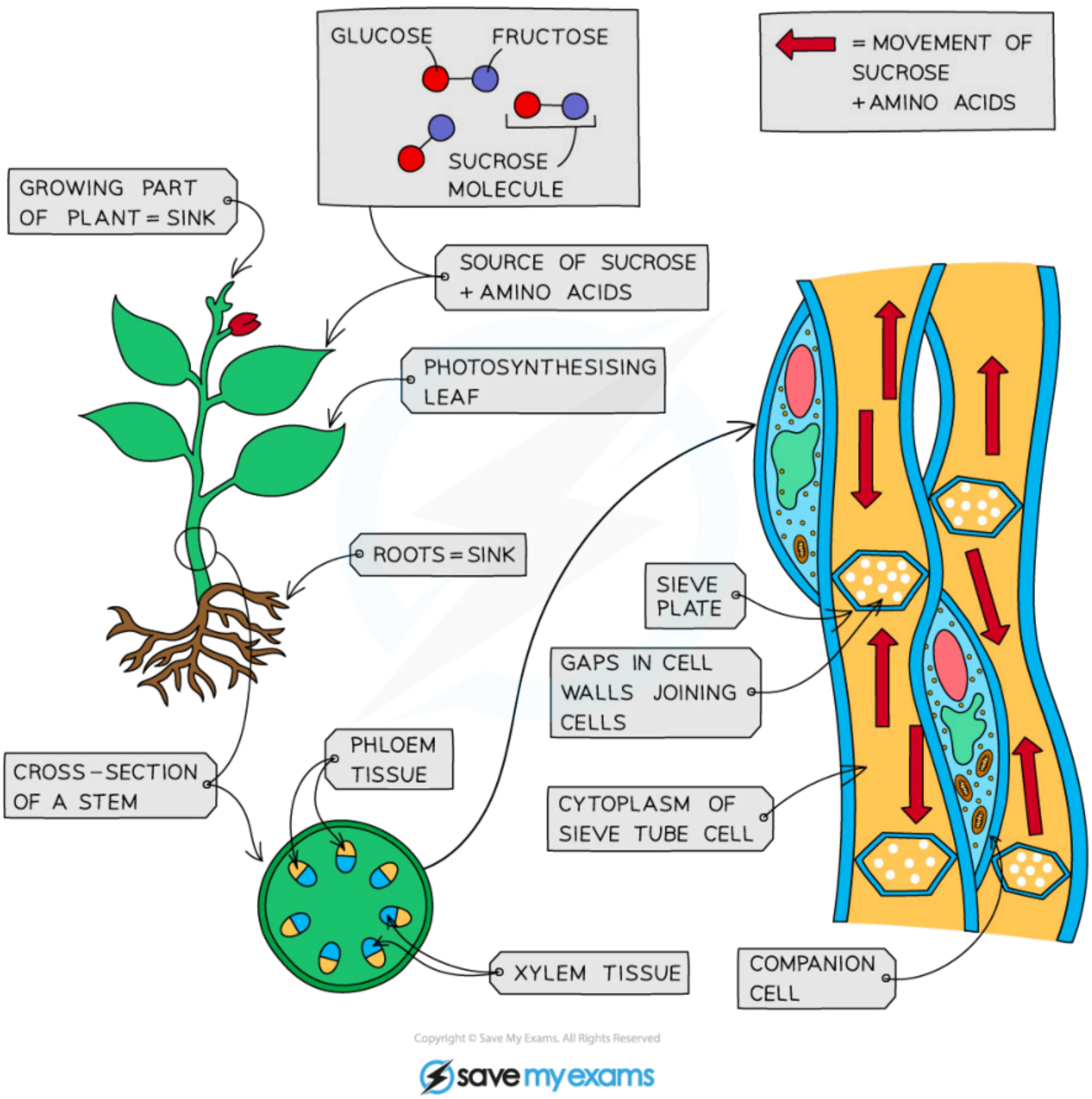
Phloem adaptations

- The function of phloem tissue in a plant is to **transport organic compounds**, particularly sucrose, **from sources to sinks**
- The cells that make up the phloem tissue are highly specialised, meaning that their **structure aids their function**
- Phloem is a complex tissue made up of different cell types; it is mainly made up of **sieve tube elements** and **companion cells**
  - Sieve tube cells, or elements, line up end-to-end to form a **continuous tube** through which phloem sap flows
    - The cells are separated by perforated **sieve plates** which allow the **passage** of assimilates
    - Sieve tube cells have **reduced cytoplasm** and **few organelles** to allow the **free flow** of phloem sap
  - Companion cells are **closely associated with the sieve tube** and aid with the loading and unloading of dissolved substances, or assimilates

Your notes

    - Companion cells contain **many mitochondria** which generate ATP for the **active loading** of sucrose into the sieve tube
- Sieve tubes and companion cells are linked by **bridges of cytoplasm** known as **plasmodesmata**

Phloem adaptations diagram



Phloem tissue contains sieve tube cells and companion cells

Sieve tube structure and function table

Structure	Function

Sieve plates	Allows for the continuous movement of the organic compounds between cells
Cellulose cell wall	Strengthens the wall to withstand the hydrostatic pressures that move the assimilates
No nucleus, vacuole or ribosomes in mature cells	Maximises the space for the translocation of assimilates
Thin cytoplasm	Reduces friction to facilitate the movement of assimilates

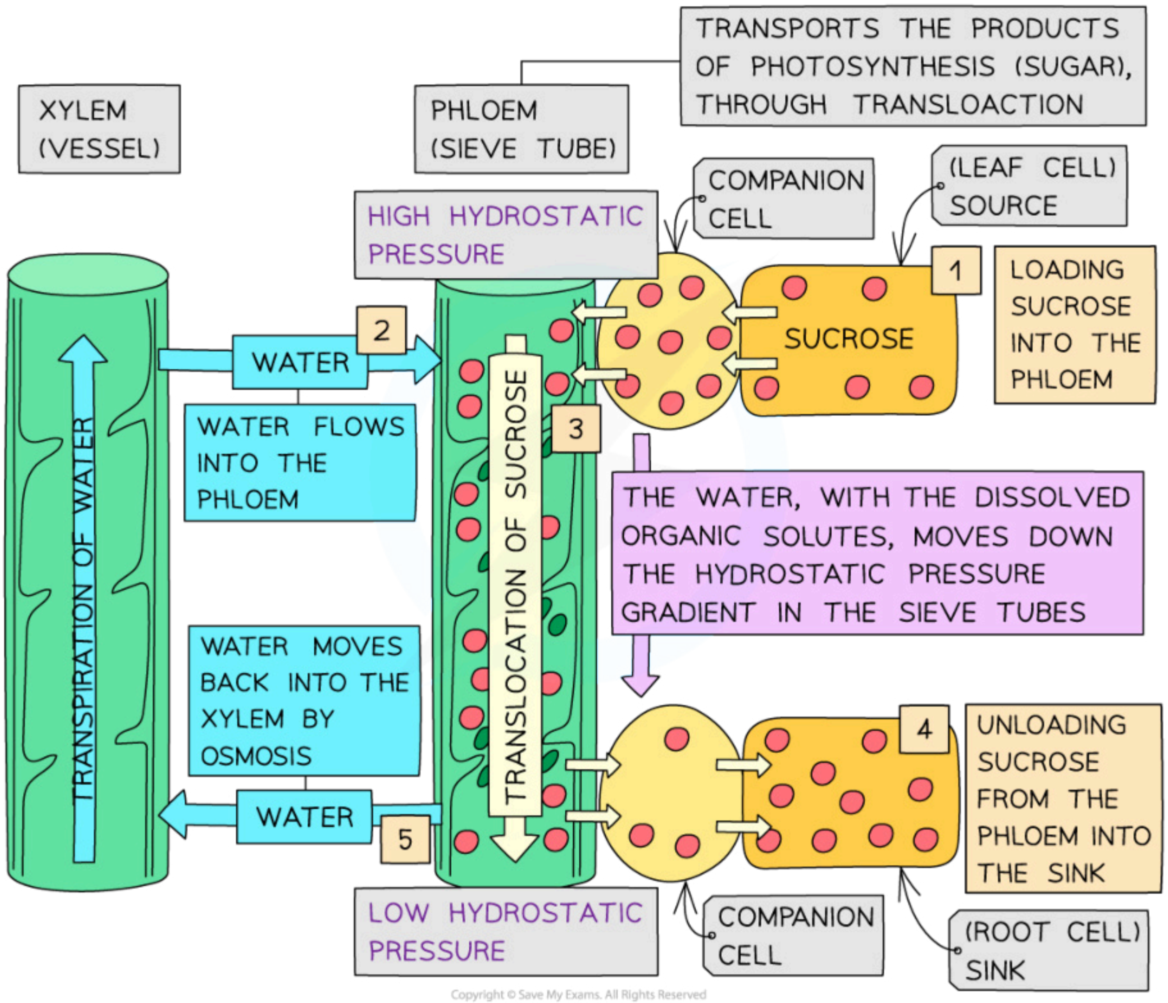
Companion cell structure and function table

Structure	Function
Nucleus and other organelles	Provides metabolic support to sieve tube elements
Transport proteins in plasma membrane	Moves assimilates into and out of the sieve tube elements
Many mitochondria	Provide ATP for the active transport of assimilates into or out of the companion cells
Plasmodesmata	Link with sieve tube elements to allow assimilates to move from the companion cells into the sieve tubes

Translocation

- The **loading** and **unloading** of sucrose and other organic compounds from the **source to the phloem**, and from the **phloem to the sink** is an **active process**, meaning that it requires energy in the form of ATP
- A summary of the process is
  1. **Active transport** is used to **load organic compounds** into the phloem at the source
  2. The high concentrations of solutes in the phloem at the source **lower the water potential** and cause **water to move into the phloem** vessels by osmosis
     - Water can move in from the neighbouring xylem vessels
  3. This results in a **raised hydrostatic pressure** and generates a hydrostatic pressure gradient between the source and the sink; this causes the **contents of the phloem to flow towards the sink** down a pressure gradient
     - Hydrostatic pressure refers to the pressure exerted by a fluid on the walls of its container; in this case the walls of the phloem
  4. At the same time **sucrose is being unloaded** from the phloem at the sink, lowering the water potential of the cells of the sink

5. Water follows by osmosis, **maintaining the hydrostatic pressure gradient** between the source and the sink



Examiner Tip

Remember that direction of movement in the phloem is determined by the locations of the source and the sink, so can be either upward or downward.

Understand the difference between sieve tube elements and companion cells, and make sure that you can describe how the **structure** of sieve tube cells is related to their **function**

Your notes