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## **Transport**



# **IB Biology - Revision Notes**

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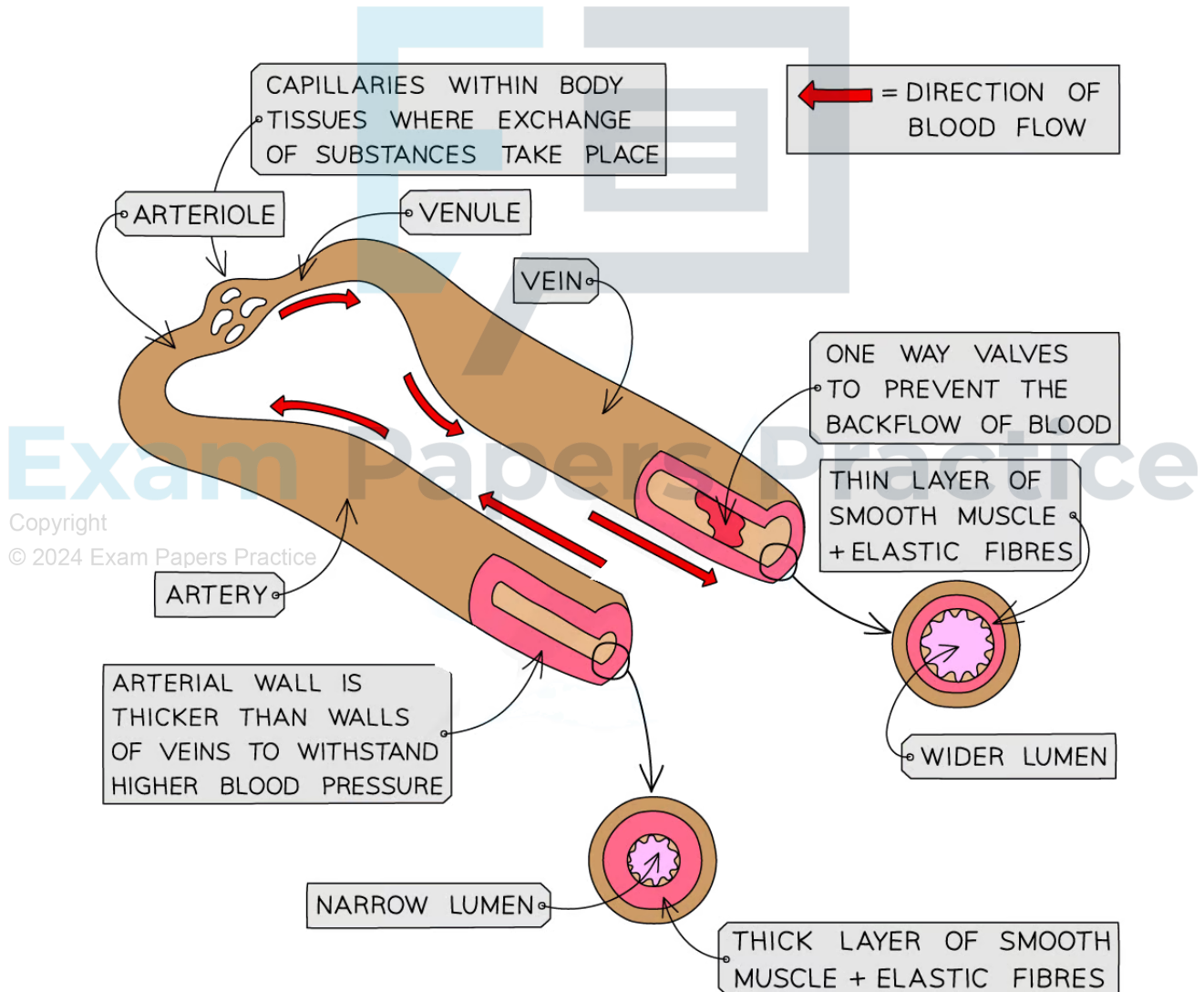
## Blood Vessels

### 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



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



## Adaptations of capillaries for exchange of materials

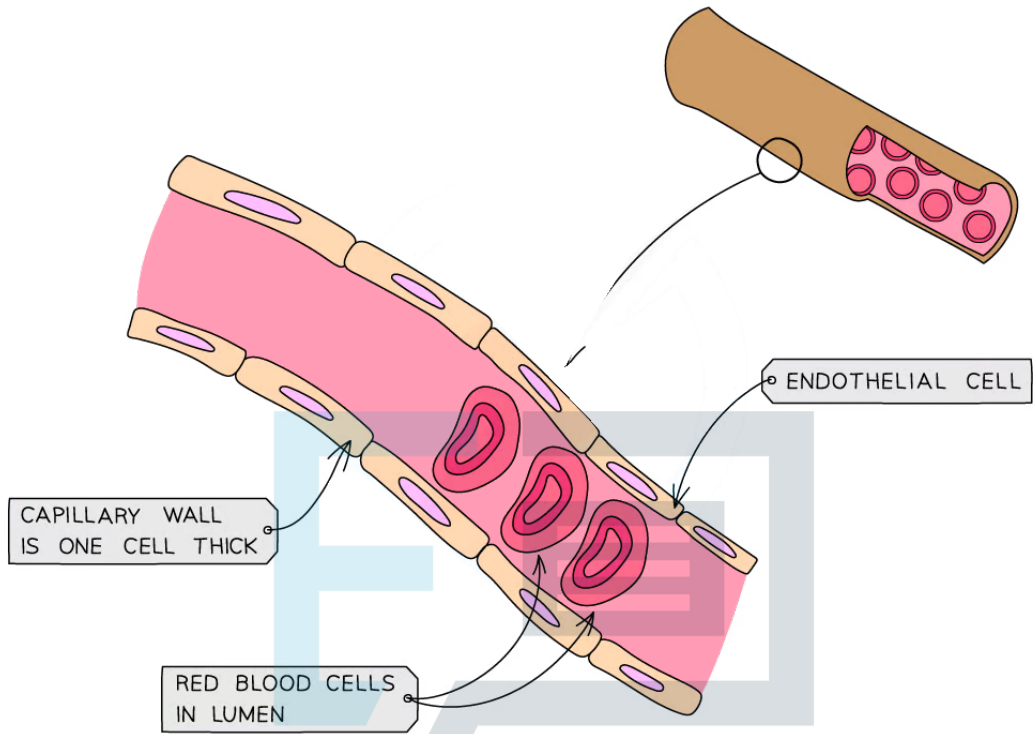
- **Capillaries** provide the **exchange surface** in the tissues of the body through a network of vessels called capillary beds
  - The wall of a capillary is made from a **single layer of endothelial cells**
    - Being just **one cell thick** reduces the **diffusion distance** for oxygen and carbon 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

### Capillary structure diagram

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

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## Arteries

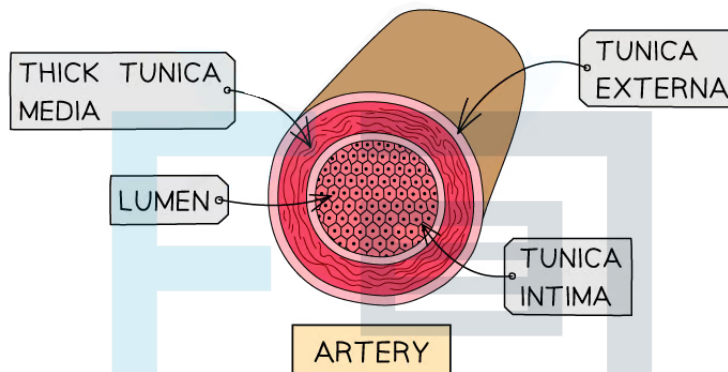
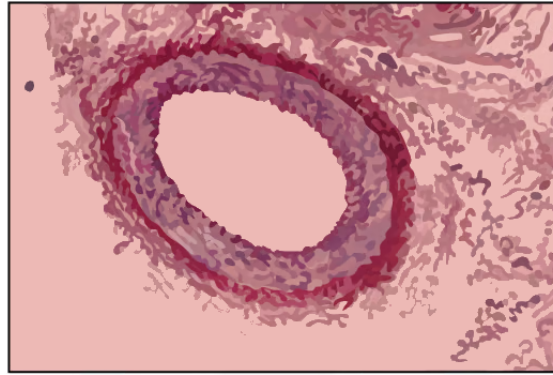
### Adaptations of arteries

- **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

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*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**

#### Exam Tip

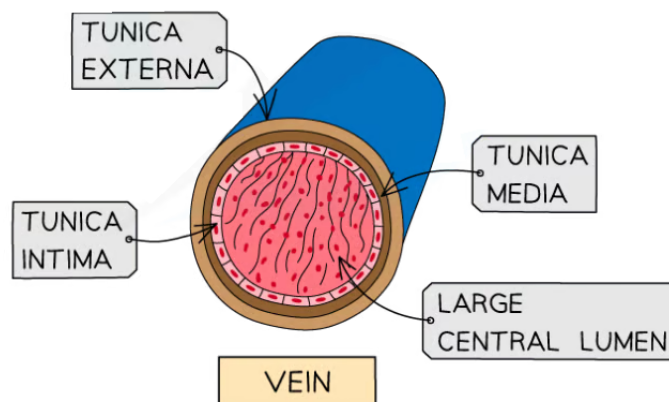
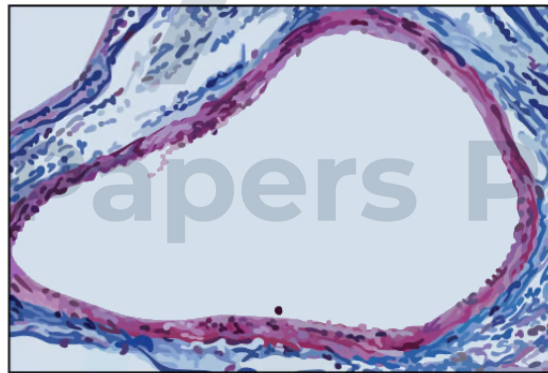
Be careful with the language you use to describe the roles of muscle and elastic tissue; muscle can **contract** and **relax**, while elastic tissue can **stretch** and **recoil**.

## Veins

### Adaptations of veins

- **Veins** transport blood to the heart at **low pressure**
  - Remember; **veins** carry blood **into** 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*



### Exam 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

### Structure of Arteries & Veins

#### Distinguishing arteries and veins in micrographs

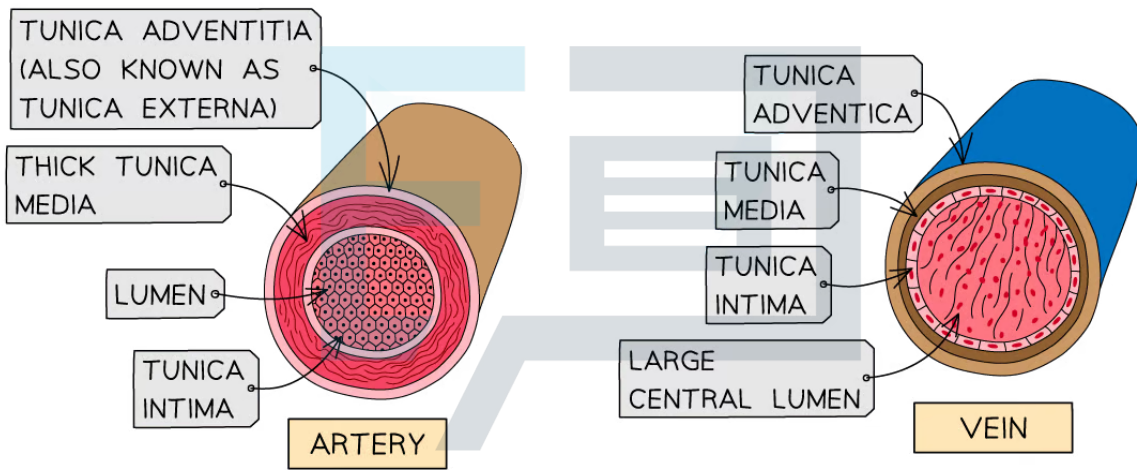
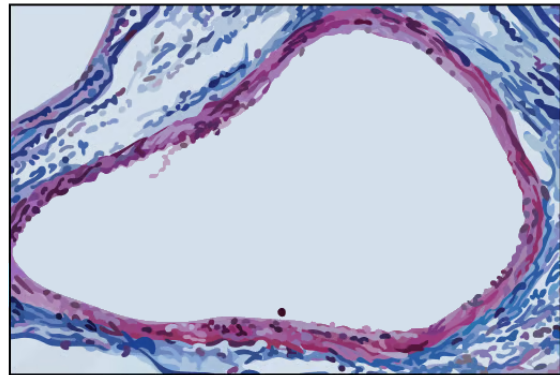
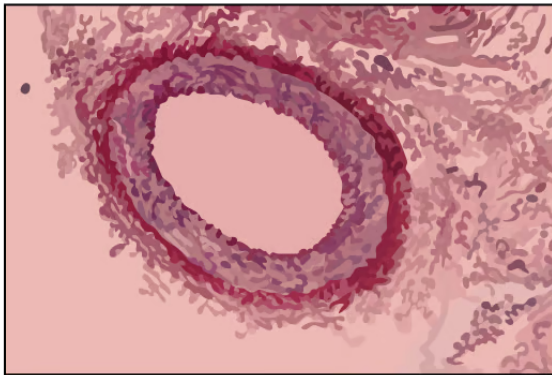
- Arteries
  - The arterial walls are **much thicker and stronger** than those of veins
    - This is due to the presence of more collagen and elastic fibres, as well as a thicker layer of smooth muscle
  - The **lumen** of arteries is relatively **narrow** compared to the thickness of the wall
    - 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

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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

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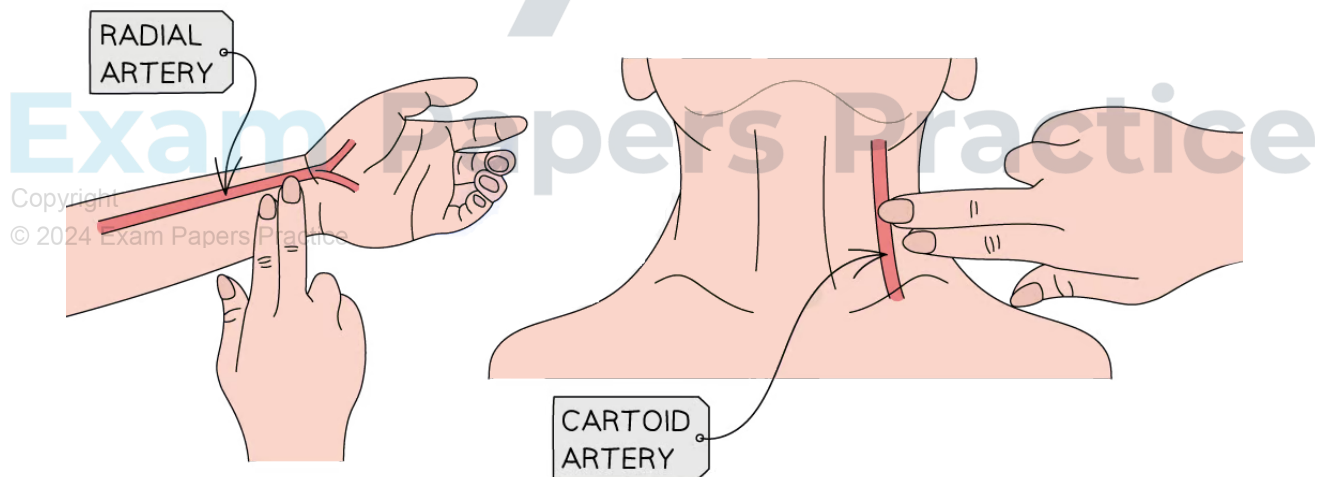
*Note that you do not need to know the scientific names for the different tissue layers in the walls of the blood vessels*

## Measuring Pulse Rate : Skills

### 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*

## Coronary Heart Disease : Skills

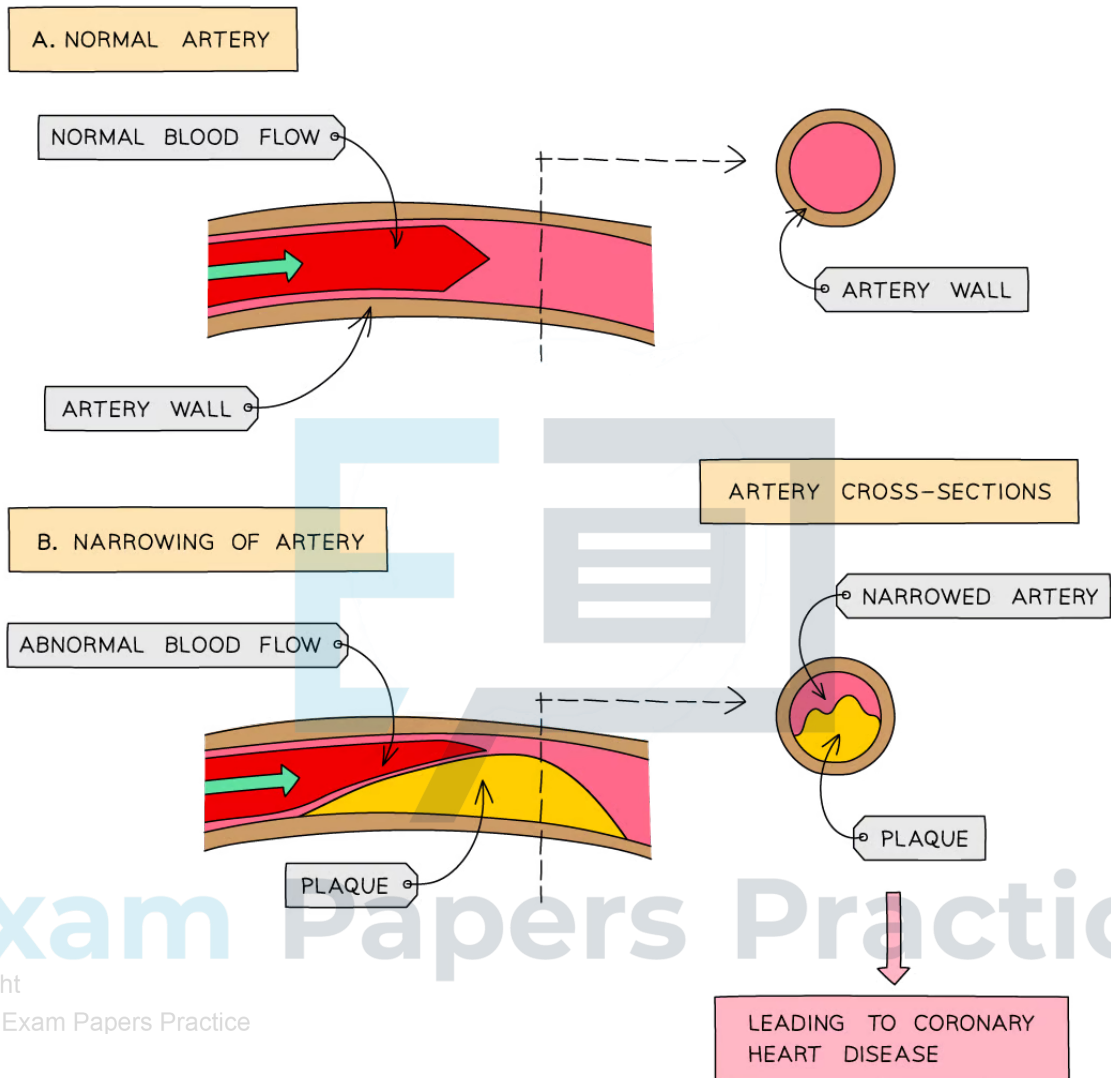
### Coronary Heart Disease

- **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

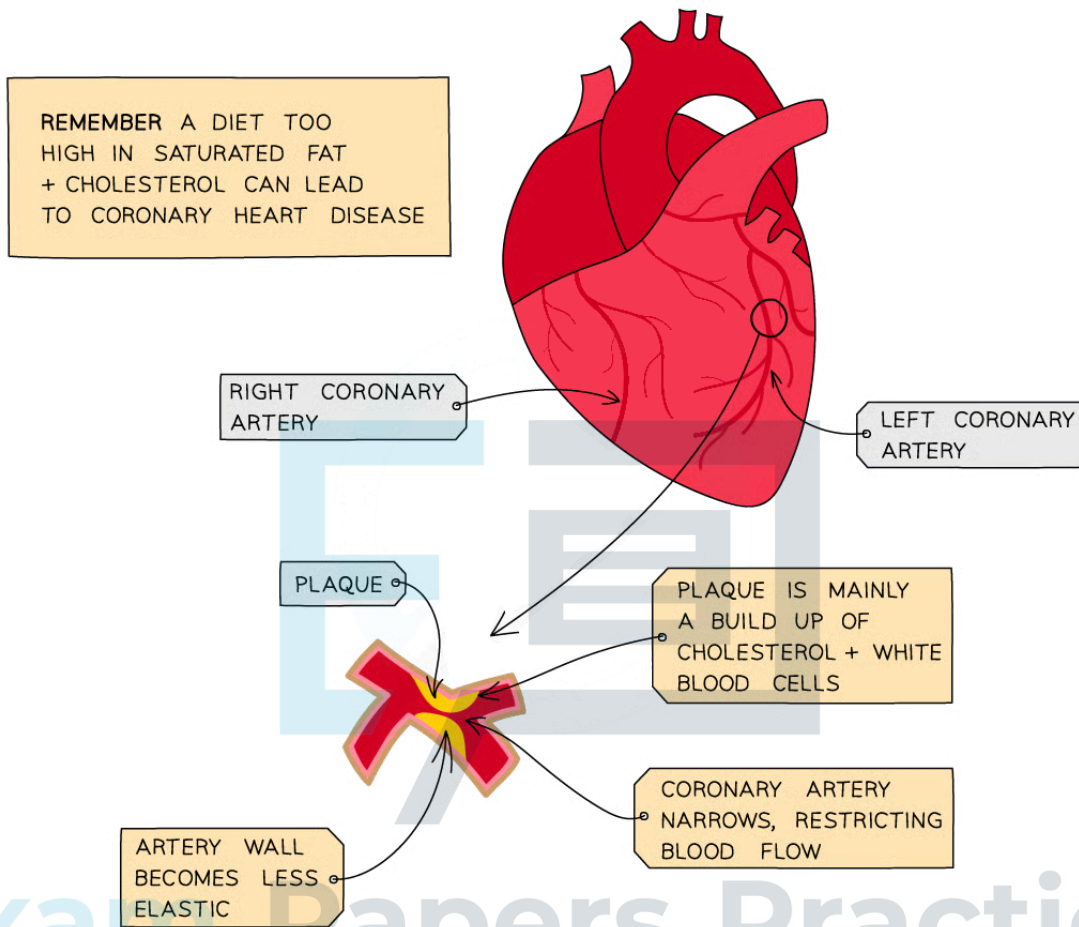
- When an embolus blocks a small artery or arteriole, tissues further down from the blockage do not receive the required level of **oxygen** and **nutrients**
  - This can **inhibit cell functions** and cause the cells to **die**
- If this happens in the **coronary arteries** then parts of the heart 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



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



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*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

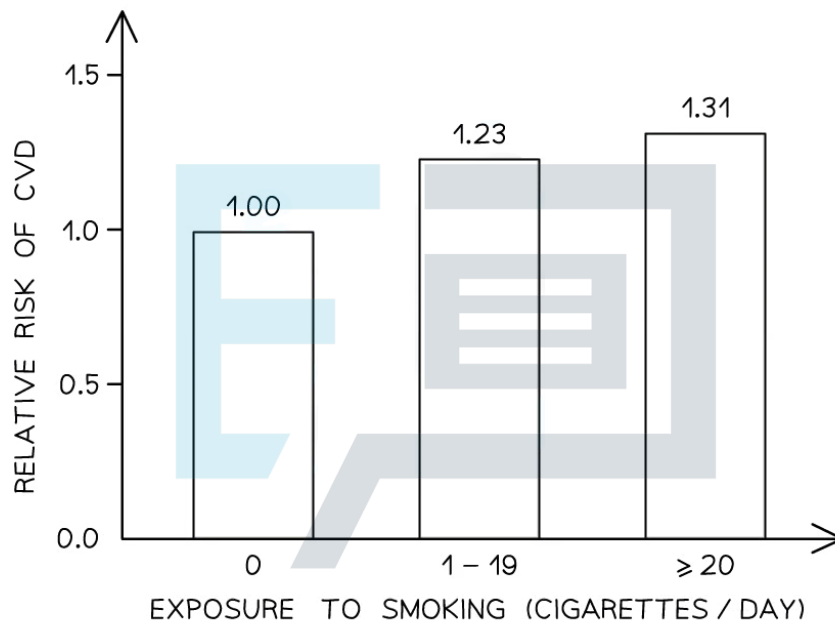


- Such studies are **small**, e.g. they may focus on just a few individuals, so they may not provide representative data
- Studies will **not include a suitable controlled experiment** so it is not possible to make a definite causal link from the results
  - A controlled experiment would involve, e.g. 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

### 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

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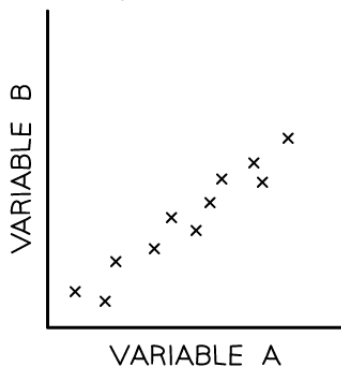
A commentary on the **validity** of the data could include

- 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

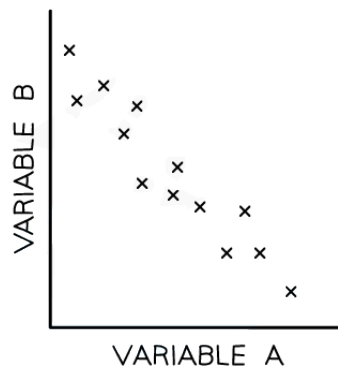
**NOS: Correlation coefficients quantify correlations between variables and allow the strength of the relationship to be assessed**

- 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

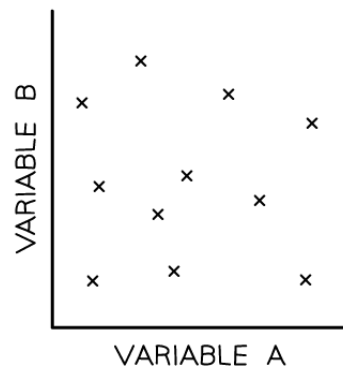
POSITIVE CORRELATION



NEGATIVE CORRELATION



NO CORRELATION



*Scatter graphs can be used to show the correlation between variables*

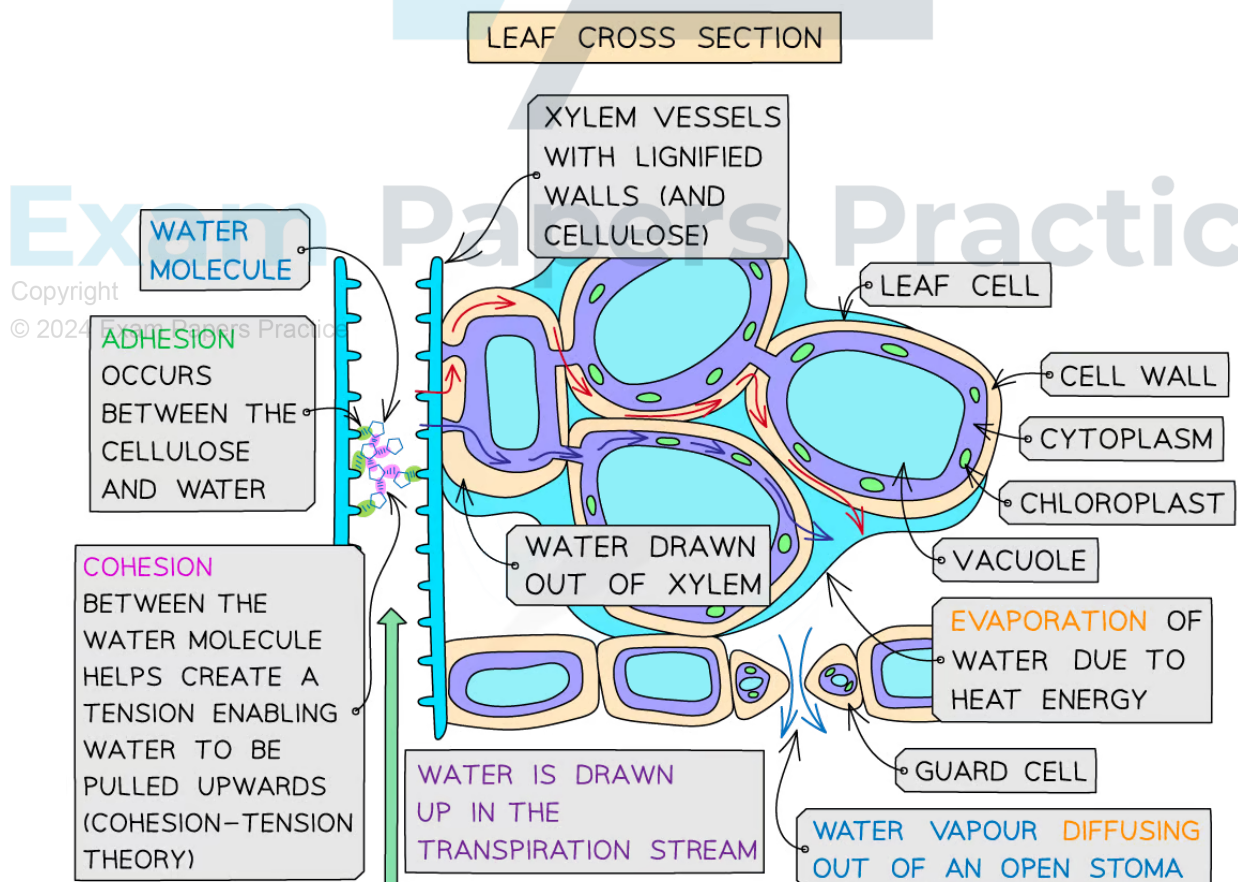


## The Transpiration Stream

### 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

## 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

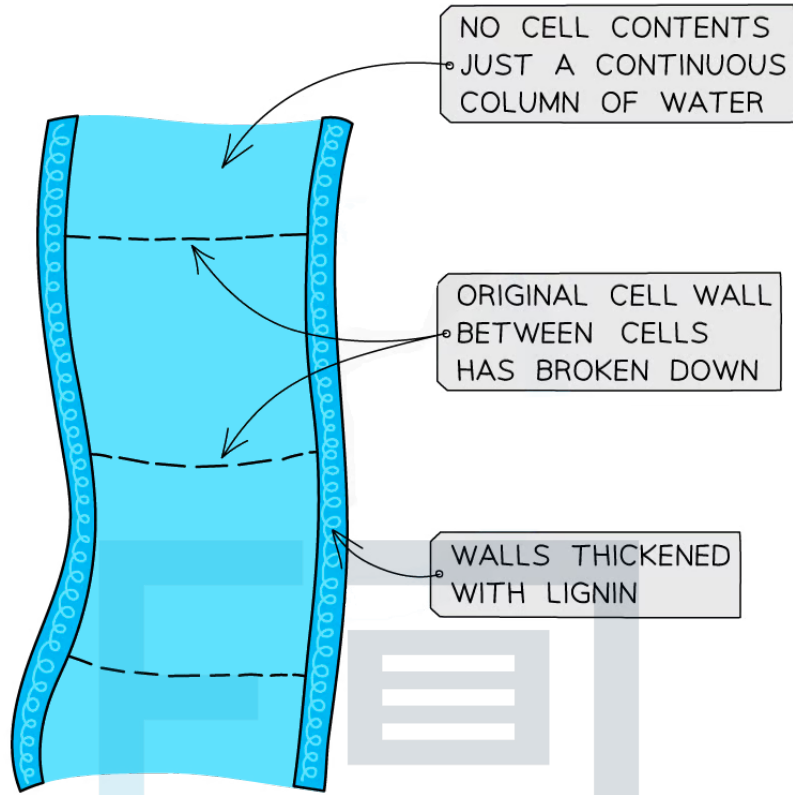
### Xylem vessel adaptations

- 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

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

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## Drawing Root & Stem Structure : Skills

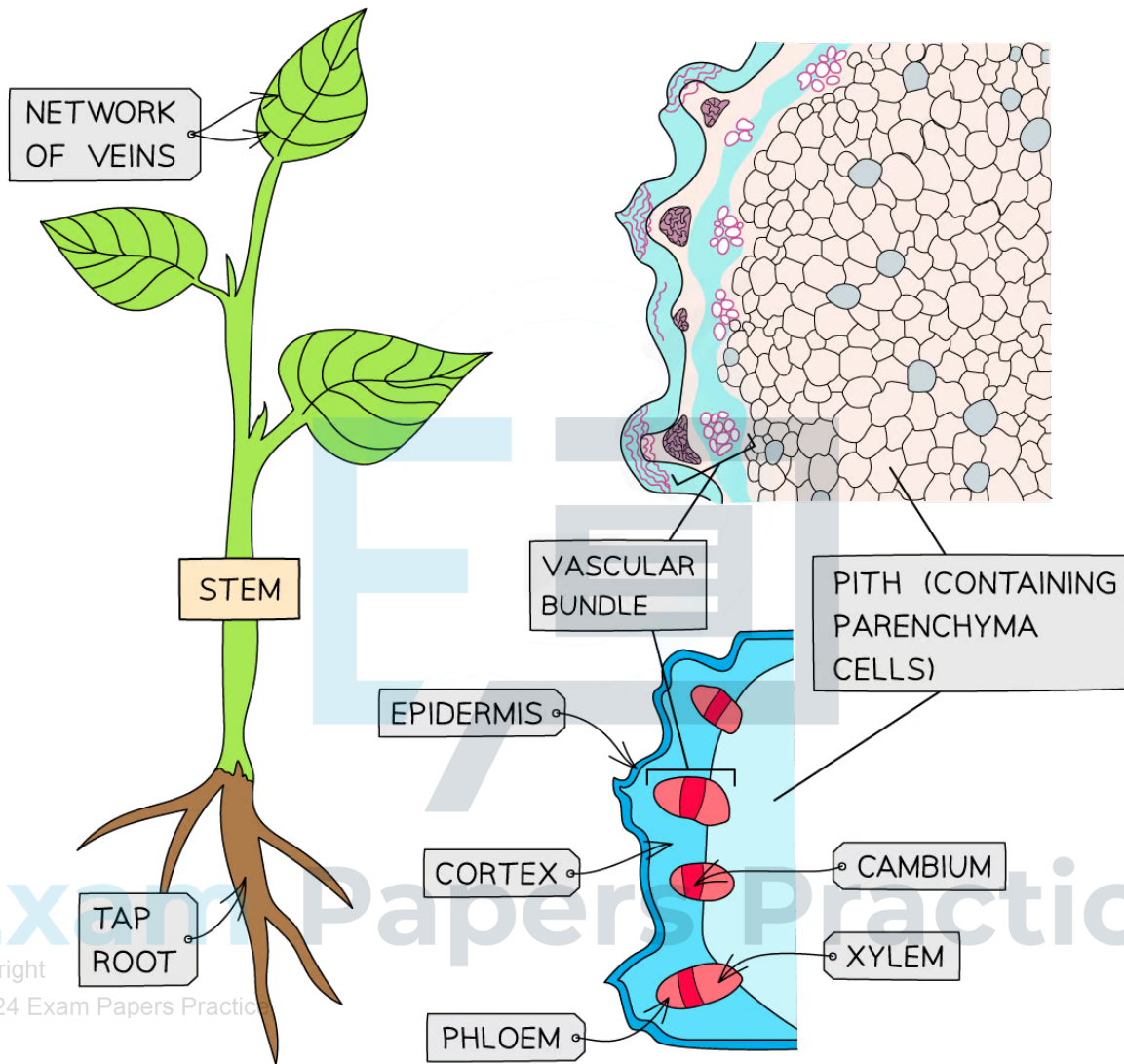
### Dicotyledonous Stem Structure

#### 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

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*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*

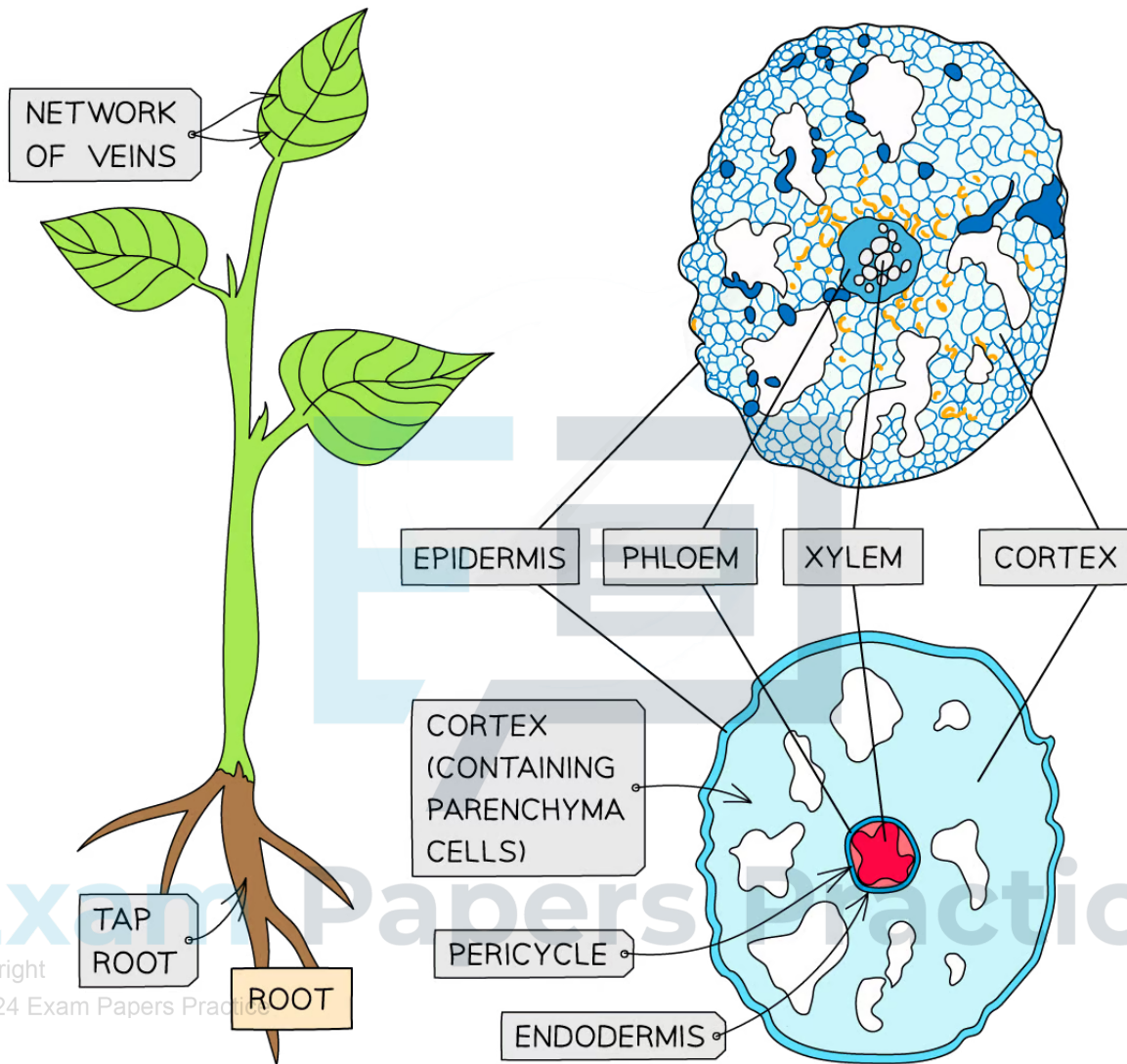
**Exam Tip**

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

## 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 = xylem
  - **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



*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*

**Exam 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