# Edexcel International AS Biology

Your notes

## Plant Structure & Function

### Contents

# Plant Cell Structure & Ultrastructure

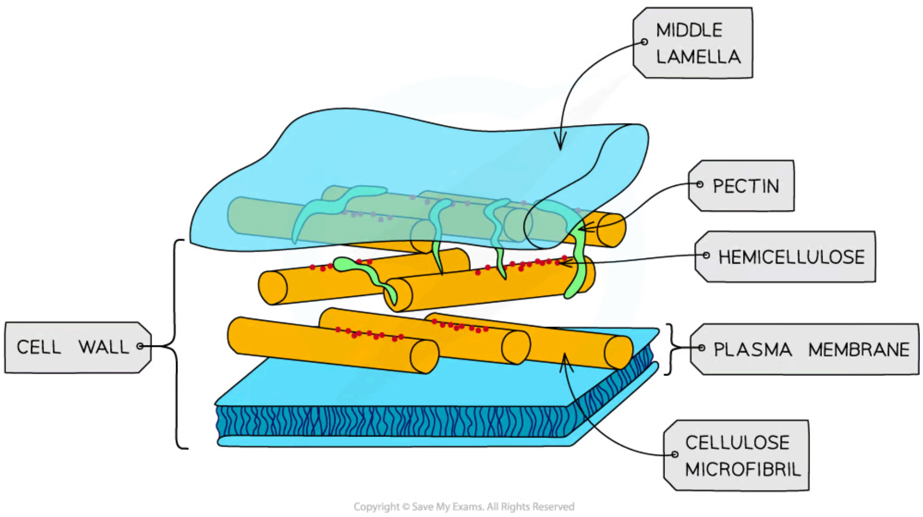
- The structure of plant cells is made up of a complex system of organelles and ultrastructures
- Plant cells contain many of the organelles found in animal cells, along with a few other organelles that are **only** found in plant cells

## Cell wall

- Cell walls are formed outside of the cell membrane and offer **structural support** to the cell
  - This structural support is provided by the polysaccharide **cellulose**
- Cell walls are **freely permeable**, and will allow most substances to enter the plant cell

## Middle lamella

- This forms the **outermost layer** of the plant cell and acts like glue to stick adjacent plant cells together
- It is mainly composed of a polysaccharide called **pectin**



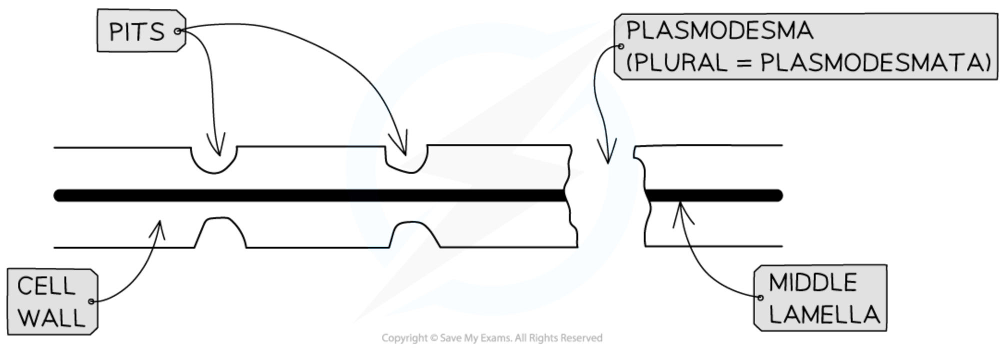

*A diagram to show the cell wall and middle lamella of one plant cell*

## Plasmodesmata

- Narrow threads of cytoplasm (surrounded by a cell membrane) called **plasmodesmata** connect the cytoplasm of neighbouring plant cells
- This interconnected system of cytoplasm between plant cells is known as the **symplast**

## Pits

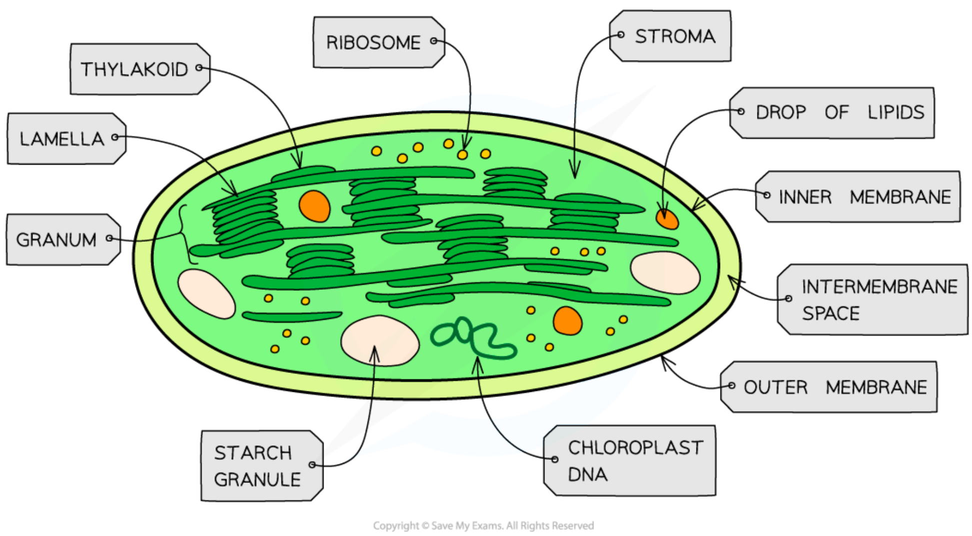
- These are **very thin** regions of the cell wall
- The pits in adjacent plant cells are lined up in **pairs**
- They are formed due to the absence of secondary thickening in the cell walls in the areas where plasmodesmata are present




***Detailed structure of plant cell wall***

## Chloroplasts

- Chloroplasts are larger than mitochondria
- Surrounded by a **double-membrane**
- Within the chloroplast there are membrane-bound compartments called **thylakoids** containing chlorophyll stack to form structures called **grana** (singular = granum)
- Grana are joined together by **lamellae** (thin and flat thylakoid membranes)
- Chloroplasts also contain small circular pieces of **DNA** and ribosomes used to synthesise proteins needed in chloroplast replication and photosynthesis

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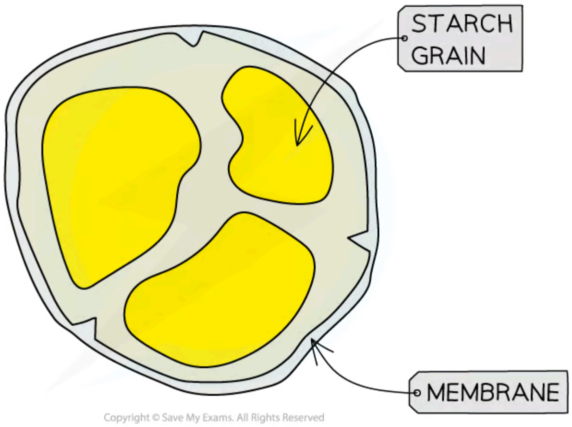
*Chloroplasts are found in the green parts of plants – the green colour is due to the presence of the pigment chlorophyll*

Your notes

## Amyloplasts

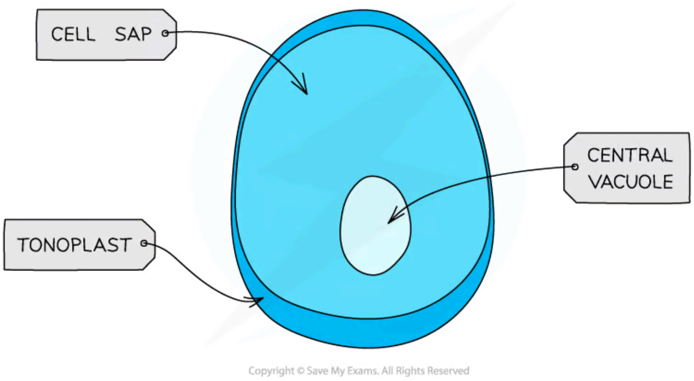
- Small, membrane bound organelle containing **starch granules**
- Large numbers are found in plant storage organs, such as potato tubers




*Structure of an amyloplast*

## Vacuole and tonoplast

- The vacuole is a sac in plant cells surrounded by the **tonoplast** (selectively permeable membrane)
- They are large, permanent structures in a plant cell
- Contains cell sap, which is a mixture of different substances such as water, minerals, waste and enzymes
- The concentration of the cell sap enables water to enter the vacuole by osmosis




*The structure of the vacuole*

# Plant Cell Structure & Ultrastructure: Function

Your notes

- The ultrastructures and organelles listed above each perform a specific function in a plant cell

## Cell wall

- The cellulose component of cell walls provides **structural support** to the cell
- Due to its rigid nature, it is responsible for the **regular shape** of a plant cell

## Middle lamella

- It provides **stability** to the plant by ensuring that adjacent plant cells are **adhered** together

## Plasmodesmata

- The cytoplasmic strands **connect** the contents of adjacent plant cells
- This allows substances to be **transported** between cells and facilitates **cell to cell communication**

## Pits

- Since the cell wall is very thin in these regions, it allows for the **transport of substances** between cells
- This is particularly useful in **xylem vessels**, where it allows for the **lateral flow** of water and mineral ions between adjacent vessels

## Chloroplasts

- Due to the presence of chlorophyll and thylakoids, chloroplasts are the **site of photosynthesis**
    - Certain parts of the process occur in **thylakoid membranes**, while other parts happen in the **stroma**

## Amyloplasts

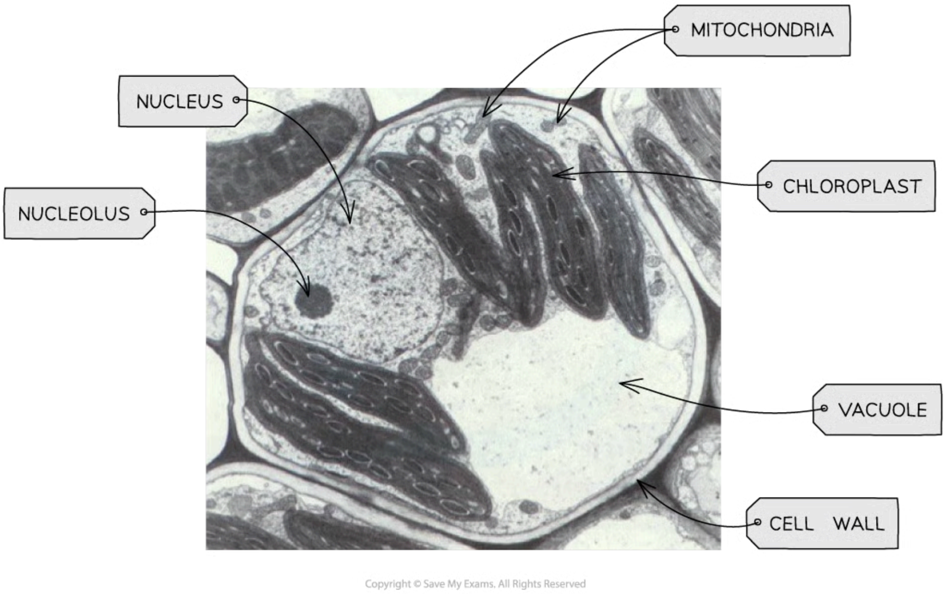
- They are responsible for **storing starch** in plants and converting it back to glucose when the plant needs it

## Vacuole and tonoplast

- Vacuoles have several functions in plant cells:
    - They keep cells turgid, which stops the plant from wilting
    - **Store various substances**, such as pigments and waste products
    - **Break down** and **isolate** unwanted chemicals in plant cells
    - The tonoplast **controls** what can enter and leave

# Electron Microscopy of Plant Cells

- It is important to be able to recognise various plant organelles from electron microscope images
  - Chloroplast
    - Has **distinctive stacks** of thylakoids
    - Double membrane
    - Has a roughly oval shape
    - Larger than mitochondria
    - Indicates the cell is a plant cell
  - Nucleus
    - Has a nuclear membrane and a **dark nucleolus** within
    - It has a roughly spherical shape
  - Vacuole
    - Occupies a large space within a cell
    - Often shows up as a very light shade (white) within an electron micrograph
    - Indicates the cell is a **plant cell**
  - Cell wall
    - Located around the perimeter of the cell
  - Mitochondria
    - Roughly oval-shaped
    - **Double membrane**
    - Sometimes observed with visible **cristae** (foldings of the inner membrane)
  - **Cell membrane (plasma membrane)**
    - Located just inside the cell wall, pressed against it
    - Appears as a thin, dark line following the inner edge of the cell wall
    - Often difficult to distinguish from the cell wall at low magnification, as the two run parallel and close together
    - Encloses the cytoplasm and all the cell's content



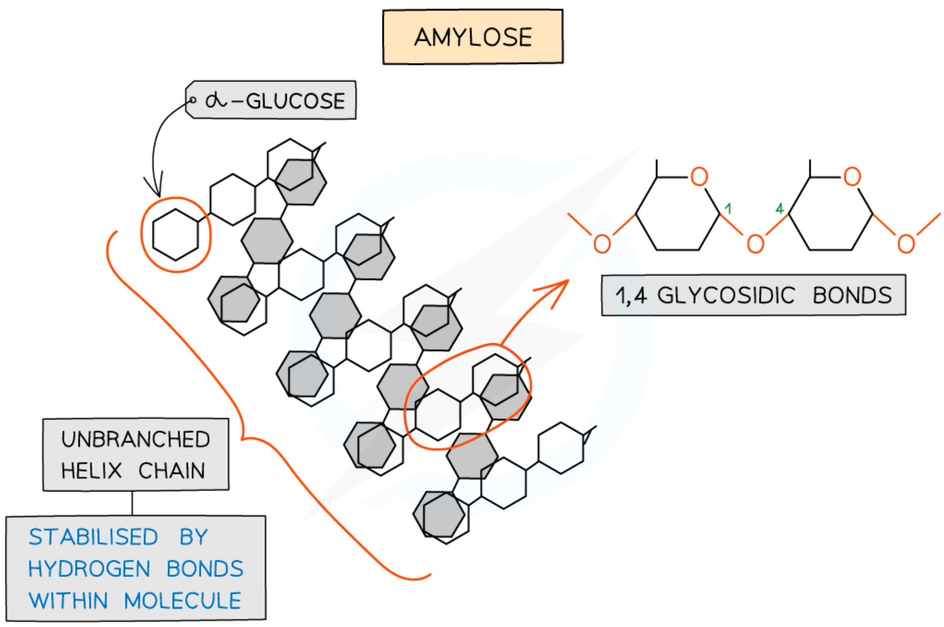

*TEM electron micrograph of a plant cell showing key features*

## Starch & Cellulose: Structure & Function

# Starch

## Starch: structure

- Starch is the **storage** polysaccharide of **plants**
- It is stored as granules in plastids (e.g. chloroplasts) and amyloplasts (small, membrane-bound organelles containing starch granules)
- Due to starch molecules being large **polymers** consisting of thousands of **glucose monomers**, starch takes **longer to digest** than glucose
- Starch is constructed from **two different** polysaccharides:
  - **Amylose** (10 - 30% of starch)
    - **Unbranched** helix-shaped chain with **1,4 glycosidic bonds** between **α-glucose** molecules
    - The helix shape enables it to be more compact and thus it is more resistant to digestion

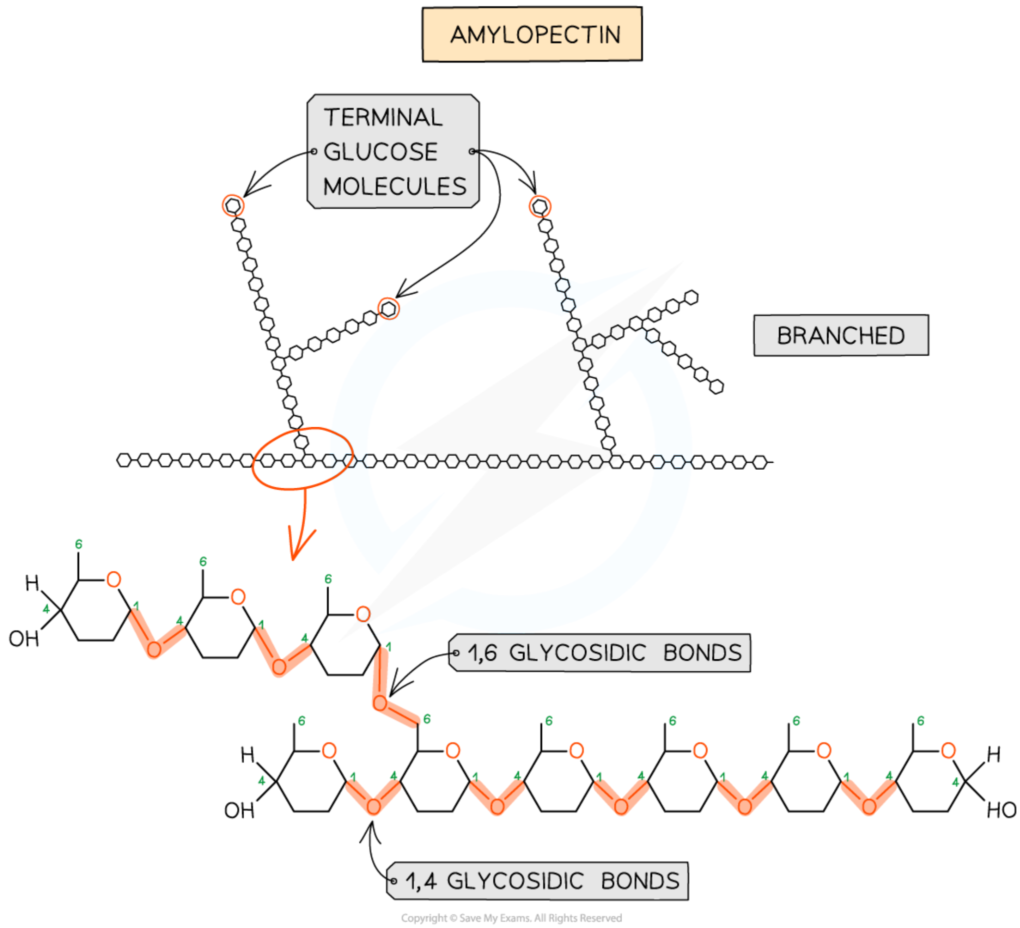




*Amylose - one of the two polysaccharides present in starch*

- **Amylopectin** (70 - 90% of starch)
  - 1,4 glycosidic bonds between α-glucose molecules (as found in amylose) **but also 1,6 glycosidic bonds** form between glucose molecules creating a **branched** molecule

- The branches result in many terminal glucose molecules that can be **easily hydrolysed** for use during **cellular respiration** or added to for storage




*Amylopectin – the other polysaccharide present in starch*

## Starch: function

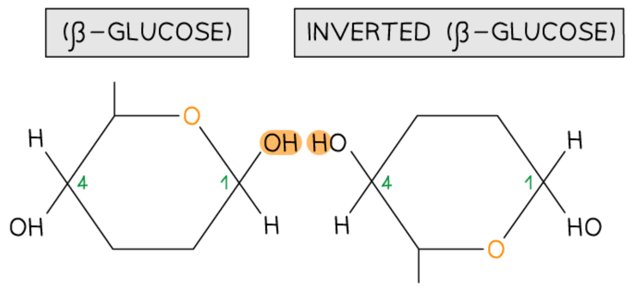
- **Starch** is a storage polysaccharide because it is:
  - **Compact** (so large quantities can be stored)
  - **Insoluble** (so will have **no osmotic effect,** unlike glucose which would cause water to move into cells, meaning cells would then have to have thicker cell walls to withstand the increased internal water pressure)

# Cellulose

## Cellulose: structure

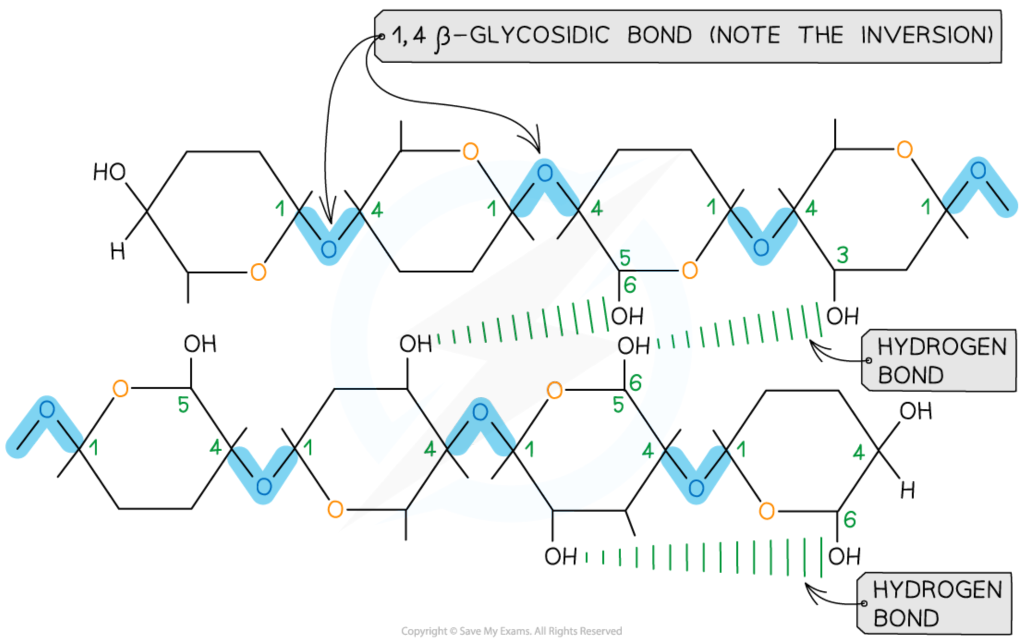
- Cellulose is a **polymer** consisting of long chains of **β-glucose** joined together by **1,4 glycosidic bonds**
- As β-glucose is an isomer of α-glucose, consecutive β-glucose molecules must be **rotated 180° to each other** in order to form the 1,4 glycosidic bonds

Your notes




***To form the 1,4 glycosidic bond between two β-glucose molecules, the glucose molecules must be rotated to 180° to each other***

- Due to the **inversion** of the β-glucose molecules **many hydrogen bonds** form between the long chains, giving cellulose it's great **strength**





***Cellulose is used as a structural component due to the strength it has from the many hydrogen bonds that form between the long chains of β-glucose molecules***

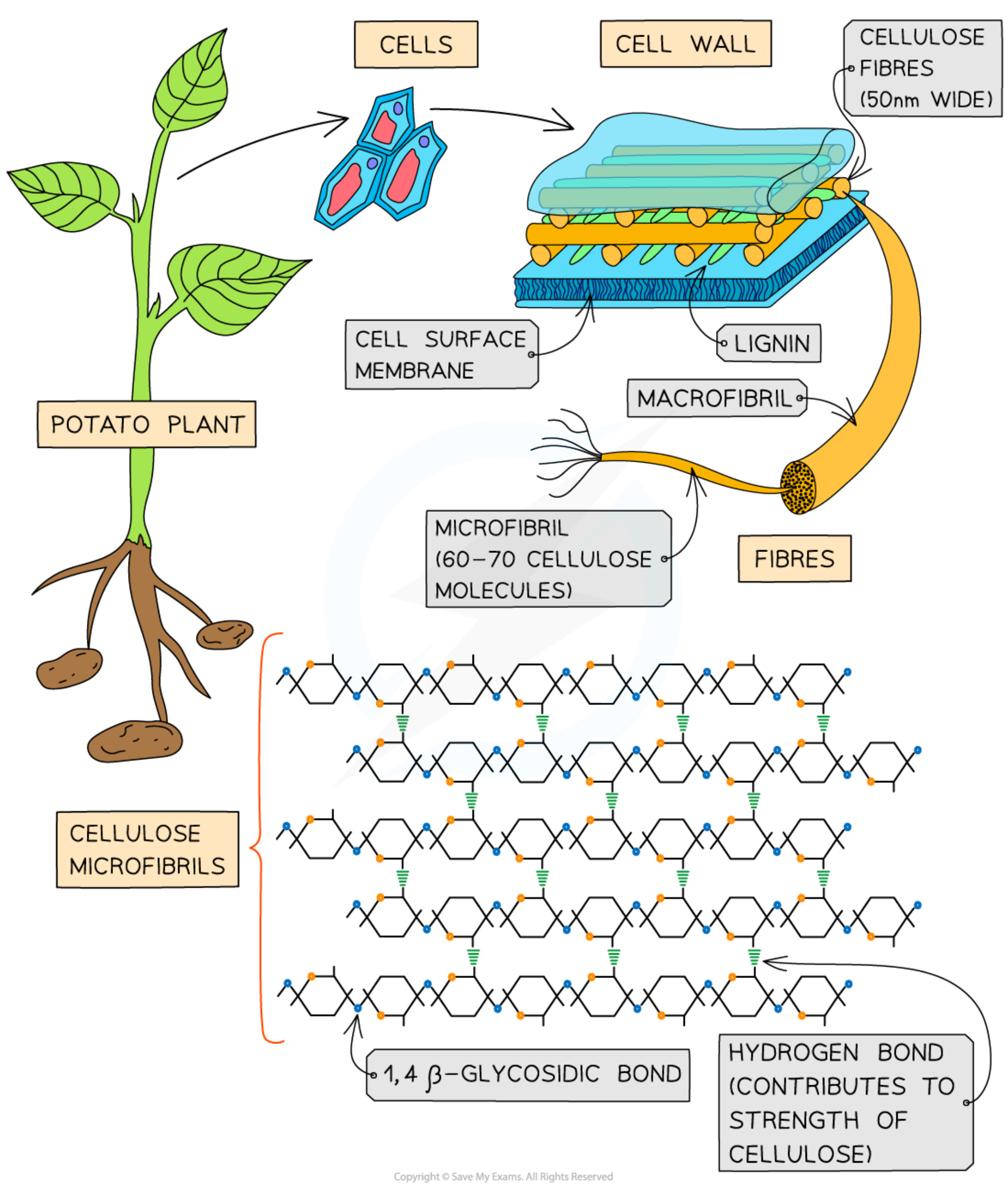
## Cellulose: function

- Cellulose is the **main structural component** of **cell walls** due to its strength, which is a result of the many hydrogen bonds found between the parallel chains of **microfibrils**
- The **high tensile strength** of cellulose allows it to be **stretched without breaking** which makes it possible for cell walls to withstand **turgor pressure**
- The cellulose fibres and other molecules (e.g. lignin) found in the **cell wall** form a matrix which increases the strength of the cell walls
- These **strengthened cell walls** provide **support** to plants

Your notes

# Plant Fibres

- Sclerenchyma fibres and xylem vessels are made of **long, hollow plant cells**
- These cells are hollow due to the fact that their cell contents **died** (often due to the lignification of the cell wall, which makes it almost impossible for substances to enter or leave the cell)
- These fibres have **great strength**, which is a property that is often exploited by humans
  - They are useful in making **rope** and certain **fabrics** are made from plant fibres (e.g. cotton and hemp)
- Their strength is due to certain factors affecting the cell wall:
  - The **arrangement of cellulose microfibrils** in a mesh-like pattern
  - **Secondary thickening**, which results in a thick secondary cell wall developing which often contains **lignin**




*The arrangement of cellulose microfibrils, along with secondary thickening, are the main reasons why plant fibres are very strong*

# The Vascular Structure of Plants

- Plant stems have two main functions in a plant
  - They provide **support**
  - They **transport** various materials around the plant

## Support

- **Leaves** are attached to stems and are responsible for carrying out **photosynthesis**
- Stems ensure that leaves are **positioned** in order to receive **maximum** levels of **sunlight** to perform this task
- It also **supports flowers** in a way that will attract the attention of **pollinators**
- Plant stems need to be **strong**, but also **flexible**, in order to withstand the forces of nature (wind, rain etc.)

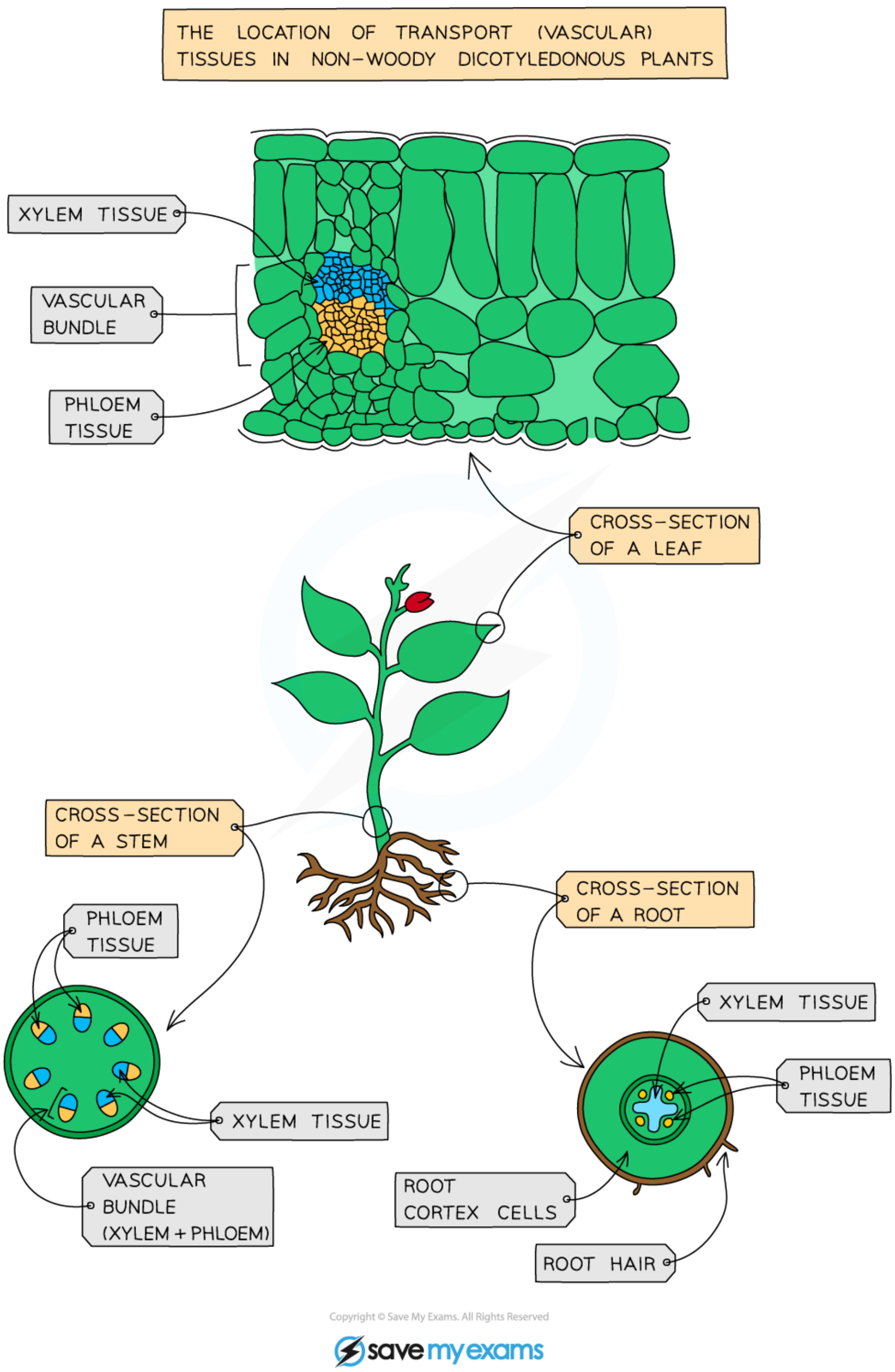
## Transport

- Leaves **require water** and **mineral ions** in order to **photosynthesise** and carry out other important functions
- The **transport tissue** in stems provide a route for these substances to travel from the roots to the leaves
- The **products of photosynthesis** also need to be transported from the tissue where photosynthesis happens to where these substances are needed
- Stems provide a **transport route** for this to occur

## Vascular structure of plants

- Plant stems are made up of different types of plant tissue
- The focus will be on the following tissue types:
  - Xylem
  - Phloem
  - Sclerenchyma
- **Xylem** and **phloem** are collectively known as **vascular tissue**
- They are responsible for **transporting** various substances around the plant
- **Sclerenchyma** fibres are associated with the vascular bundles and provide additional **support** to a stem
- Xylem and phloem are arranged in structures known as **vascular bundles**
- The arrangement of xylem and phloem differs in the different plant organs

- In a stem, the **xylem vessels** are always located towards the middle of the stem, while the **phloem** can be found closer towards the outside of the stem




*The arrangement of vascular tissue (xylem and phloem) in roots, stems and leaves*

# Sclerenchyma

- Sclerenchyma fibres are not involved in the transport of substances, they **provide support**

Your notes

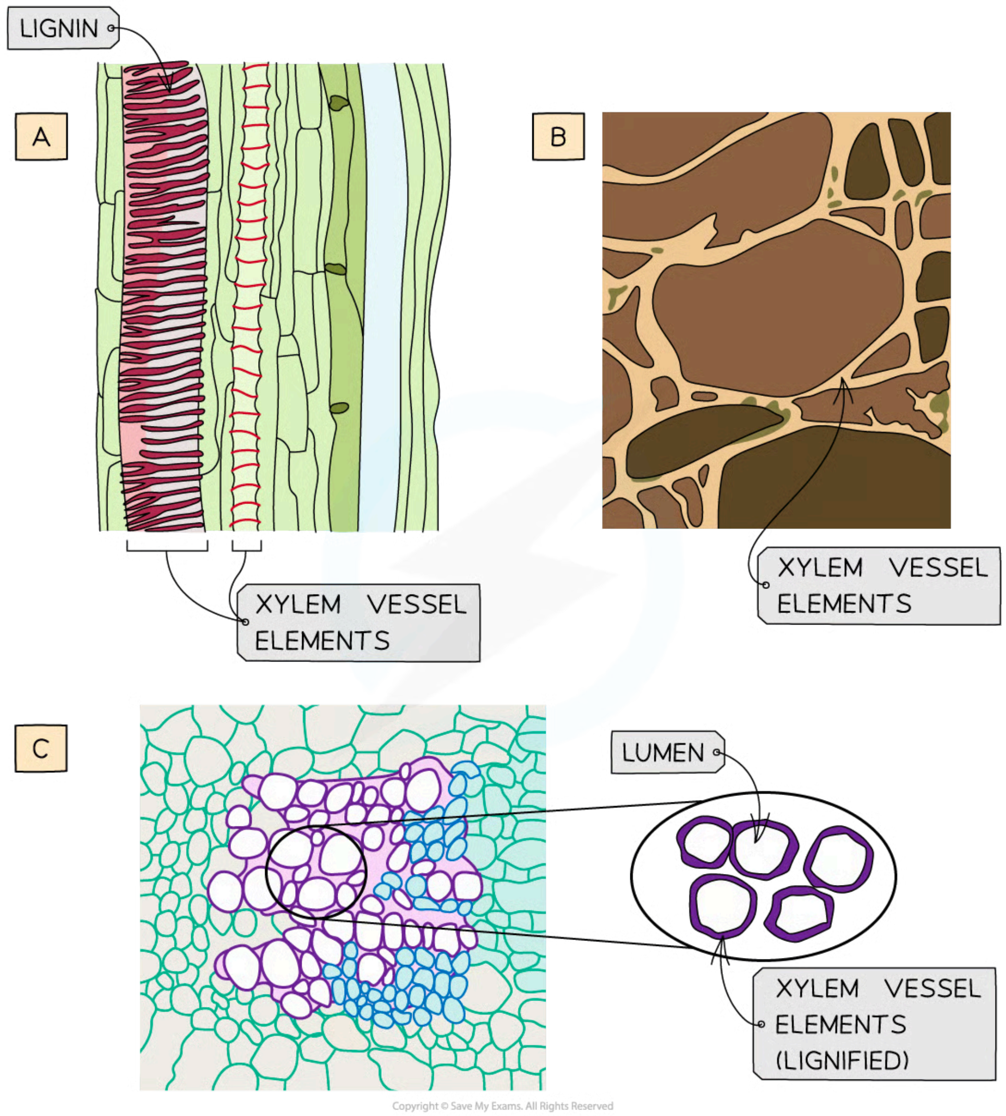
- They consist of bundles of **dead cells** which form **long, hollow tubes**, but they do have **end walls** present
- **Lignification** of cell walls occur, which provides **structural support** to allow the plant to bear the load of its own mass
- They have **more cellulose** in their walls compared to other plant cells

Your notes

# Xylem

## Xylem vessels

- The functions of **xylem** tissue in a plant are:
  - Vascular tissue that **transports** dissolved minerals and water around the plant
  - Structural **support**
- Their cell walls contain **lignin**, which enables the vessels to withstand the pressure created by the moving column of water
- Xylem vessels form **long, hollow** straw-like structures that are formed by **dead cells** (due to lignification of cell walls)
- This means that they **do not** contain any cytoplasm or organelles that could slow down the flow of water
- There are small regions in the walls that are not lignified, known as **pits**, which allows for lateral movement of water and minerals between xylem vessels




*Images of xylem vessel elements: A = photomicrograph (drawing) in longitudinal section (lignin is stained red), B = scanning electron micrograph (drawing) in transverse section, C = microscope image (drawing) in transverse section (lignin is stained purple)*

Structure and Function of Xylem Vessels Table

| Structure | Function |
|---|---|
| Lignified cell walls (mature cells) | Adds strength to withstand the hydrostatic pressure so the vessels do not collapse, impermeable to water |
| No end plates (mature) | Allows the mass flow of water and dissolved solutes as cohesive (between water molecules) and adhesive (between water and the walls) forces are not impeded |
| No protoplasm (cells are dead when mature) | Doesn't impede the mass flow of water and dissolved solutes (transpiration stream) |
| Pits in wall (non–lignified sections) | Lateral movement of water, allows continual flow in case of air bubbles forming in the vessels |
| Small diameter of vessels (although they are larger than tracheids | Helps prevent the water column from breaking and assists with capillary action |



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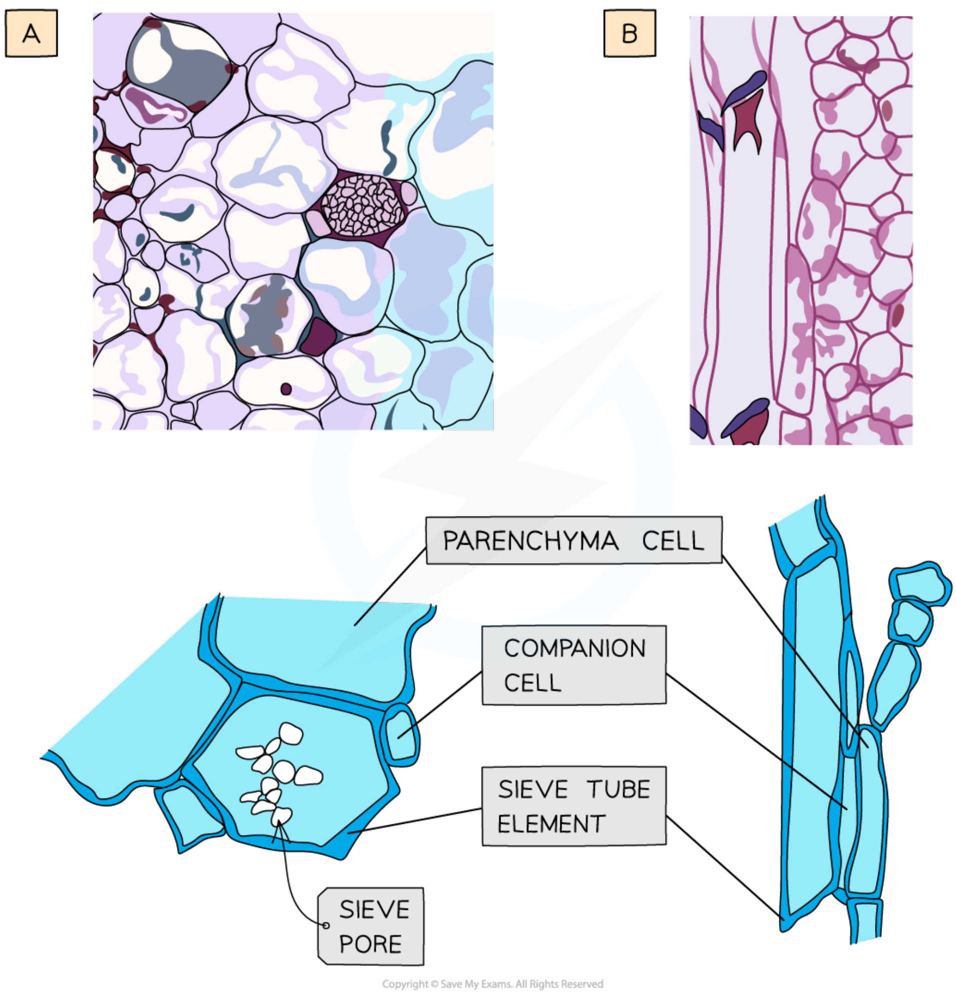
# Phloem

## Phloem tissue

- The functions of **phloem** tissue in a plant are:
  - Transport **organic compounds** (assimilates), particularly sucrose, from sources (e.g. leaves) to sinks (e.g. roots). The transport of these compounds can occur **up** and **down** the plant
  - This is known as **translocation**
  - Phloem has no support function in a plant
- The organic compounds are dissolved in water to form sap
- Phloem is a complex tissue made up of various cell types; its bulk is made up of **sieve tube elements** which are the main conducting cells and **companion cells**
- Other cell types of phloem tissue also include parenchyma for storage, and strengthening fibres
- Mature phloem tissue contains living cells, unlike xylem tissue




***Structure of phloem tissue: A = microscope slide image (and below drawing) of a sieve tube element and companion cell in transverse section, B = photomicrograph image (and below drawing) of a sieve tube element and companion cell in longitudinal section***

Your notes

Your notes

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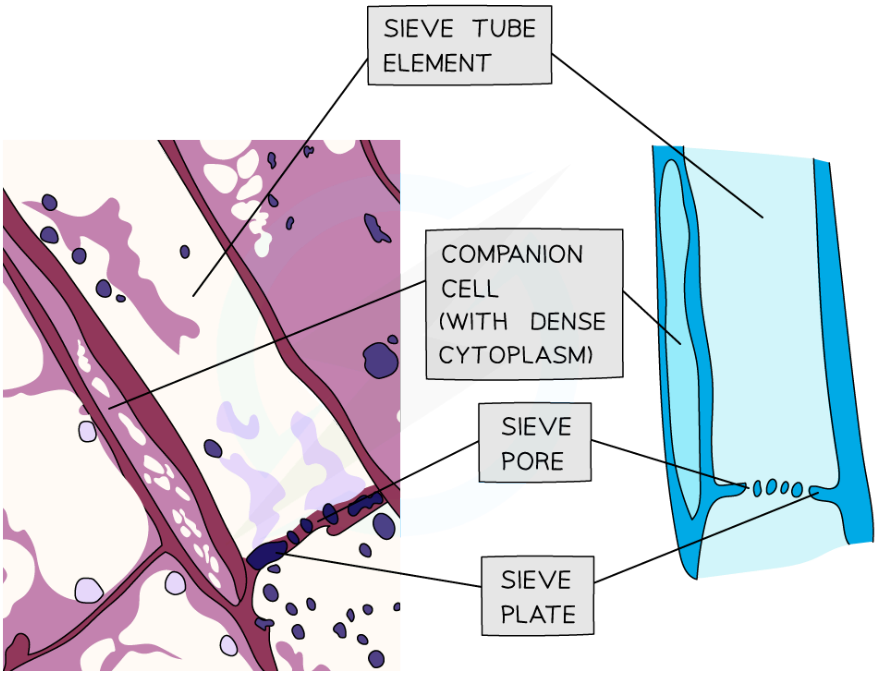




*Structure of phloem tissue: C = transmission electron micrograph image (and drawing) of a sieve tube element and companion cell in transverse section*

## Sieve tube elements

- Sieve tube elements line up end to end to form a **continuous tube**

**Phloem Sieve Tube Elements Structure & Function Table**

| Structure | Function |
|---|---|
| **Sieve plates with sieve pores** | Allows for the continuous movement of the organic compounds |
| **Cellulose cell wall** | Strengthens the wall to withstand the hydrostatic pressures that move the assimilates |
| **No nucleus, vacuole or ribosomes in mature cells (some ER and mitochondria are present)** | Maximises the space for the translocation of the assimilates |
| **Thin cytoplasm** | Reduces friction to facilitate the movement of the assimilates |

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## Companion cells

- Each sieve tube element has a companion cell associated with it as companion cells control the metabolism of their associated sieve tube member
- They also play a role in **loading and unloading of sugars into the phloem sieve tube elements**

**Phloem Companion Cells Structure & Function Table**

| Structure | Function |
|---|---|
| Nucleus and other organelles present, e.g. RER | Provides metabolic support to sieve tube elements and helps with the loading and unloading of the assimilates |
| Transport proteins in plasma membrane | Moves assimilates into and out the sieve tube elements |
| Large numbers of mitochondria | To provide ATP for the active transport of assimilates into or out of the companion cells |
| Plasmodesmata (channels in the cell wall) | The link to sieve tube elements which allows organic compounds to move from the companion cells into the sieve tube elements |



### Examiner Tips and Tricks

Understand the difference between sieve tube elements and companion cells, and how they are different to xylem tissue. Remember that mature xylem tissue is dead, so there is no evidence of organelles, and they have lignified cell walls, whereas sieve tube elements have no lignin, have sieve plates and companion cells that contain nuclei and cytoplasm.

# Identifying Tissue Types Within Stems

- In order to identify tissue types within stems, a **permanent pre-prepared slide** could be used
- Alternatively, a section of a plant stem could be cut and stained before preparing a **temporary slide**

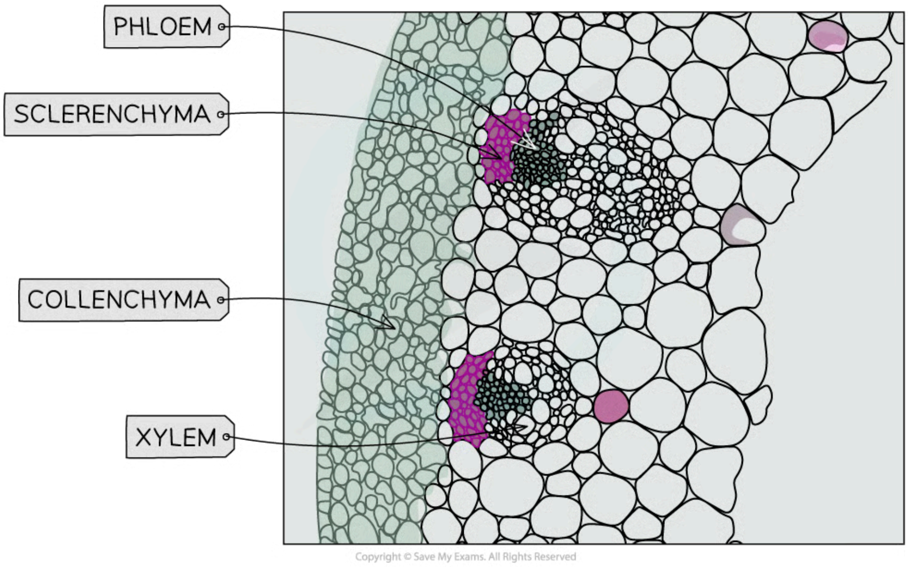
## Apparatus

- Plant stem
- Scalpel
- Suitable stain
- Microscope slide
- Cover slip
- Forceps
- Dissecting needle
- Light microscope
- Gloves

## Method

1. Cut a **very thin** cross-section of the stem using a scalpel
2. Carefully transfer each section into a dish containing a **suitable stain** and leave for one minute
    - E.g. toluidine blue O (TBO) stains xylem and sclerenchyma fibres blue-green, and phloem will appear pinkish purple
3. Rinse off each section in water and mount onto a microscope slide, before adding a cover slip
    - take care to lower the coverslip **slowly** over the sample **from one side to the other** to **avoid trapping air bubbles**, which could be mistaken for plant tissue structures
4. View under a microscope and adjust the focus to form a clear image
5. Make a labelled drawing of the positions of the xylem vessels, phloem sieve tubes and sclerenchyma fibres



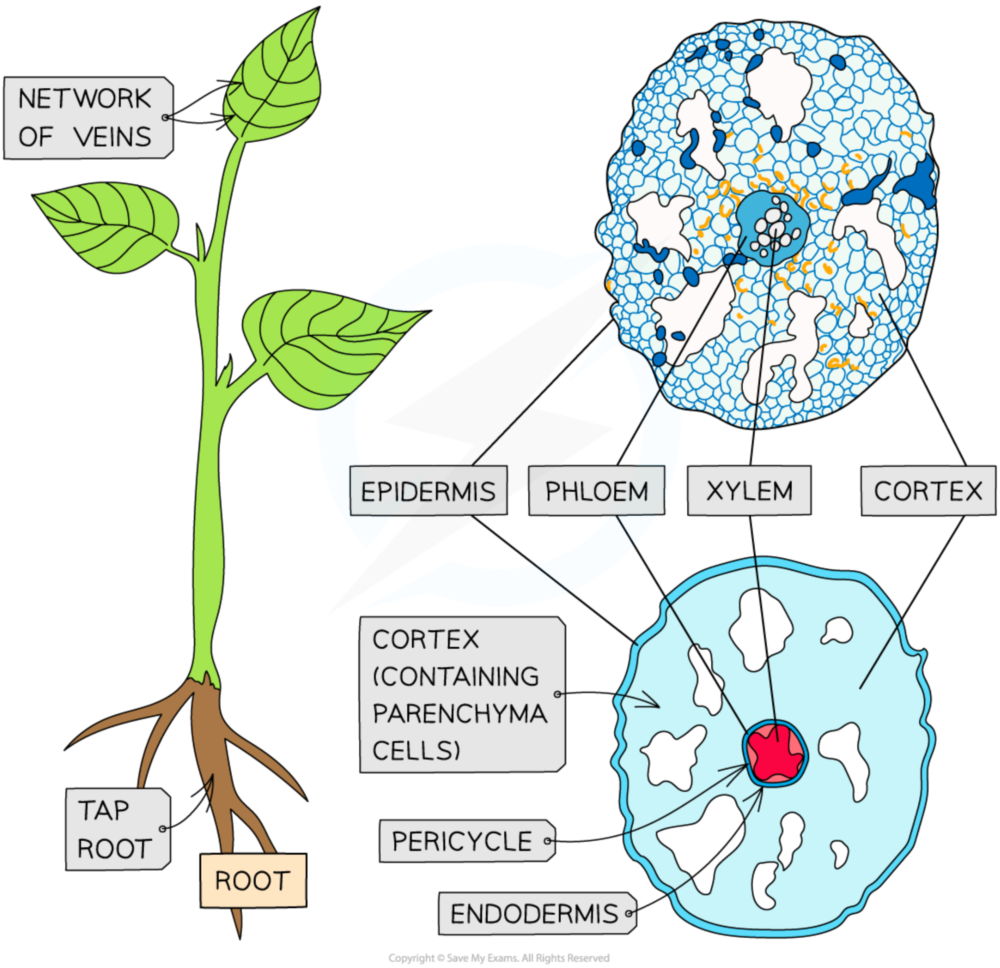

***Microscopes can be used to view the location of different plant tissues within a cross-section; note that the stain used to generate this image is not the TBO stain described in the method above***

Your notes

## Plan diagrams

- When drawing **tissue plan diagrams** you need to:
  - Read the instructions carefully
  - Draw a large diagram
  - Use a sharp pencil and do not shade (including the nucleus)
  - Use clear, continuous lines (no sketching)
  - When using an eyepiece graticule, use it to ensure you have correct proportions or if you are not using a microscope then endeavour to keep the proportions between tissues to scale
- If drawing from a **low-power image**:
  - Do not draw individual cells
  - Read the question carefully as you may only have to draw a portion of the image
  - Include the magnification on the drawing
- If drawing from a **high-power image**:
  - Draw only a few of the required cells
  - Draw the cell wall of the plant cells
  - Include the magnification on the drawing
- When **labelling**, remember:
  - Use a ruler for label lines (and scale lines if appropriate)

- Label lines should stop exactly at the structure (do not use arrows)
- Don't cross label lines over each other
- Label all tissues and relevant structures that are requested



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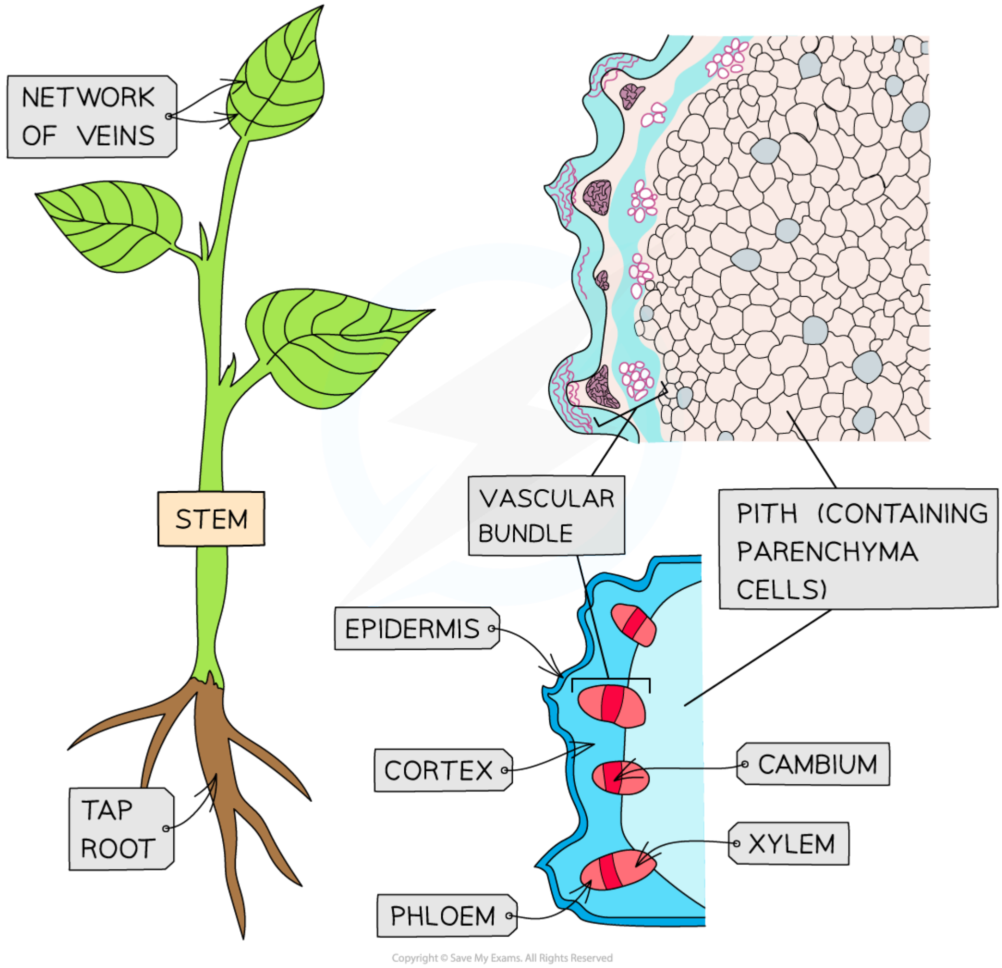

NETWORK OF VEINS
STEM
TAP ROOT
VASCULAR BUNDLE
PITH (CONTAINING PARENCHYMA CELLS)
EPIDERMIS
CORTEX
CAMBIUM
XYLEM
PHLOEM
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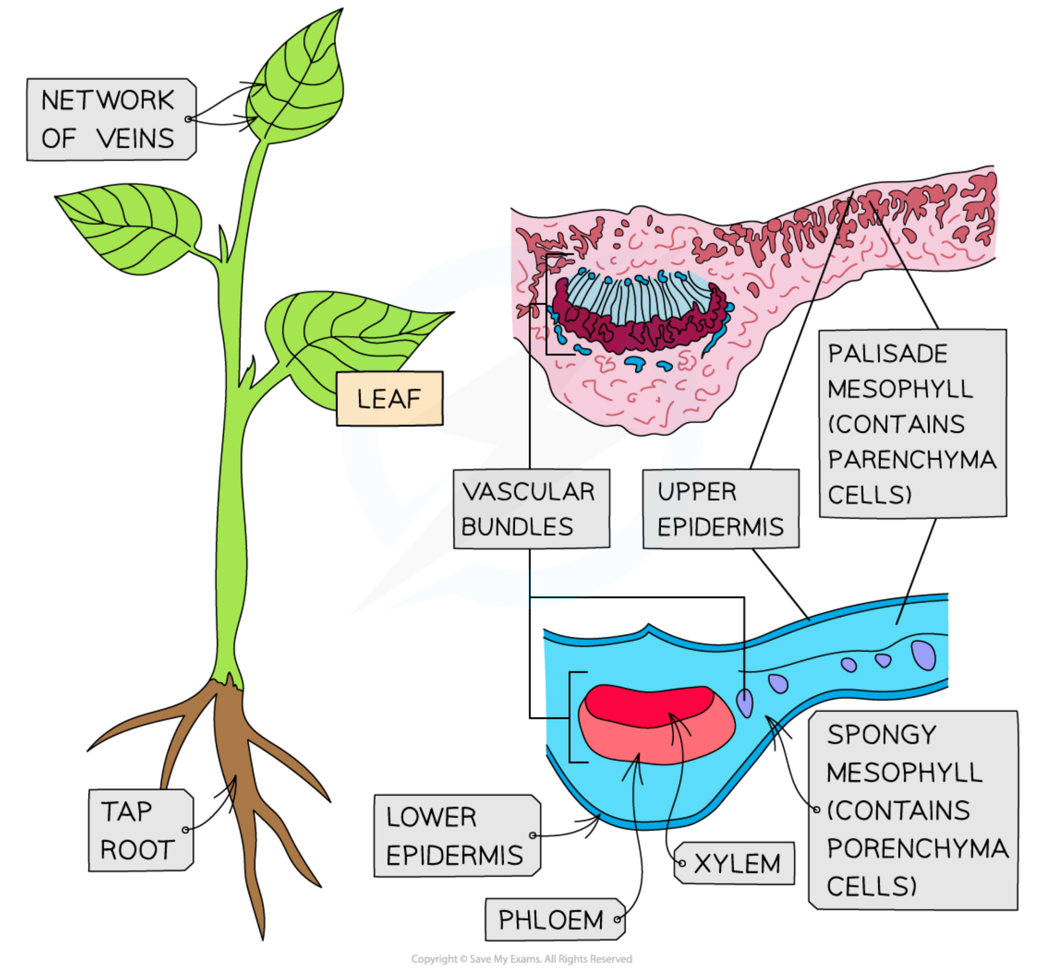


*Tissue plan drawings can be produced from cross-sections of roots (top), stems (middle) and leaves (bottom)*