

Plant tissues, fibres and mineral nutrition

Revision notes · Sclerenchyma, xylem and phloem, plan diagrams and tissue drawings, sustainable plant products, why plants need water and ions, and tensile strength.

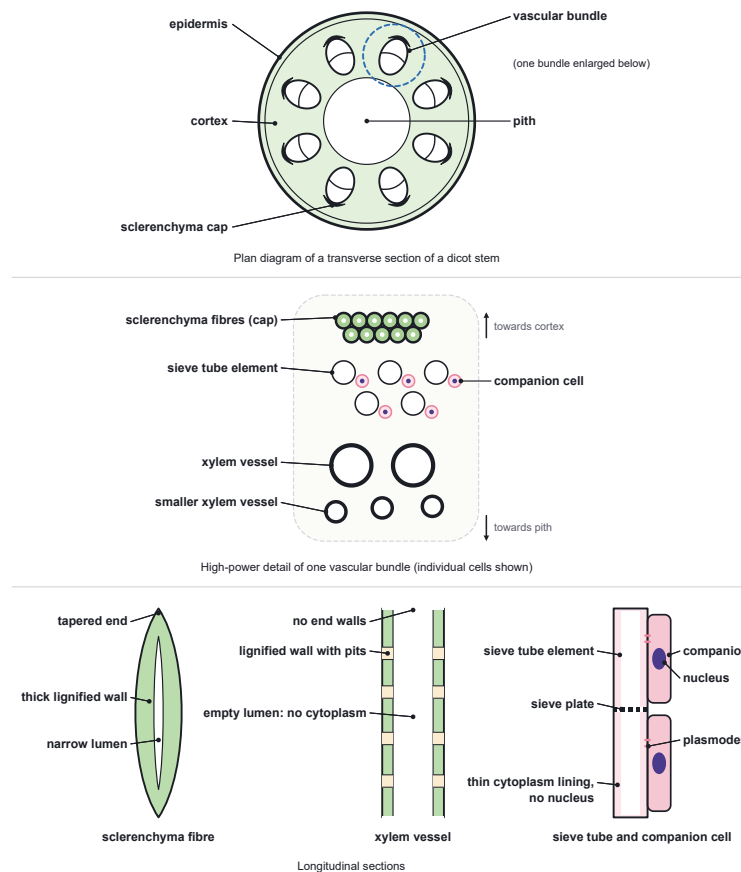
For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

Plant tissues, fibres and mineral nutrition Spec 4.5-4.9

Sclerenchyma fibres, xylem vessels and phloem Spec 4.5

These three tissues are all elongated cells arranged in strands that run along the length of roots and stems. Know where they are in the stem, what their cells look like and what they do.

Sclerenchyma fibres, xylem vessels and phloem			
Feature	Sclerenchyma fibres	Xylem vessels	Phloem (sieve tubes and companion cells)
Function	Support (mechanical strength)	Support and transport of water and mineral ions	Translocation of organic solutes (mainly sucrose and amino acids)
Living or dead at maturity	Dead	Dead	Sieve tube elements living; companion cells living
Cell wall	Thick, lignified secondary wall; narrow lumen	Thick lignified secondary wall in rings, spirals or nearly continuous layers; pits	Thin cellulose walls, not lignified
Cell contents	None	None; hollow lumen, no end walls between vessel elements, forming a continuous tube	Sieve tube: little cytoplasm, no nucleus, few organelles; sieve plates with pores at the ends. Companion cell: dense cytoplasm, nucleus, many mitochondria
Cell shape	Very long, narrow, tapered ends overlapping	Long, wide tubes joined end to end	Sieve tube elements joined end to end; companion cell alongside each
Direction of flow	Not applicable	One direction only: upwards from roots	Both directions, from sources to sinks
Position in a dicot stem	In a cap on the outer side of each vascular bundle, and as a ring or patches towards the outside of the stem	Inner (central) side of each vascular bundle, towards the pith	Outer side of each vascular bundle, between the xylem and the sclerenchyma



Dicot stem: plan diagram, one vascular bundle in detail, and the three cell types seen in longitudinal section.

Similarities

- All three are elongated cells arranged end to end or side by side.
- Fibres and xylem vessels both have thick lignified walls and are dead when mature.
- All three are found in the vascular bundles (fibres also outside them).
- Fibres and xylem vessels both support the plant; phloem does not have a support role.

Roots and leaves

In a root the xylem forms a central star or cross shape, with phloem between its arms, which helps the root resist pulling forces. In a leaf, the vascular bundles in the midrib and veins have xylem on the upper side and phloem on the lower side.

Exam tip: In stems, remember the order from the centre outwards: pith, xylem, phloem, sclerenchyma cap. Questions often ask you to name a tissue from its position and description.

Core practical 7: plant tissues under the light microscope Spec 4.6

Core practical: Core practical 7: use a light microscope to make observations, draw and label plan diagrams of transverse sections of roots, stems and leaves; draw and label cells of plant tissues; and identify sclerenchyma fibres, phloem, sieve tubes and xylem vessels and their location.

Preparing a section

1. Use a sharp razor blade or scalpel to cut a very thin transverse section of the stem, root or leaf. Cut away from your fingers, and place the blade in a sharps container or as directed after use.
2. Float the sections in water in a dish. Choose the thinnest, most complete section with a fine paintbrush.

3. Stain: toluidine blue stains lignified walls blue-green; phloroglucinol with hydrochloric acid stains lignin red. Treat hydrochloric acid as corrosive and wear eye protection.
4. Mount on a slide in a drop of water or stain. Lower a coverslip at an angle, using a mounted needle, to avoid trapping air bubbles.
5. Start with the lowest power objective, focus with the coarse focus and then the fine focus, then move to a higher power for detail.

Plan diagrams

- Draw with a sharp pencil, using clean single lines, with no shading and no colouring.
- Draw the outline of the whole section and the boundaries between tissues. Do not draw individual cells.
- Make the drawing large (using at least half the page) and in proportion.
- Label with straight lines ruled from the structure, not crossing each other, with a title, and record the magnification.

What to show on plan diagrams of transverse sections

Section	Tissues to outline and label
Root	Epidermis (with root hairs), cortex, endodermis, and a central vascular cylinder with xylem in a star or cross shape and phloem between its arms
Stem	Epidermis, cortex, a ring of vascular bundles (xylem on the inner side, phloem outside it, sclerenchyma cap outermost) and central pith
Leaf	Upper and lower epidermis, palisade mesophyll, spongy mesophyll, and the midrib vascular bundle with xylem on the upper side and phloem on the lower side

Drawing cells of a tissue

Use a higher power objective and draw a small number of cells in one tissue with a continuous line, showing the cell walls, lumen and contents. Show thick walls as double lines. Identify the tissues from their appearance.

- **Xylem vessels**: large circular lumens, no contents, thick walls (stained blue-green or red by lignin stains).
- **Sclerenchyma fibres**: small lumens, very thick walls, in groups outside the phloem.
- **Phloem**: thin-walled; **sieve tubes** are larger and empty-looking, with companion cells smaller and with dense cytoplasm beside them. In a longitudinal section a sieve plate may be visible.

magnification = size of image ÷ size of real object

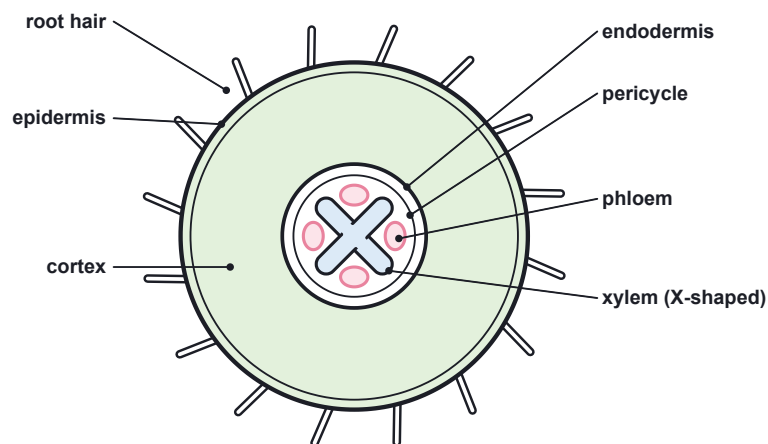
Calculating the magnification of a plan diagram

A student's plan diagram of a stem section is 96 mm wide. The real section, measured using an eyepiece graticule that was calibrated with a stage micrometer, is 3.2 mm wide. Calculate the magnification.

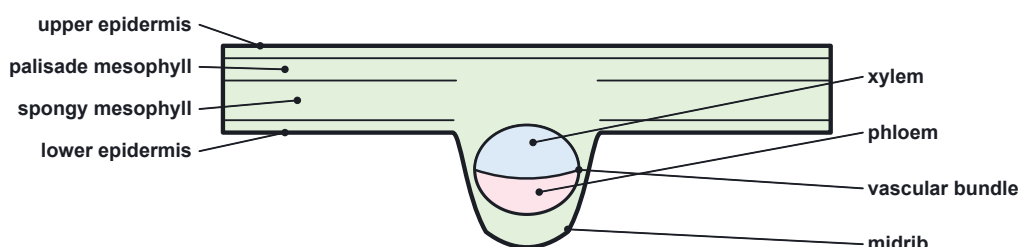
1. Both lengths must be in the same units: 96 mm and 3.2 mm.
2. magnification = $96 \div 3.2$

Answer: $\times 30$

Maths skill: To find the real size from a drawing, rearrange: $\text{real size} = \text{image size} \div \text{magnification}$.
Convert units first: $1 \text{ mm} = 1000 \mu\text{m}$.



Plan diagram of a transverse section of a young dicot root



Plan diagram of a transverse section through a dicot leaf midrib

Plan diagrams: a young root and a leaf midrib. Plan diagrams show tissues as outlines only, with no individual cells.

Common mistake: A plan diagram must not show individual cells, and labels must not cross. Both are common ways to lose marks.

Plant fibres, starch and sustainability Spec 4.7

Oil-based plastics are made from crude oil, a **finite resource**, and most do not break down quickly, so they build up as waste. Plant-based materials offer alternatives that can contribute to **sustainability**, which means meeting the needs of the present without harming the ability of future generations to meet their own needs.

Plant-based products that can replace oil-based plastics

Material	Source	Example uses
Plant fibres (hemp, flax, jute, sisal)	Sclerenchyma fibres from stems and leaves	Rope, string, textiles, bags, and fibre-reinforced materials used in place of plastic or glass fibre composites
Starch-based plastics	Starch from crops such as maize, potato or cassava	Packaging, carrier bags, cutlery, food containers, loose-fill packaging

How they contribute to sustainability

- They are renewable: new crops can be grown each year.
- Plants take in carbon dioxide during photosynthesis, so the carbon released when products are used or break down was recently removed from the atmosphere. This can reduce net carbon dioxide emissions compared with using oil.
- They are often biodegradable, so microorganisms can break them down and less waste accumulates.
- Less crude oil is needed, which reduces the use of a finite resource.

Limitations

- Growing crops for materials needs land, water and fertiliser, which can compete with food production and reduce biodiversity if natural habitat is cleared.
- Some starch-based plastics break down only under particular conditions, such as in industrial composting, and may be less strong or less waterproof than oil-based plastics.
- Processing and transport still use energy.

Exam tip: A balanced answer scores best: give one or two points on renewability or biodegradability and a limitation such as land use competing with food crops.

Water and inorganic ions in plants Spec 4.8

Water

- Keeps cells **turgid**, which supports the stems and leaves of non-woody plants and opens stomata.
- A solvent and transport medium: ions are carried in the xylem and sucrose in the phloem.
- A reactant in photosynthesis (light-dependent reactions) and in hydrolysis reactions.
- Evaporation (transpiration) cools the leaf and pulls water and ions up the plant.
- Needed for cell expansion during growth.

Inorganic ions

Ions needed by plants		
Ion	Used for	Effect of deficiency
Nitrate (NO_3^-)	Source of nitrogen to make amino acids, proteins, nucleotides and nucleic acids (DNA and RNA bases), and chlorophyll	Stunted growth; older leaves turn yellow (chlorosis) because nitrogen is moved to young leaves
Calcium (Ca^{2+})	Forms calcium pectate in the middle lamella and helps build cell walls; also helps maintain membrane structure	Poor growth, especially of young tissues and roots; distorted young leaves
Magnesium (Mg^{2+})	Central atom of the chlorophyll molecule, needed to make chlorophyll	Chlorosis: leaves, especially older ones, turn yellow between the veins, so photosynthesis is reduced

Plants absorb these ions as dissolved ions from the soil water, mainly through the root hair cells by active transport.

The specification recommends (as an additional practical, not a core practical) that you **investigate plant mineral deficiencies**. Seedlings of the same species and age are grown in culture solutions that are identical except that one lacks nitrate, calcium or magnesium ions, with a complete solution as the control. After a few weeks, compare growth (for example height, number of leaves or dry mass) and leaf colour.

Common mistake: Say that magnesium ions are the central atom in the chlorophyll molecule, and that plants absorb nitrogen as nitrate ions, not as nitrogen gas.

Core practical 8: tensile strength of plant fibres Spec 4.9

Core practical: Core practical 8: determine the tensile strength of plant fibres.

Tensile strength

The maximum force per unit cross-sectional area that a material can withstand when it is pulled before it breaks. Units: N mm^{-2} or Pa ($1 \text{ N mm}^{-2} = 1 \text{ MPa}$).

$$\text{tensile strength} = \text{breaking force} \div \text{cross-sectional area}$$

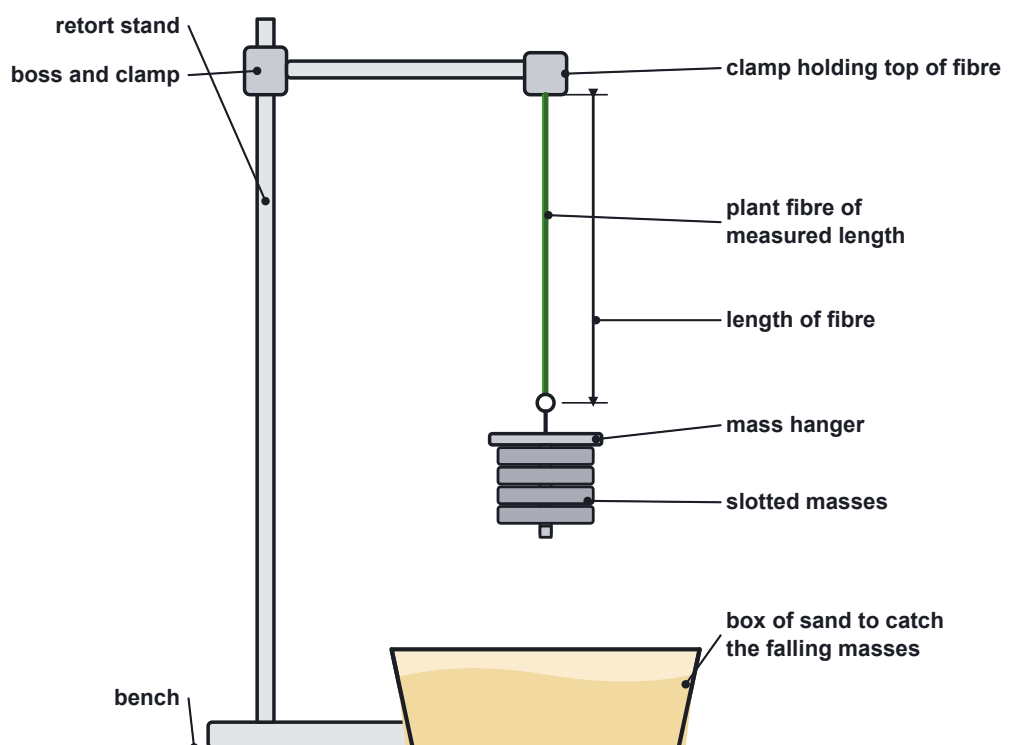
$$\text{force (N)} = \text{mass (kg)} \times 9.81 \text{ N kg}^{-1} \text{ and area} = \pi r^2$$

Method

1. Cut fibres of the same length from each plant being compared (for example 20 cm). Measure the diameter at several points with a micrometer or under a microscope with a graticule, and calculate the mean radius.
2. Clamp one end of the fibre firmly to a retort stand at the top. Tie a mass hanger securely to the other end.
3. Place a box of soft material, such as sand or cushioning, below the hanger, and wear eye protection and closed shoes.
4. Add masses one at a time (for example 100 g), waiting a few seconds each time, until the fibre breaks.
5. Record the total mass, including the hanger, at which the fibre broke. Repeat with at least five fibres of each type and calculate a mean.
6. Calculate the breaking force, the cross-sectional area from the radius, and then the tensile strength.

Variables

Type	Variable	How
Independent	Type of plant fibre (or treatment)	Choose fibres from different plants
Dependent	Mass or force at which the fibre breaks	Add masses until the fibre snaps
Control	Length of fibre; diameter (or calculate per unit area); moisture content; temperature; how the fibre is attached; size of mass increments	Same length, same age and storage, same increments and time between additions



Apparatus for measuring the tensile strength of a plant fibre. Add masses until the fibre breaks.

Risks and reliability

- Falling masses can injure feet: use a box of soft material and closed shoes.
- Fibres may snap near the knot or clamp. Discard these as anomalies and repeat.
- Fibres vary in thickness along their length, so measure the diameter in several places and calculate area per fibre.
- Repeating with many fibres and calculating a mean improves reliability. Use the same increments of mass for all fibres.

Calculating tensile strength

A plant fibre of diameter 0.40 mm breaks when the total mass hanging from it is 4.5 kg. Calculate the tensile strength in N mm^{-2} . Use $g = 9.81 \text{ N kg}^{-1}$.

1. $\text{force} = 4.5 \times 9.81 = 44.1 \text{ N}$

2. $\text{radius} = 0.40 \div 2 = 0.20 \text{ mm}$, so $\text{area} = \pi \times 0.20^2 = 0.126 \text{ mm}^2$

3. $\text{tensile strength} = 44.1 \div 0.126$

Answer: 350 N mm^{-2} (to 2 significant figures)

Maths skill: Show every step: convert mass to force, convert diameter to radius, then area, then divide. Check that the units match (N and mm^2).

Quick check

- 1 . Name the tissue that carries sucrose around the plant.
- 2 . Why can xylem vessels carry water in one continuous column?
- 3 . State the formula for magnification.
- 4 . Why do plants need magnesium ions?
- 5 . Give the unit of tensile strength.

Quick check answers

Plant tissues, fibres and mineral nutrition

1. Phloem (sieve tubes).
2. They are dead, have no cell contents and no end walls, so form a hollow tube.
3. Magnification = size of image $\div$ size of real object.
4. Magnesium is the central atom in chlorophyll, so it is needed to make chlorophyll for photosynthesis.
5. N mm^{-2} (equivalent to MPa) or Pa.