

Transport in plants

A-Level Biology 9700 · Topic 7 revision notes

Everything from the 4 lessons of this topic on a few pages: the key idea of each lesson, the diagram to remember, the points to learn and the traps examiners set. Read it, cover it, test yourself.

1. Xylem and phloem: structure and distribution
2. From soil to xylem, and up the stem

3. Transpiration and xerophytic leaves
4. Translocation: loading the phloem and mass flow

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1 Xylem and phloem: structure and distribution

Syllabus 7.1

In a herbaceous dicotyledonous plant the **xylem** carries water and mineral ions up from the roots, and the **phloem** carries assimilates such as sucrose and amino acids from sources to sinks. Their positions differ: in the **root** the xylem is in the centre, often X or star shaped, with phloem between its arms; in the **stem** the vascular bundles form a ring near the outside, with xylem on the inner side and phloem on the outer side of each bundle; in the **leaf** midrib and veins the xylem is on the upper side and the phloem on the lower side. **Xylem vessel elements** are dead, empty and joined end to end, with lignified walls and pits. **Sieve tube elements** are living but have no nucleus and very little cytoplasm, with sieve plates between them; each is kept alive by a **companion cell** with a nucleus, many mitochondria and many plasmodesmata.

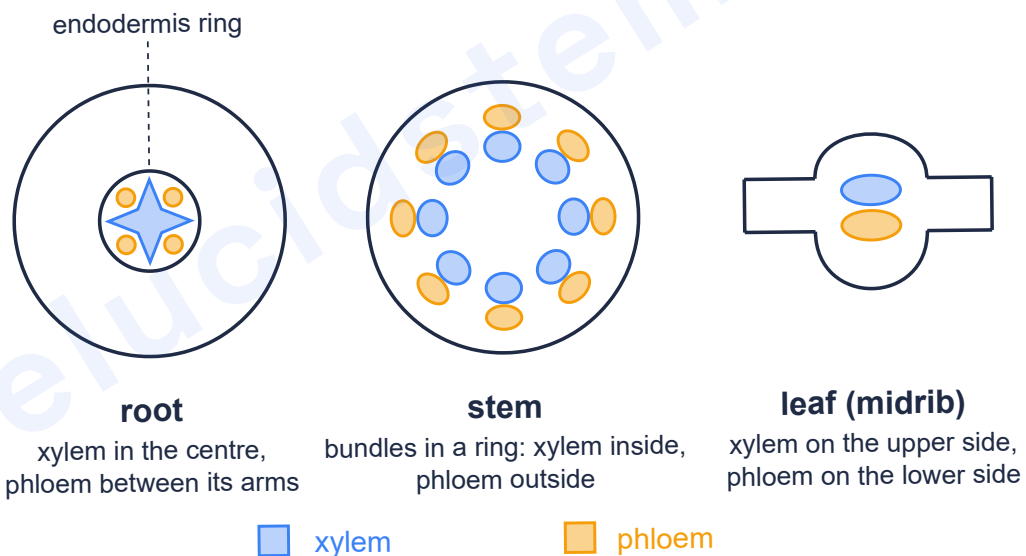


Fig. 1: plan diagrams of transverse sections of a dicotyledonous root, stem and leaf, showing the distribution of xylem and phloem

Position, then structure.

- ✓ **Root:** xylem central, X or star shape; phloem between the arms.
- ✓ **Stem:** ring of bundles; xylem inside, phloem outside, cambium between.
- ✓ **Leaf:** xylem upper, phloem lower in each vein.
- ✓ **Xylem** dead, empty, lignified; **sieve tube** living, no nucleus, sieve plates.

Watch out!

A **plan diagram** shows the outlines of tissues only: no individual cells, no shading, clear continuous lines, proportions that match the specimen and label lines drawn with a ruler. Drawing cells in a plan diagram loses marks.

Xylem vessel elements are **dead**, so they cannot actively transport anything; water moves up them passively. Sieve tube elements are **alive** even though they lack a nucleus. Mixing these up is a common error.

2 From soil to xylem, and up the stem

Syllabus 7.2

Mineral ions and some organic compounds are carried around a plant **dissolved in water**. Water enters root hair cells by osmosis and crosses the cortex by two routes: the **apoplast pathway** through the permeable **cellulose cell walls** and spaces between cells, and the **symplast pathway** through the cytoplasm, passing from cell to cell through **plasmodesmata**. At the **endodermis** a band of waterproof **suberin**, the **Casparian strip**, blocks the apoplast, so all water must pass through the endodermal cells, letting the plant control which ions reach the xylem. In the xylem, water molecules form **hydrogen bonds** with each other (**cohesion**) and with the cellulose of the walls (**adhesion**). As water is lost from the leaves, the continuous column is pulled up under **tension**: the **transpiration pull**. Lignin keeps the vessels from collapsing and makes their walls waterproof.

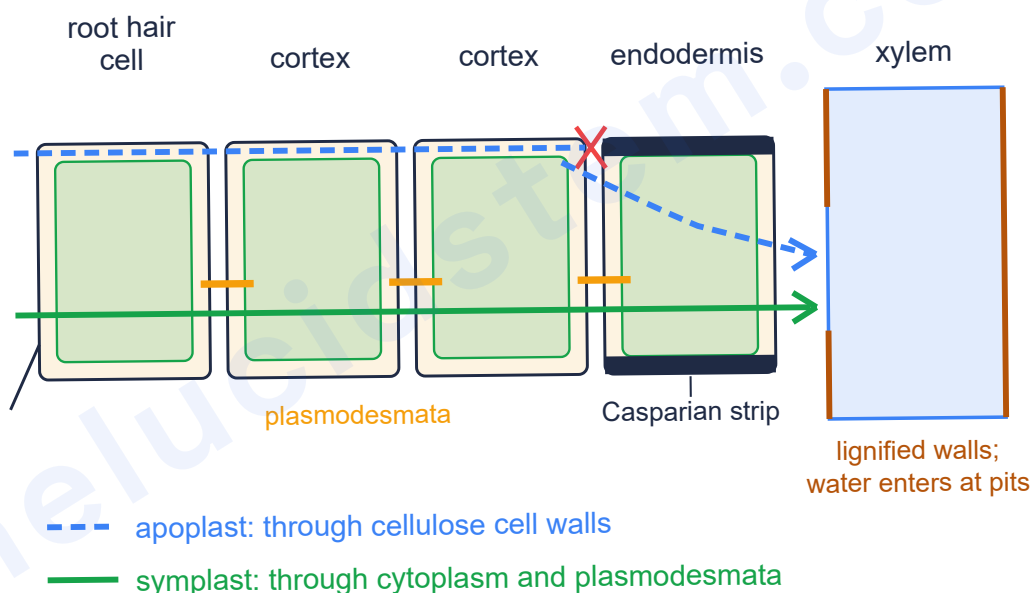


Fig. 1: the apoplast and symplast pathways across the root cortex, with the Casparian strip blocking the apoplast at the endodermis

Two routes, one column.

- ✓ **Apoplast:** cellulose walls and spaces, no membranes, fast.
- ✓ **Symplast:** cytoplasm and plasmodesmata.
- ✓ **Casparian strip** (suberin) blocks the apoplast at the endodermis: control of ions.
- ✓ **Cohesion** water to water, **adhesion** water to cellulose, both hydrogen bonds; **tension** from transpiration.

Watch out!

The Casparian strip blocks the **apoplast** only. It does not stop water reaching the xylem: water simply has to go through the cytoplasm of the endodermal cells (the symplast) for that step. Never write that the Casparian strip "stops water entering the xylem".

Water moves up the xylem **passively**: the energy comes from the Sun evaporating water in the leaf, not from ATP in the xylem. Xylem vessel elements are dead and cannot pump anything.

3 Transpiration and xerophytic leaves

Syllabus 7.2

Transpiration is the loss of water vapour from the aerial parts of a plant, mainly the leaves. Water **evaporates** from the wet surfaces of mesophyll cell walls into the air spaces inside the leaf, and the water vapour then **diffuses** out through open stomata, down a water potential gradient, to the drier air outside. Low humidity, high temperature, wind and the light that opens stomata all increase the rate. The water lost is replaced from the xylem, which is what pulls the water column up the plant. **Xerophytes** are plants adapted to dry places. Marram grass reduces transpiration with **rolled leaves** (rolled by **hinge cells**), **sunken stomata** in grooves on the inner surface, **hairs** that trap moist air and a **thick waxy cuticle** on the exposed outer surface. Each adaptation either keeps humid air next to the stomata, so the water potential gradient is shallow, or makes the surface less permeable.

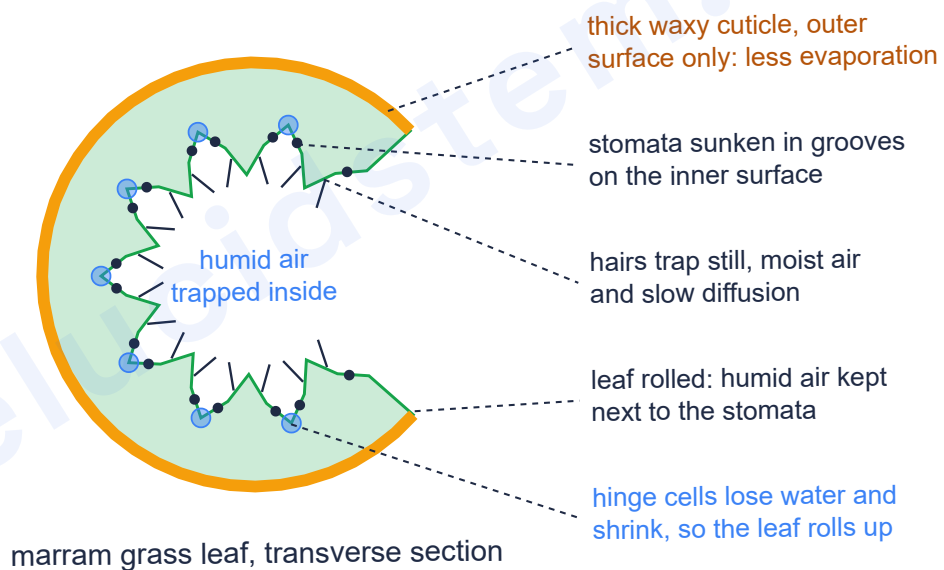


Fig. 1: an annotated drawing of a transverse section of a rolled marram grass leaf, a xerophyte

Two steps, then the gradient.

- ✓ **Evaporation** from mesophyll cell walls into air spaces.
- ✓ **Diffusion** of water vapour out through stomata, down a water potential gradient.
- ✓ **Humidity** down, **temperature**, **wind** and **light** up: rate up.
- ✓ **Xerophytes**: trap humid air near stomata or thicken the cuticle.

Watch out!

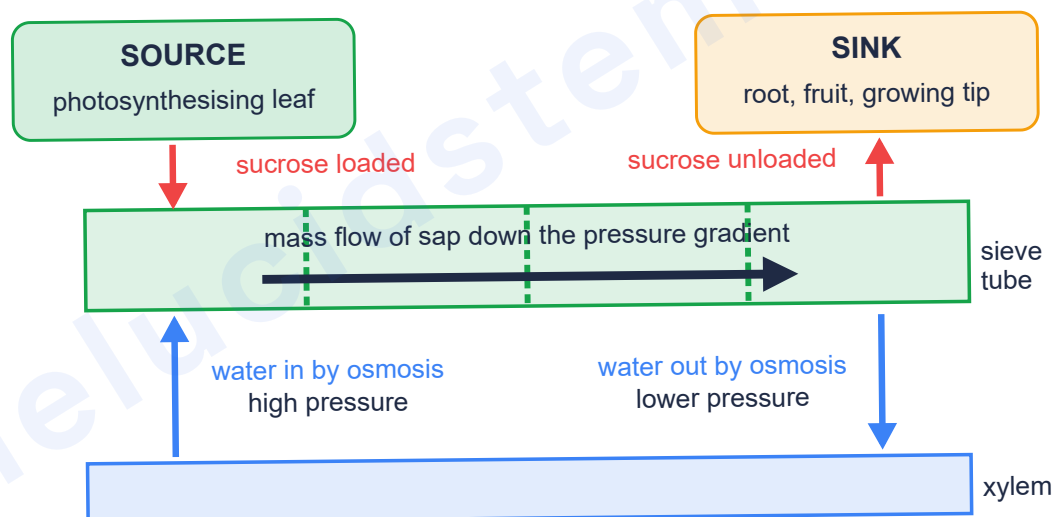
Say that water **evaporates** from the internal surfaces (the mesophyll cell walls) and then water **vapour diffuses** out through the stomata. Writing that "water evaporates out of the stomata" or that "water diffuses out of the leaf" merges two steps and loses marks.

Xerophyte adaptations **reduce** water loss; they do not stop it. The stomata still have to open for carbon dioxide, so some transpiration always happens.

4 Translocation: loading the phloem and mass flow

Syllabus 7.2

Assimilates, mainly **sucrose** and **amino acids**, are carried dissolved in water in phloem sieve tubes from **sources**, where they are made or released (photosynthesising leaves, storage organs being emptied), to **sinks**, where they are used or stored (roots, growing tips, fruits, storage organs being filled). At the source, **companion cells** use ATP to drive **proton pumps** that move hydrogen ions out of the cell. The ions diffuse back in through **cotransporter proteins**, carrying sucrose with them against its concentration gradient, and the sucrose passes into the sieve tube through plasmodesmata. This lowers the water potential in the sieve tube, so water enters from the xylem by osmosis and the **hydrostatic pressure** rises. At the sink, sucrose is removed, water leaves and the pressure is lower, so the sap moves by **mass flow** down the pressure gradient from source to sink.



loading: companion cells use ATP to pump H^+ out; H^+ diffuses back in through cotransporter proteins, carrying sucrose with it

Fig. 1: mass flow in a phloem sieve tube from source to sink, driven by a hydrostatic pressure gradient

Energy at the source, flow down the gradient.

- ✓ **Source** makes or releases sucrose; **sink** uses or stores it.
- ✓ **Proton pump** uses ATP; **cotransporter** uses the H^+ gradient.
- ✓ Sucrose in, water potential down, water in, **pressure up**.
- ✓ **Mass flow** from high to low hydrostatic pressure, source to sink.

Watch out!

The cotransporter does not use ATP directly. ATP is used by the **proton pump**; the cotransporter uses the energy of H^+ ions diffusing back down their gradient. Saying "sucrose is actively pumped by the cotransporter using ATP" is a common error.

Mass flow is a **passive** movement down a pressure gradient. The energy is spent at the source, on loading. Do not write that sieve tubes "pump" sap or that sucrose diffuses all the way to the sink.