

Transport in plants revision notes

Plants move water, mineral ions and the products of photosynthesis around their bodies in two transport tissues, xylem and phloem. Water is taken up by root hair cells and pulled up to the leaves, where it is lost by transpiration. Sucrose and amino acids are moved by translocation from sources to sinks.

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). **Supplement** is Extended content, only examined on Papers 2 and 4.

1 Xylem and phloem **Spec 8.1**

Xylem and phloem **Spec 8.1.1, 8.1.3**

Plants have two transport tissues. Together they make up the vascular tissue, which runs from the roots through the stem and into the leaves.

Functions of xylem and phloem

Tissue	Function
Xylem	transport of water and mineral ions (from the roots upwards), and support for the plant
Phloem	transport of sucrose and amino acids

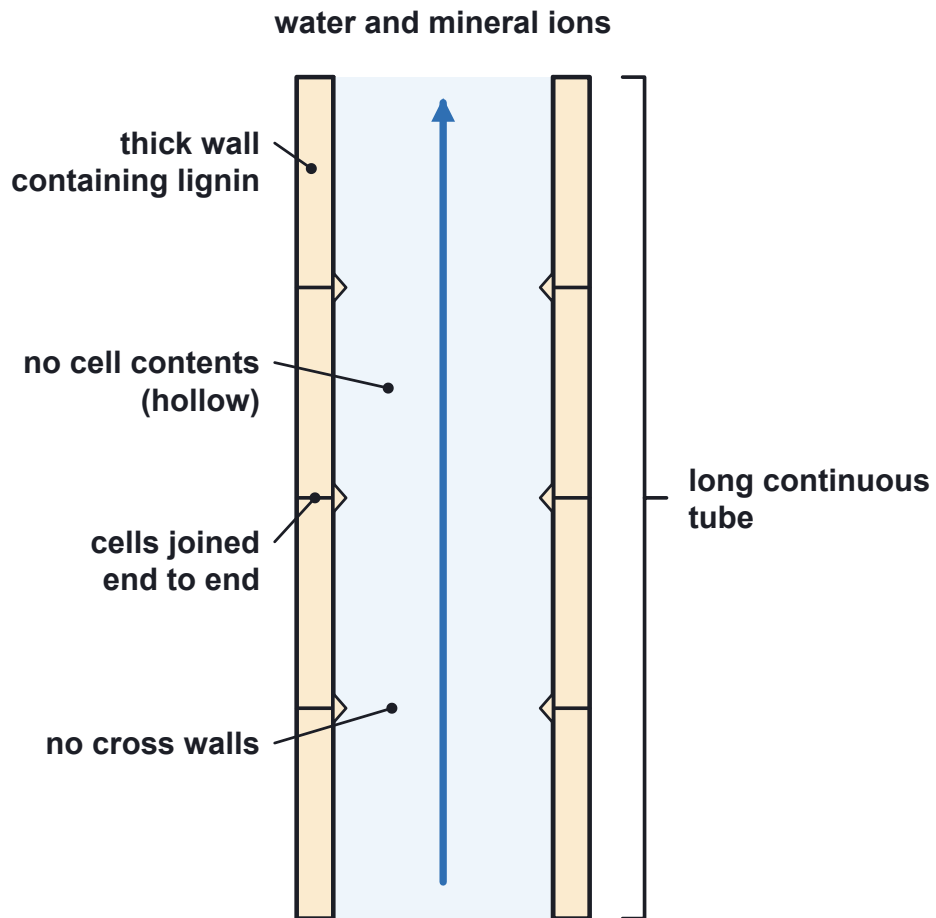
Supplement

Xylem vessels: structure and function

Supplement

Xylem vessels are adapted to carry water over long distances. Each feature links to a job.

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A xylem vessel is a **long continuous tube** of dead cells with thick, lignified walls and no cross walls.

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Structure of a xylem vessel

Feature	How it helps
Thick walls containing lignin	Strong, so the vessel does not collapse and the plant is supported. The details of lignification are not required.
No cell contents	Nothing blocks the vessel, so water flows through easily.
Cells joined end to end with no cross walls	Forms a long continuous tube , so water can move up in one unbroken column.

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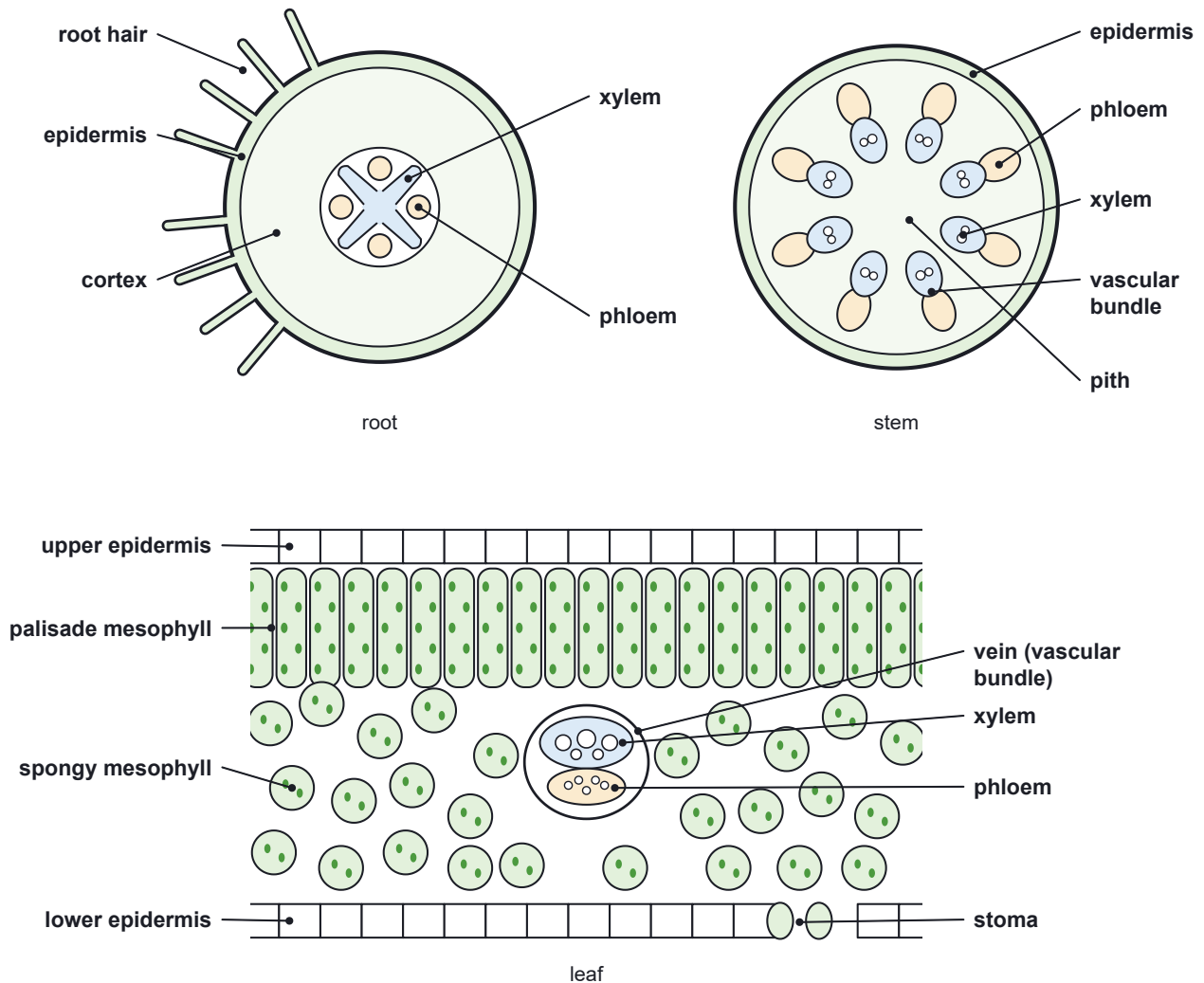
Exam tip: Always link the feature to its function. 'No cross walls' earns the mark only if you say it makes a continuous tube or lets water flow without obstruction.

Xylem and phloem in roots, stems and leaves Spec 8.1.2

You must be able to find xylem and phloem in sections of the roots, stems and leaves of a non-woody dicotyledonous plant. In all three organs they are found together, in groups called **vascular bundles** (veins in the leaf).

Position of xylem and phloem

Organ	Where the vascular tissue is	Xylem and phloem
Root	in the centre of the root	xylem in the middle, often in an X or star shape, with phloem between the arms of the X
Stem	vascular bundles in a ring near the outside of the stem	in each bundle, xylem is on the inside and phloem on the outside
Leaf	in the midrib and the veins	in each vein, xylem is on the upper side and phloem on the lower side



Root: xylem in the centre. Stem: bundles with **phloem outside, xylem inside**. Leaf vein: **xylem above phloem**.

To identify the tissues in a photograph, find the vascular bundle or vein first, then use its position to decide which tissue is which.

Common mistake: Do not mix up the order in the stem. Phloem is on the outside of each bundle and xylem is on the inside.

Quick check

- 1 . What does phloem transport?
- 2 . What are the two functions of xylem?
- 3 . In a stem, which tissue is on the outside of a vascular bundle?
- 4 . **Supplement** Why do xylem vessels have no cross walls?

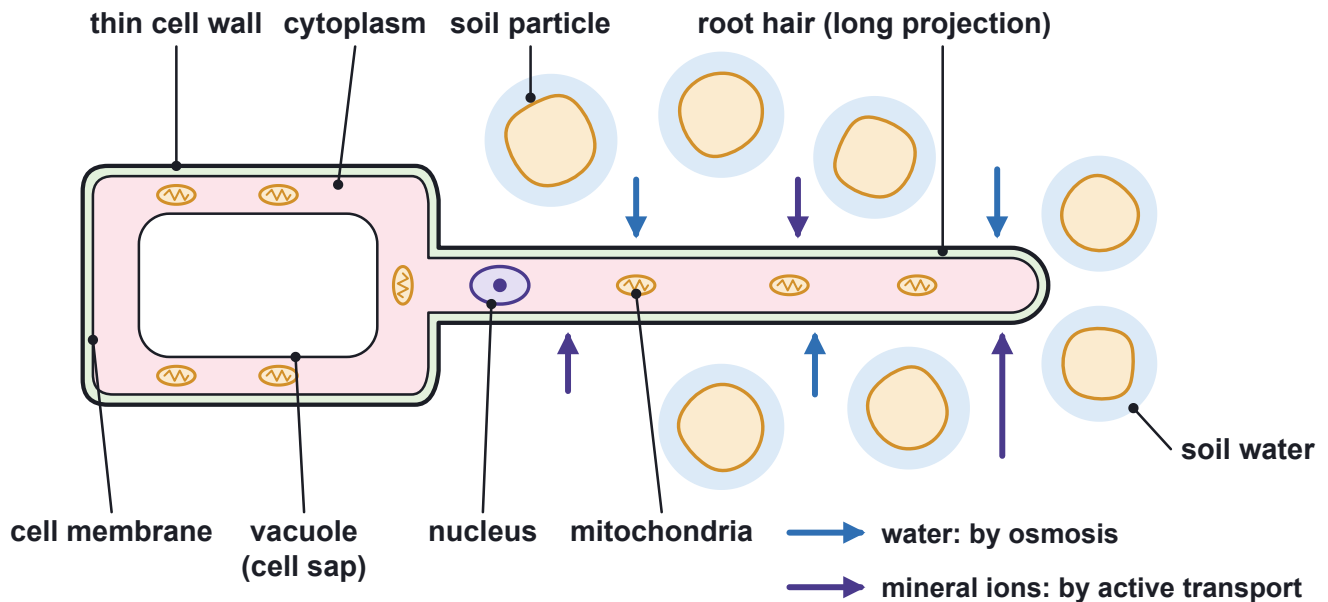
2 Water uptake Spec 8.2

Root hair cells and the pathway of water Spec 8.2.1, 8.2.2, 8.2.3

Root hair cells

A **root hair cell** is a cell in the outer layer of the root that has a long, thin extension called the root hair. Its functions are to absorb water from the soil and to absorb mineral ions from the soil.

The root hair gives the cell a **large surface area**, which increases the uptake of water and mineral ions.

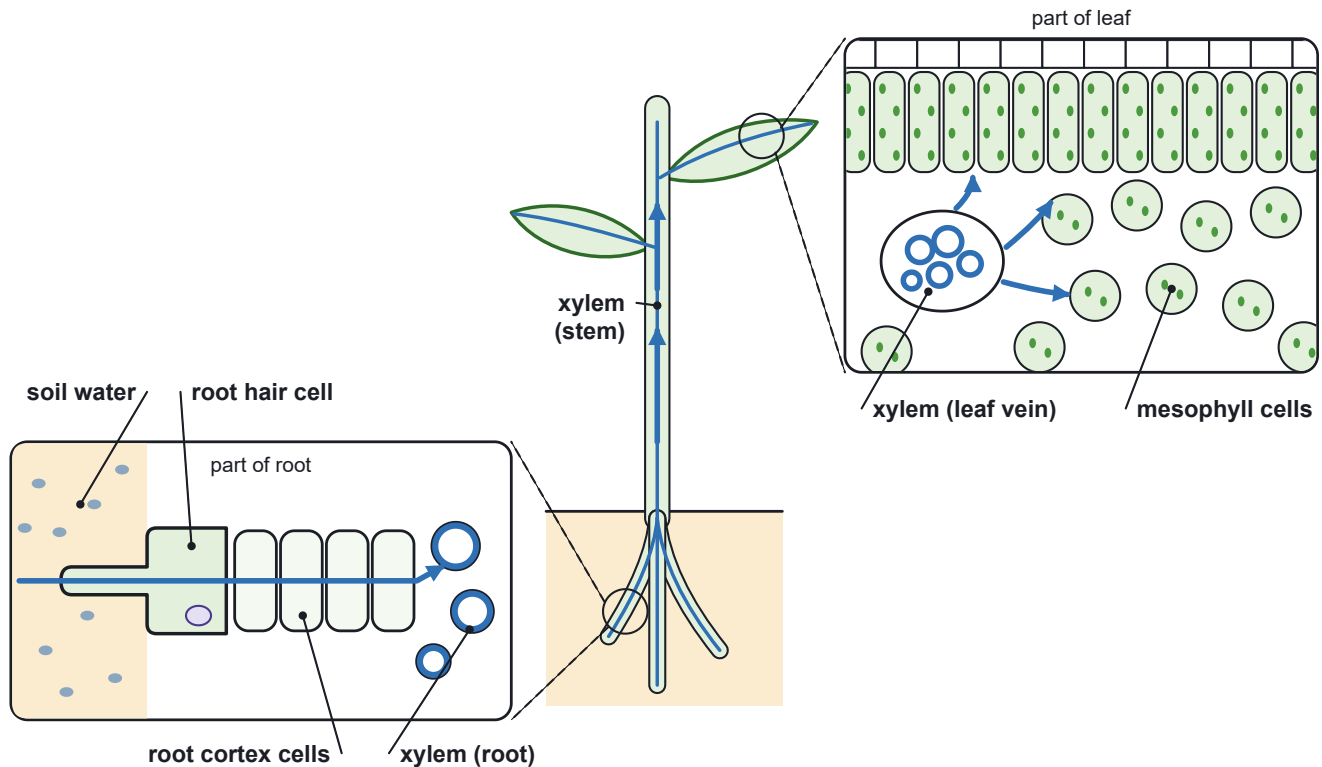


A root hair cell. Its long extension gives a large surface area for absorbing water and mineral ions.

The pathway of water

Water takes the same route from the soil to the air. You need to be able to outline it.

1. Water enters the **root hair cells** from the soil.
2. It passes through the **root cortex cells**.
3. It enters the xylem and moves up the root and stem.
4. It leaves the xylem in the leaf and reaches the **mesophyll cells**.



Water moves from the soil into the **root hair cells**, across the **root cortex cells**, up the **xylem** and into the **mesophyll cells**.

Exam tip: Give the cells in the right order: **root hair cells, root cortex cells, xylem, mesophyll cells**.

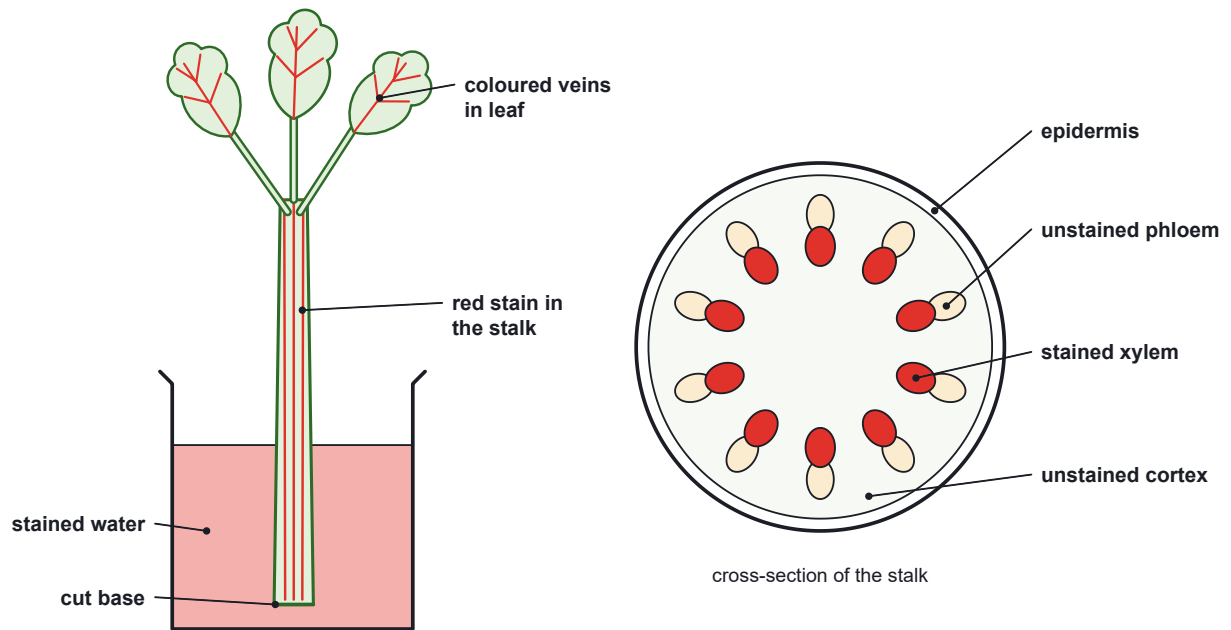
Writing 'roots to leaves' alone will not score.

Investigating the pathway of water with a stain Spec 8.2.4

You can show where water travels in a plant by putting the cut stem in water that contains a coloured stain (dye), such as red food colouring or eosin. The stain is carried in the water, so it shows the route.

1. Fill a beaker with water and add a few drops of the stain.
2. Cut the base of a stem (for example celery, or a white flower) so that it has a fresh end, and stand it in the stained water.
3. Leave the plant in a warm, light place for several hours, or overnight.
4. Look for stain in the veins of the leaves or the petals.
5. Cut a thin cross-section (transverse section) of the stem with a sharp blade and look at it with a hand lens or microscope. Cut away from your fingers.

The stain is found in the **xylem**. In a cross-section of the stem, only the xylem in the **vascular bundles** is coloured, in a ring of small dots. This shows that water travels up the stem in the xylem. In a longitudinal section, the stain appears as coloured lines.



The stain travels with the water, so only the **xylem** is coloured.

Practical skill: Control the variables if you are comparing plants: same type of plant, same volume and concentration of stain, same time, same light and temperature. Write what you see, not just what you expect.

Quick check

1. What do root hair cells absorb?
2. Why does a root hair increase uptake?
3. Give the pathway of water in order.
4. Where is a stain found after a stem stands in stained water?

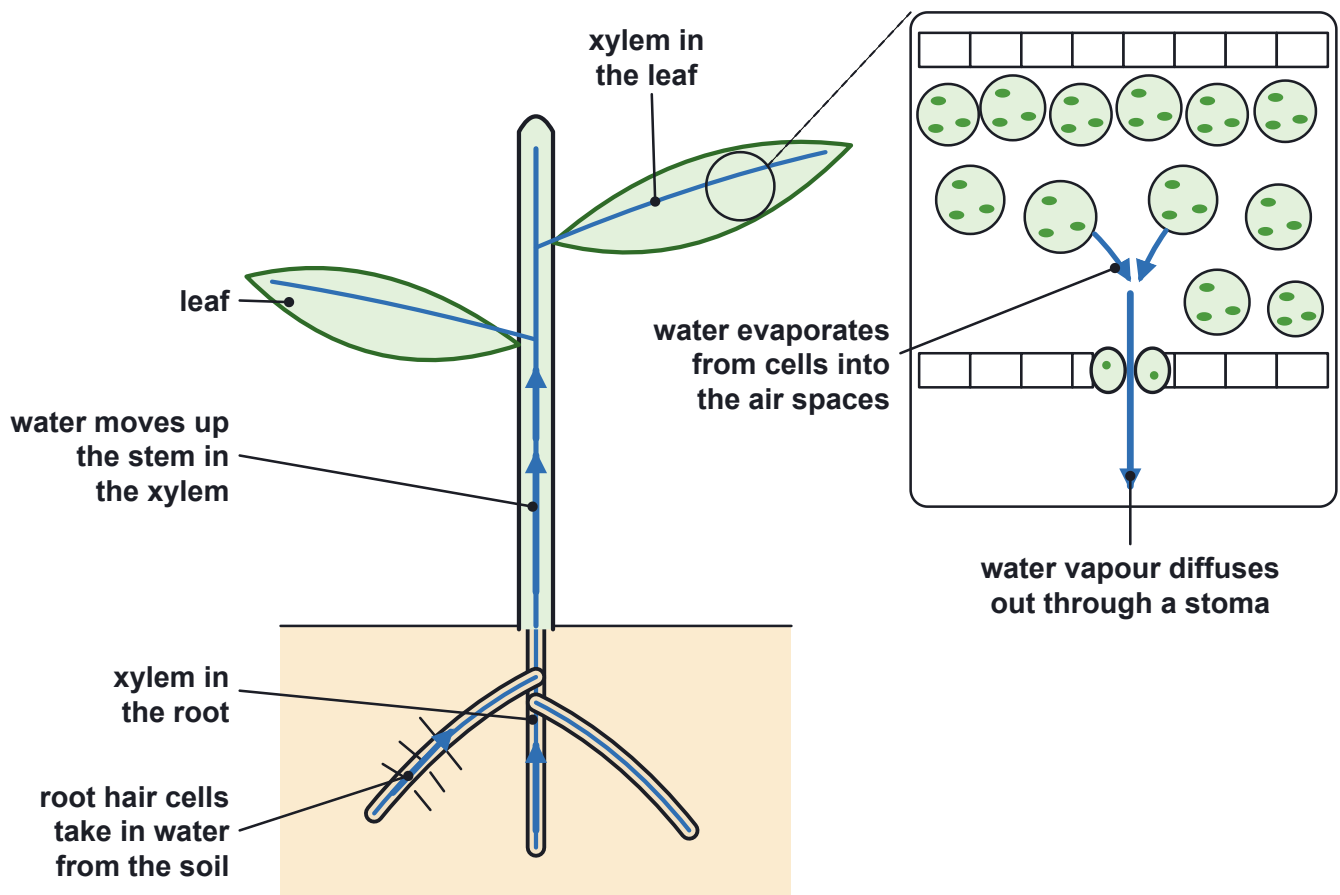
3 Transpiration Spec 8.3

Transpiration Spec 8.3.1, 8.3.2, 8.3.4

Transpiration is the loss of water vapour from leaves.

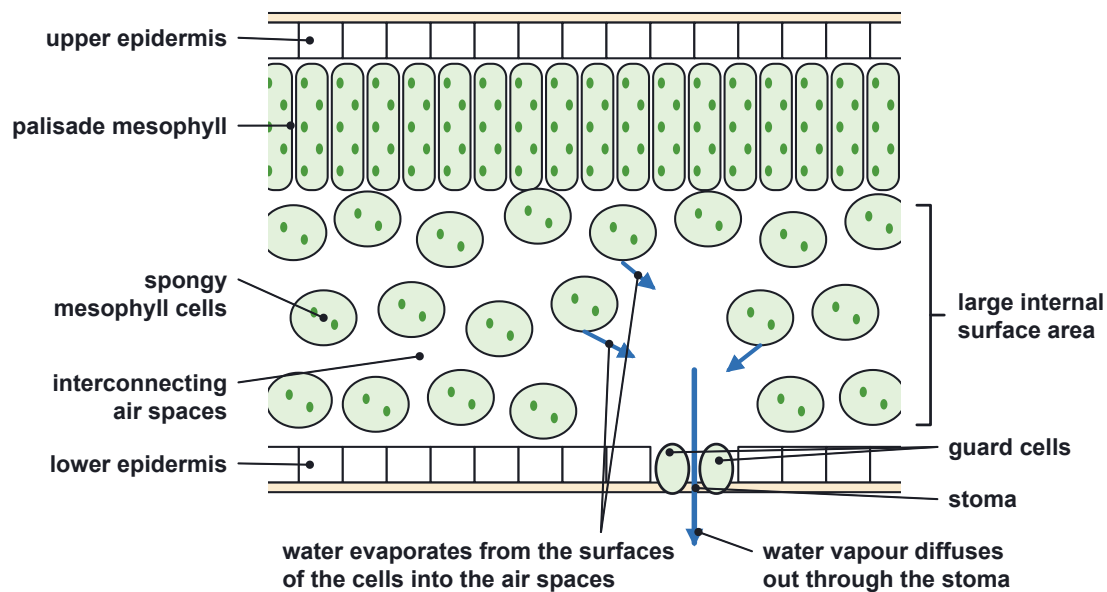
Water evaporates from the surfaces of the mesophyll cells into the air spaces inside the leaf. The water vapour then diffuses out of the leaf through the stomata, down a concentration gradient, into the drier air outside.

1. Water moves from the xylem into the mesophyll cells.
2. Water evaporates from the surfaces of the mesophyll cells into the air spaces.
3. Water vapour diffuses out of the leaf through the stomata.

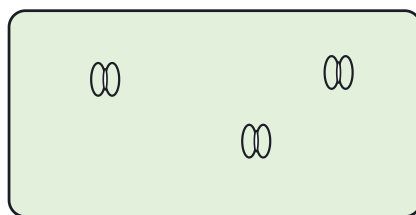


In the leaf, water evaporates from the mesophyll cells and the vapour diffuses out through the stomata.

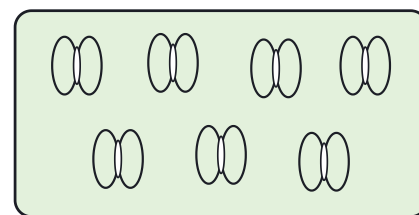
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leaf surfaces seen from below



few, small stomata
less water vapour lost



many, large stomata
more water vapour lost

The air spaces give a **large internal surface area**. More stomata, or larger stomata, means **more water vapour lost**.

Supplement

Why leaves lose water so quickly

Supplement

Two features of a leaf mean that a lot of water vapour can be lost.

Supplement

- The mesophyll cells are surrounded by interconnecting air spaces. These give a **large internal surface area** from which water can evaporate.
- The **size and number of stomata** affect how much water vapour can diffuse out. More stomata, or larger stomata, means more water vapour is lost.

Exam tip: Use the correct words: water **evaporates** from the mesophyll cells and water vapour **diffuses** out through the stomata. Do not say that water 'escapes' or 'leaks'.

Factors affecting the rate of transpiration Spec 8.3.3, 8.3.6

The rate of transpiration changes with the conditions around the plant. You must be able to describe the effects of **temperature** and **wind speed**.

Effect of environmental factors on the rate of transpiration

Factor	Effect on rate
Temperature	higher temperature gives a faster rate
Wind speed	higher wind speed gives a faster rate

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Explaining the effects of temperature, wind speed and humidity

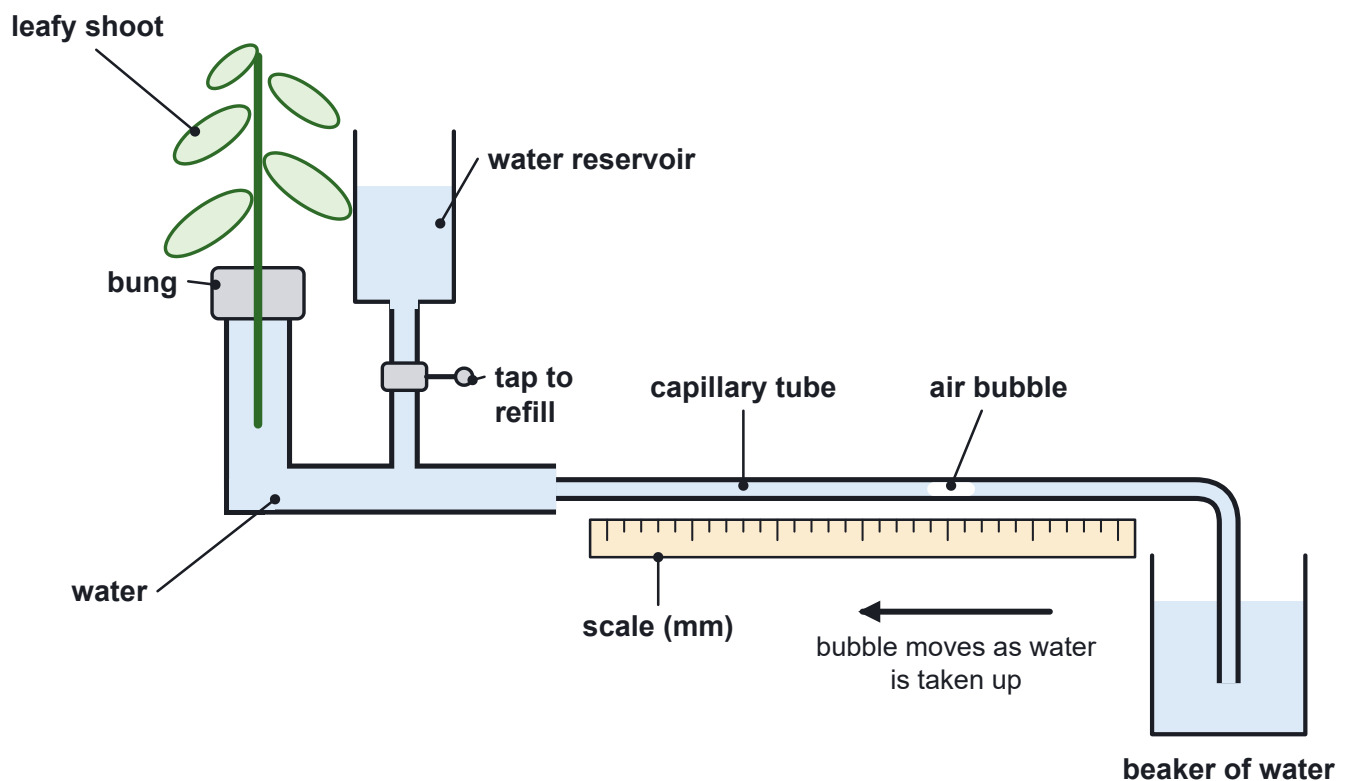
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- **Temperature:** a higher temperature gives water molecules more energy, so they evaporate from the mesophyll cells faster. Water vapour also diffuses faster.
- **Wind speed:** wind blows water vapour away from around the stomata. This keeps the **concentration gradient** between the air spaces and the outside air steep, so diffusion is faster.
- **Humidity:** higher humidity gives a slower rate. Humid air already contains a lot of water vapour, so the concentration gradient between the air spaces and the air outside is less steep and diffusion out of the leaf is slower. In dry air the gradient is steeper and transpiration is faster.

Measuring the rate: the potometer

A **potometer** measures how much water a cut shoot takes up. Most of the water taken up is lost by transpiration, so water uptake is used as an estimate of the rate of transpiration. As the shoot takes up water, an air bubble in the capillary tube moves along a scale.

1. Cut a leafy shoot under water and fit it into the potometer, keeping the apparatus full of water with no air bubbles.
2. Introduce an air bubble into the capillary tube and note its starting position.
3. Change one factor, for example place a fan at different distances to vary wind speed, or use rooms or water baths at different temperatures.
4. Measure the distance moved by the bubble in a set time.
5. Repeat and calculate a mean. Keep everything else the same.



As the shoot takes up water, the **air bubble** moves along the scale.

rate of water uptake = distance moved by bubble ÷ time

Calculating a rate

In a potometer, the air bubble moved 45 mm in 15 minutes. Calculate the rate of water uptake in mm / min.

1. rate = distance ÷ time
2. rate = $45 \div 15$

Answer: 3 mm / min

Practical skill: Name the independent variable (for example wind speed), the dependent variable (distance moved by the bubble in a set time) and at least two controlled variables (such as the same shoot, temperature and light). Repeat the experiment for reliability.

Transpiration pull and wilting Spec 8.3.5, 8.3.7 Supplement

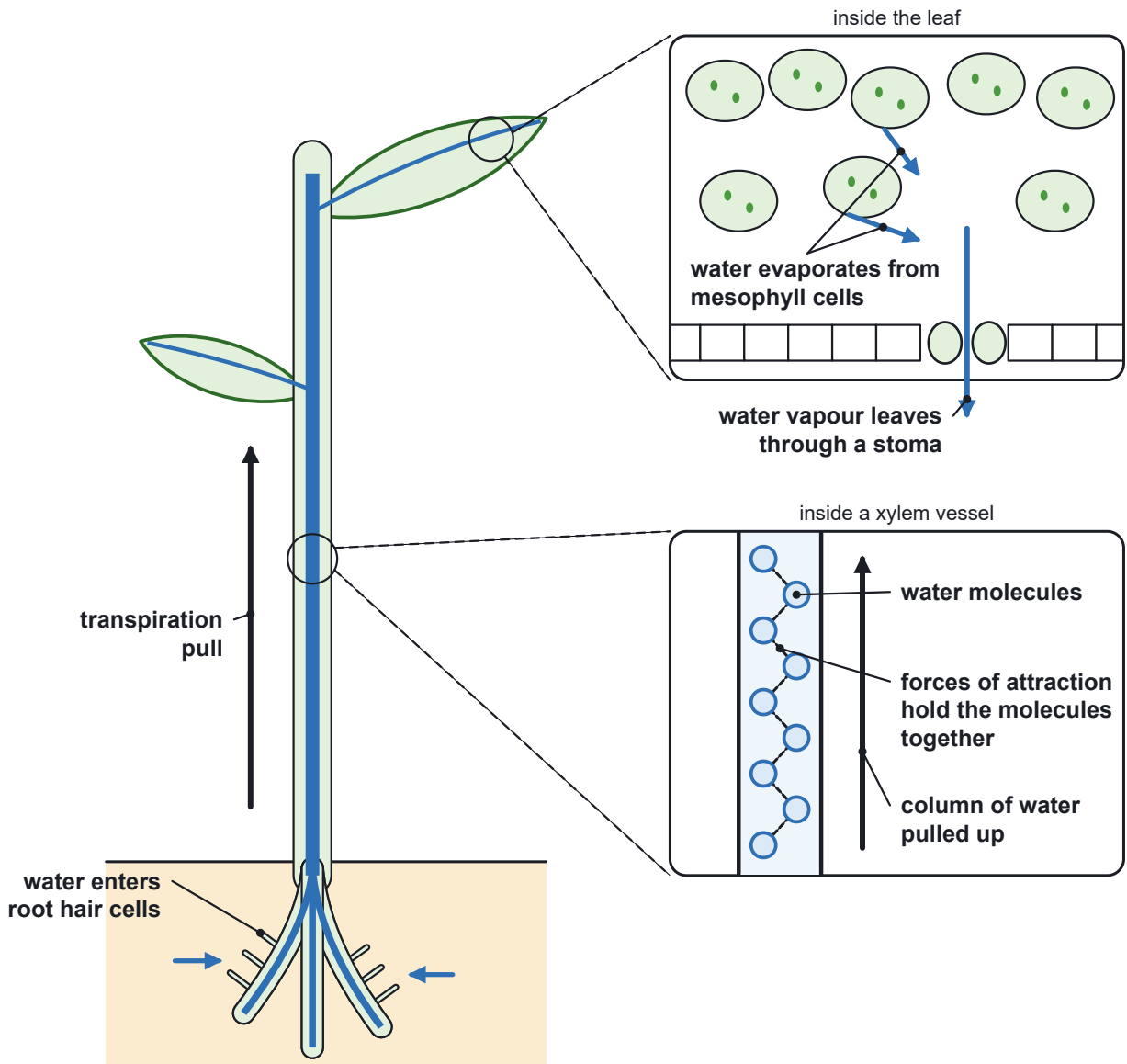
How water moves up the xylem

Water is lost from the mesophyll cells by evaporation. This pulls more water out of the xylem to replace it. This pull is called the **transpiration pull**.

The pull is passed down the xylem because water molecules are **attracted to each other**. These forces of attraction hold the water molecules together as a continuous **column of water**, so the whole column is drawn up the xylem, from the roots to the leaves.

1. Water evaporates from the surface of the mesophyll cells and diffuses out through the stomata.
2. Water is drawn out of the xylem to replace it. This is the transpiration pull.
3. The water molecules are held together by forces of attraction, so the column of water is pulled up the xylem.

4. More water enters the root to replace it.



Evaporation from the leaves causes the **transpiration pull**. Forces of attraction between water molecules hold the column together.

Wilting

Wilting happens when a plant loses water by transpiration faster than it can take water up from the soil. Water leaves the cells by osmosis, so the cells lose their **turgor** (they become flaccid). The cells no longer press against each other, so the leaves and stems are not supported and droop.

- Wilting is more likely in hot, dry or windy conditions, because transpiration is fast.
- Wilting also happens when the soil is dry, because there is little water to take up.
- When water uptake is greater than water loss again, the cells take in water, become turgid and the plant recovers.

Exam tip: Explain wilting in terms of cells: water loss means the cells lose turgor (become flaccid), so the plant loses its support and droops.

Quick check

1. Define transpiration.
2. Name two factors that increase the rate of transpiration when they increase.
3. **Supplement** How does higher humidity affect the rate?
4. **Supplement** What holds the water column together in the xylem?

4

Translocation

Spec 8.4

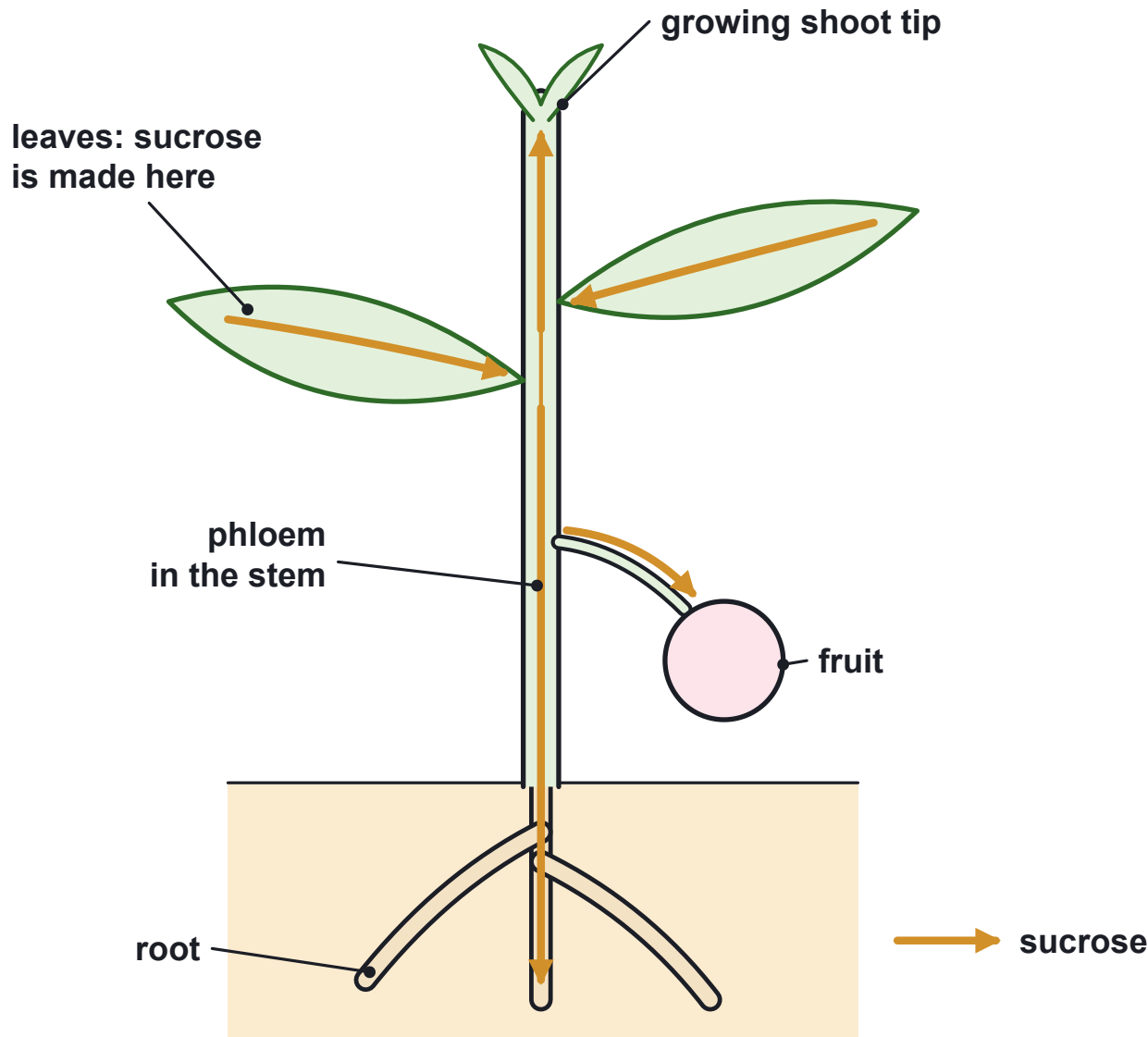
Supplement

Translocation, sources and sinks

Spec 8.4.1, 8.4.2, 8.4.3

Translocation is the movement of sucrose and amino acids in the phloem from **sources** to **sinks**.

Source	a part of the plant that releases sucrose or amino acids
Sink	a part of the plant that uses or stores sucrose or amino acids



Sucrose moves in the phloem from the source (the leaves) to the sinks, up and down the plant.

Examples of sources and sinks

Part of the plant	Source or sink	Why
Mature green leaf (in the light)	source	releases sucrose made in photosynthesis
Growing shoot tip or root tip	sink	uses sucrose for growth
Developing fruit or seed	sink	stores or uses sucrose
Storage organ such as a potato tuber, while the plant is photosynthesising	sink	stores the sucrose it receives (as starch)

Some parts are both

A part of a plant can be a source at one time and a sink at another. A potato tuber receives sucrose while the plant is growing and photosynthesising, and stores it as starch, so it is a **sink**. When the tuber starts to grow new shoots, the starch is broken down and sucrose is released and moved to the growing shoots, so the same organ becomes a **source**.

A young leaf is a sink because it uses sucrose to grow. Once it is fully grown, it makes more sucrose than it uses, so it becomes a source.

Exam tip: Use 'releases' for a source and 'uses or stores' for a sink. Always say which direction sucrose moves: from source to sink.

Quick check

1. **Supplement** Define translocation.
2. **Supplement** What is a sink?
3. **Supplement** Give an example of a source.
4. **Supplement** Why can a tuber be both?

Quick check answers

Xylem and phloem

1. Sucrose and amino acids.
2. Transport of water and mineral ions, and support.
3. Phloem.
4. The cells are joined end to end to make a long continuous tube.

Water uptake

1. Water and mineral ions.
2. It gives the cell a large surface area.
3. Root hair cells, root cortex cells, xylem, mesophyll cells.
4. In the xylem.

Transpiration

1. The loss of water vapour from leaves.
2. Temperature and wind speed.
3. It slows transpiration, because the concentration gradient is less steep.
4. Forces of attraction between water molecules.

Translocation

1. The movement of sucrose and amino acids in the phloem from sources to sinks.
2. A part of the plant that uses or stores sucrose or amino acids.
3. A fully grown green leaf.
4. It stores sucrose (as starch) as a sink, then releases sucrose as a source when new shoots grow.