IGCSE BIOLOGY 0610 · CHAPTER 7 NOTES · ~11 MIN READ

Transport in plants

Xylem versus phloem, how a root hair cell takes in water, the transpiration stream, what speeds it up, potometer calculations, wilting and sources and sinks — every diagram you need.

Xylem & phloem | Water uptake | Transpiration | Factors | Translocation

AS
by Aiza Ma'am
mentorriyaz.in

No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

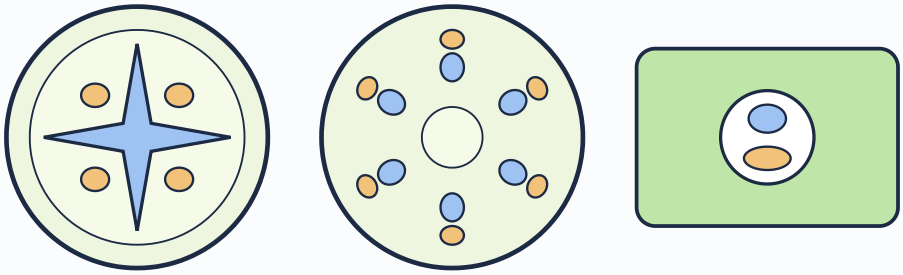
- **Xylem** carries **water and mineral ions** up from the roots and helps to support the plant. **Phloem** carries **sucrose and amino acids** (translocation) from **sources** to **sinks**.
- Water path: soil → **root hair cell** → **root cortex** → **xylem** → **mesophyll cells** → evaporates → vapour leaves through **stomata**. Losing water vapour like this is **transpiration**.
- Transpiration is faster when it is **hot, windy, dry (low humidity) or bright**. If water is lost faster than it is taken up, the plant **wilts**.

BY THE END YOU CAN

- State the functions of xylem and phloem and find them in a root, stem and leaf.
- Describe a root hair cell and say how its shape helps it absorb water and ions.
- Describe the path taken by water through a plant and how to show it with a stain.
- Define transpiration and describe how temperature, wind speed, light and humidity affect it.
- Describe how a potometer is used and calculate a rate of water uptake.
- Explain transpiration pull and wilting. EXT
- Define translocation, source and sink. EXT

1 Xylem and phloem

Two transport tissues



ROOT
xylem in the centre (star-shaped), phloem between the arms

STEM
bundles in a ring: xylem on the inside, phloem outside

LEAF VEIN
xylem on the upper side, phloem on the lower side

xylem phloem

Where the two tissues sit in a root, a stem and a leaf (dicotyledonous plant).

	Xylem	Phloem
carries	**water and mineral ions**	**sucrose and amino acids**
direction	**upwards only**: roots → shoots and leaves	**up and down**: from sources to sinks
cells	**dead**, hollow, no cytoplasm	**living** sieve tubes with companion cells
extra job	**support**: lignin makes it strong	none

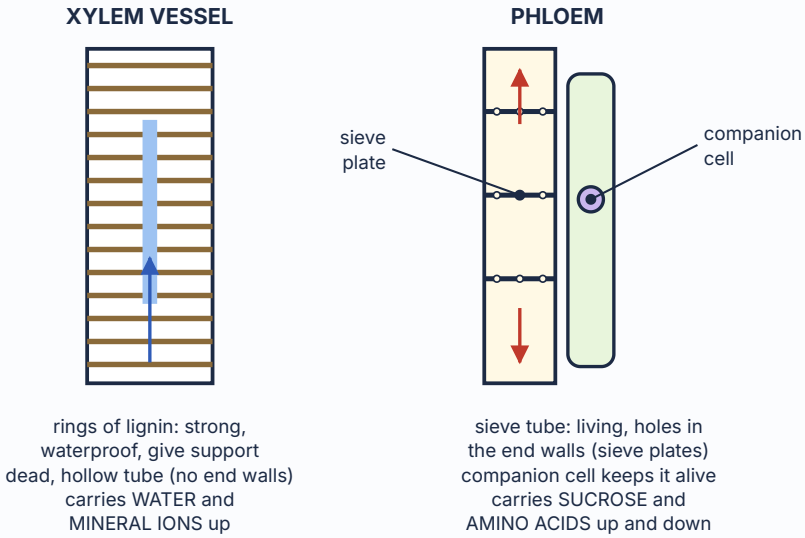
MEMORY TRICK

Xylem = **X**tra water going up. **P**hloem = **P**roducts of **P**hotosynthesis (sugar) going everywhere.

- In the **root**, xylem is in the **centre**, so the root can resist being pulled. In the **stem**, xylem and phloem are in **bundles** in a ring. In the **leaf**, the vein has xylem on the **upper** side and phloem on the **lower** side.

Built for the job

EXTENDED



EXT The structure of each tissue matches what it does.

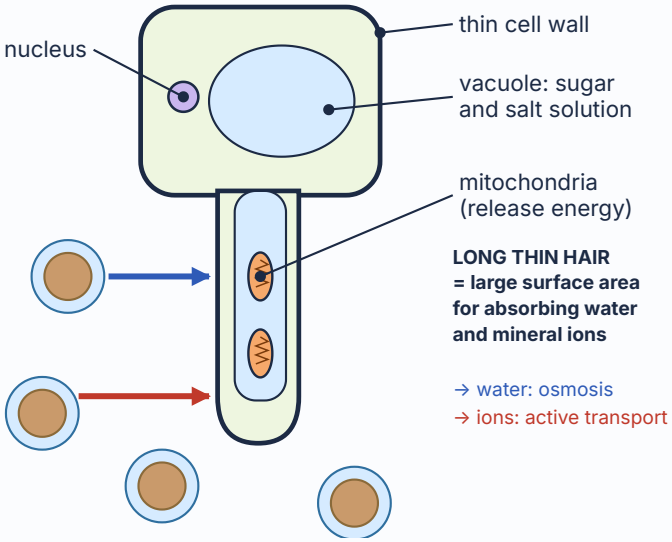
- EXT **Xylem vessels** are **long hollow tubes** with **no end walls** and **no cell contents**, so water flows freely. **Lignin** in the walls is **strong and waterproof**: it **supports** the plant and stops the tubes collapsing under suction.
- EXT **Phloem sieve tubes** have **holes (sieve plates)** in the end walls so sap can pass. Each is kept alive by a **companion cell** that makes the energy it needs.

COMMON MISTAKE

"Phloem carries food up and xylem carries it down." **Both are wrong.** Xylem carries **water** and only goes **up**. Phloem carries **sugar** and goes **both ways**.

2 Taking in water

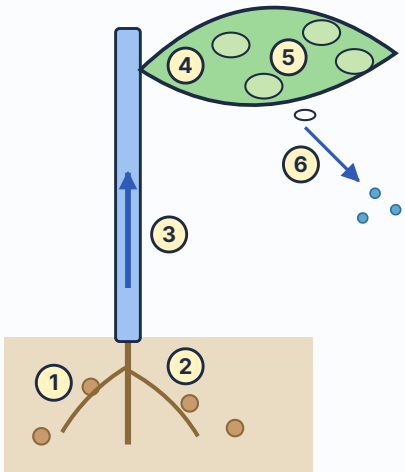
The root hair cell



A root hair cell: a long thin "hair" pushes between soil particles.

- **Root hair cells** are on the surface of roots. They **absorb water and mineral ions** from the soil.
- The hair gives a **large surface area**, and its **wall is very thin**, so water gets in quickly.
- **Water** enters by **osmosis**, because the cell sap (sugars and salts) is **more concentrated** than the soil water. The cell has a **lower water potential**, so water moves in.
- EXT **Mineral ions** such as nitrate are taken in by **active transport**, using energy from **mitochondria**, because the soil often has **fewer** ions than the cell.

The path of water



1. Root hair cells take in water by osmosis
2. Water crosses the cortex into the xylem
3. Transpiration pull draws it up the xylem
4. Water leaves the xylem and enters the mesophyll cells
5. Water evaporates from the surface of the mesophyll cells
6. Vapour diffuses out through the stomata

Follow the numbers from soil to air.

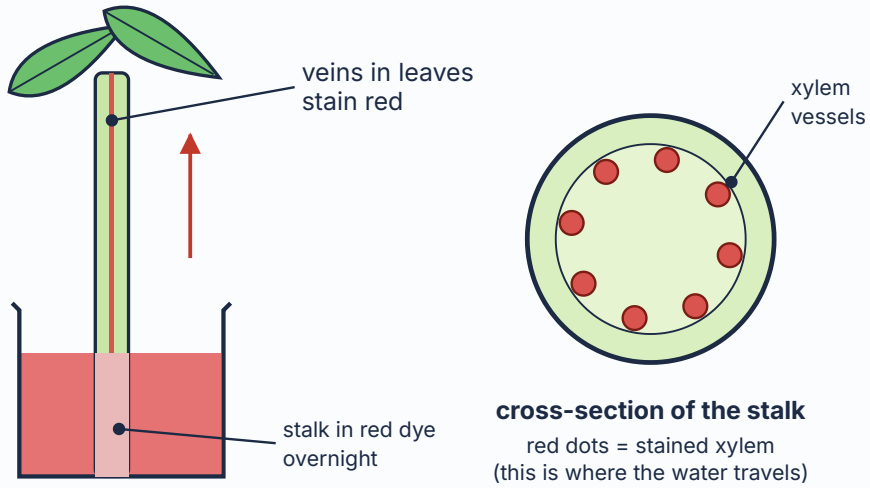
- **Root hair cell → root cortex cells → xylem → mesophyll cells in the leaf.**

MEMORY TRICK

Water's route in four words: **Hair → Cortex → Xylem → Mesophyll.**

- Water moves **across the cortex** from cell to cell by osmosis, then enters the **xylem** in the centre of the root.
- In the leaf, water **leaves the xylem**, moves into the **mesophyll cells**, and **evaporates** from their wet surfaces into the **air spaces**.

Show the path with a stain



Stand a stalk (or a white flower) in coloured water. The dye shows where the water travels.

- **Method:** stand a **celery stalk** (or a white carnation) in **water with red food dye** for several hours. **Cut across** the stalk, and also cut a thin **slice** lengthways. Look at it with a **hand lens** or microscope.
- **Result:** the **dye is only in the xylem**: red dots in a ring in the cross-section, red lines along the stalk and in the leaf veins.
- **Conclusion:** water moves **up the xylem**, not through the whole stem.

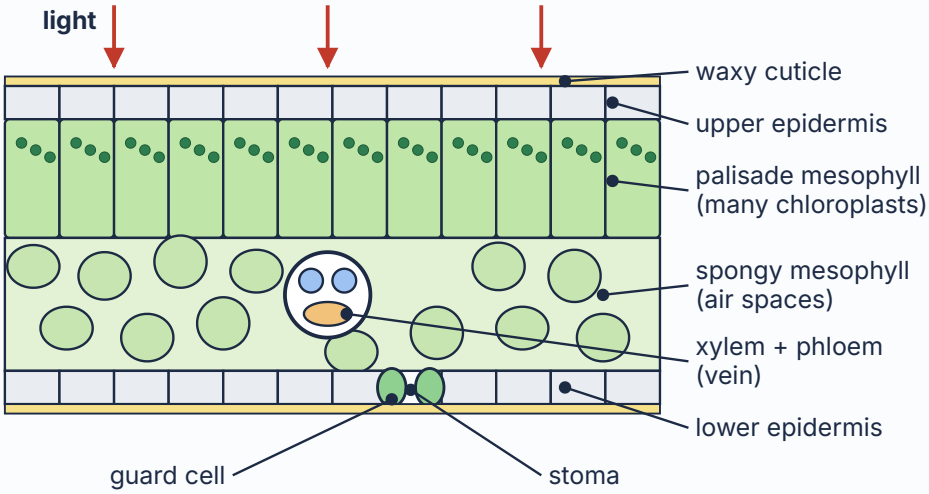
EXAM TIP

Use a **fresh** stalk and leave it in the **light and warmth**. More transpiration pulls the dye up faster, so the result shows sooner.

3 Transpiration

What is transpiration?

Transpiration — the **loss of water vapour** from plant leaves by **evaporation** of water at the surfaces of the **mesophyll cells**, followed by **diffusion** of the vapour through the **stomata**.

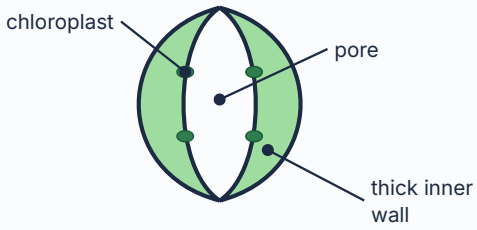


air spaces let CO_2 diffuse to the cells; stomata control gas exchange

Water evaporates from the wet surfaces of the mesophyll cells into the air spaces, then vapour diffuses out through the stomata.

- **Two steps:** (1) evaporation inside the leaf, (2) diffusion out of the stomata. Both words appear in the definition, so write both.
- **Why it matters:** the moving water **carries mineral ions** up to the leaves, **supplies water** for photosynthesis, keeps cells **turgid** and **cools** the leaf as water evaporates.
- EXT The **stomata** are surrounded by **guard cells** that open and close them. They are usually **open in the day** (so CO_2 can enter) and **closed at night**.

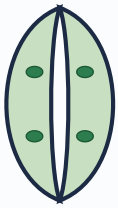
OPEN (daytime)



guard cells TURGID
(full of water)
bend apart: the pore opens

CO_2 diffuses in,
water vapour diffuses out

CLOSED (night / dry)



guard cells FLACCID
(lost water)
straighten: the pore closes

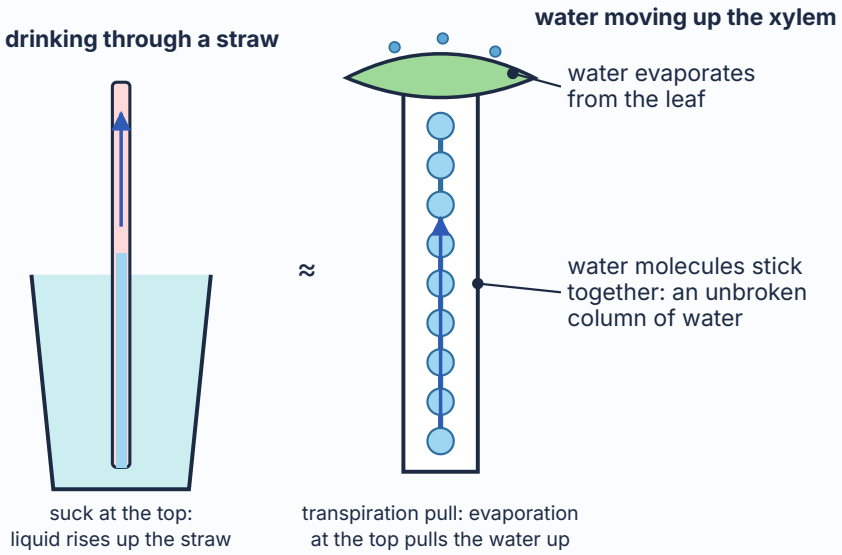
very little water vapour
escapes

Guard cells are the only epidermal cells with chloroplasts

EXT Turgid guard cells bend apart and open the stoma; flaccid guard cells straighten and close it.

Transpiration pull

EXTENDED



EXT Evaporation at the top acts like suction on a straw. The water column does not break because water molecules stick together.

- EXT Water **evaporating from the mesophyll cells** pulls more water out of the xylem. This **suction (transpiration pull)** draws water up from the roots as a **continuous unbroken column**, because **water molecules stick to each other (cohesion)**.
- EXT **The plant does not need energy to lift the water.** The energy comes from the **Sun**, which drives evaporation.

What speeds it up?

LIGHT ↑



stomata open wider so more water vapour escapes

rate of transpiration ↑

TEMPERATURE ↑



water evaporates faster and vapour diffuses out faster

rate of transpiration ↑

HUMIDITY ↓ (drier air)



drier air

steeper concentration gradient: vapour leaves the leaf faster

rate of transpiration ↑

WIND SPEED ↑



blows away the humid air next to the leaf, keeping the gradient steep

rate of transpiration ↑

Four conditions that increase the rate of transpiration.

Condition	Effect on rate	Why
higher temperature	**faster**	water evaporates faster and vapour diffuses faster
higher wind speed	**faster**	wind blows away the humid air at the leaf surface, so the **concentration gradient** stays steep
EXT **brighter light**	**faster**	guard cells open the stomata for photosynthesis, so more vapour escapes
EXT **lower humidity** (drier air)	**faster**	a **steeper concentration gradient** of water vapour between the air spaces and the air

- **Opposites** slow it down: cool, still, humid, dark.

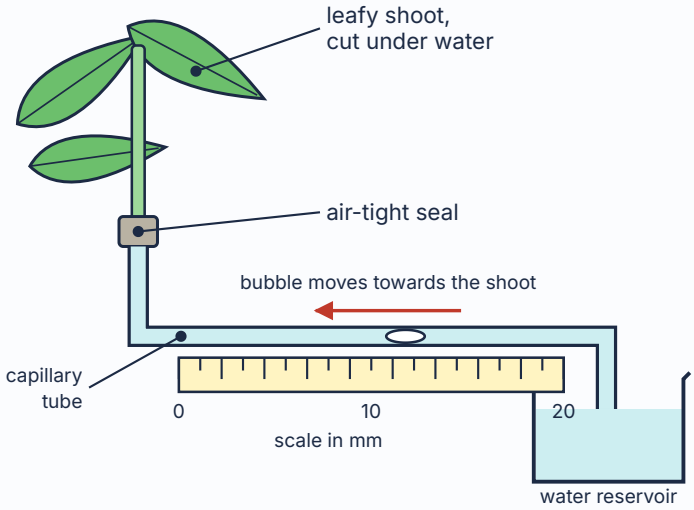
COMMON MISTAKE

"High humidity makes the plant take up more water." **Humid air reduces** the concentration gradient, so transpiration **slows**.

4 Measuring uptake

The potometer

rate of water uptake = distance moved by bubble ÷ time



A potometer measures how fast a cut shoot takes up water. The bubble moves as the shoot takes up water.

- **Set up:** cut the shoot **under water** (so no air enters the xylem), fit it **air-tight**, and fill the tube with water. Introduce **one air bubble** and start timing.
- **Measure:** the **distance** the bubble moves in a set time. **Rate = distance ÷ time.**
- **Test a factor:** change **one** thing (a fan for wind, a lamp for light, a water bath for temperature) and keep the rest the same. Repeat and find a **mean**.
- **Limitation:** it measures **water uptake**, not transpiration itself. Most of the water taken up is lost by transpiration, so it is a **good estimate**.

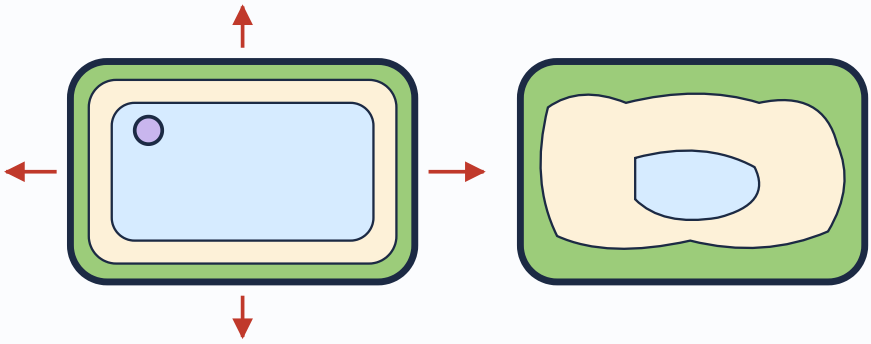
WORKED EXAMPLE

In a potometer the bubble moves 24 mm in 6 minutes in still air and 45 mm in 6 minutes with a fan on. Find each rate and the percentage increase.

1. still air: 24 ÷ 6 = **4.0 mm/min**
2. fan: 45 ÷ 6 = **7.5 mm/min**
3. increase = (7.5 − 4.0) ÷ 4.0 × 100 = **87.5%**
4. **the wind removed humid air around the leaf, keeping a steeper concentration gradient**

Too much water lost: wilting

EXTENDED



TURGID CELL
vacuole full of water, pushing on the cell wall

FLACCID CELL
little water: membrane pulls away from the wall

turgid cells hold leaves and stems up → flaccid cells = wilting

(red arrows = turgor pressure; wilting = water lost faster than roots can replace it)

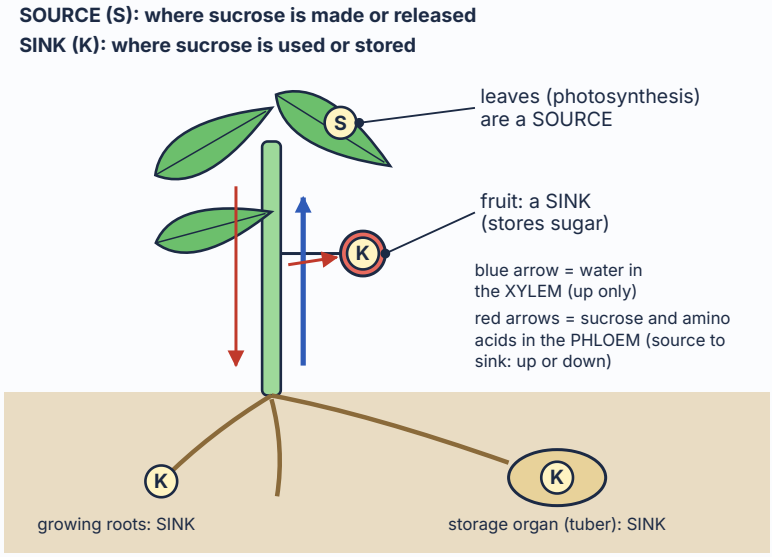
EXT A turgid cell is firm; a flaccid cell is limp. When many cells go flaccid the plant wilts.

- EXT If the plant loses water **faster than the roots can replace it**, the cells lose water, their vacuoles shrink and they become **flaccid**. The plant **wilts**.
- EXT Wilting has a **benefit**: leaves droop, less surface is in the Sun, and the **stomata close**, so less water is lost. Watering restores **turgor**.

Aiza Ma'am

5 Moving sugar around

Translocation



Sucrose and amino acids travel in the phloem from sources to sinks.

Translocation — 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, for example **leaves** (photosynthesis).

Sink — a part of the plant that **uses or stores** sucrose or amino acids, for example **roots, fruits, growing shoot tips and storage organs**.

- EXT A part can be a **source at one time and a sink at another.** A **potato tuber** is a **sink** in summer (it stores starch made from sucrose) but a **source** in spring (stored starch is changed back to sucrose to feed the new shoots).

EXAM TIP

Source → sink can be **up or down**. Translocation depends on **where sugar is needed**, not on gravity.

Aiza Ma'am

6 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. Name the tissue that carries water up a plant.
2. What do phloem tubes carry?
3. Which cells absorb water from the soil?
4. How does water get into a root hair cell?
5. Define transpiration.
6. Give two conditions that speed up transpiration.
7. Name the structure that measures water uptake of a shoot.
8. EXT What substance makes xylem walls strong and waterproof?
9. EXT Why does a plant wilt?
10. EXT Name a part of a plant that is a sink.

EXAM-STYLE

11. Describe how you would show that water travels in the xylem. [3]
12. Explain why transpiration is faster on a windy day. [3]
13. EXT Explain how the structure of a xylem vessel helps it carry water. [3]
14. EXT Explain why a potato tuber is a sink in summer and a source in spring. [3]

Aiza Ma'am

Show answers

1. xylem
2. sucrose and amino acids
3. root hair cells
4. by osmosis
5. loss of water vapour from leaves by evaporation at the mesophyll cell surfaces, then diffusion through the stomata
6. high temperature, wind (or low humidity, bright light)
7. potometer
8. lignin
9. it loses water faster than it takes it up, so cells lose turgor
10. roots, fruits, growing shoot tips or storage organs
11. stand a celery stalk or white flower in coloured water
    leave for some hours
    cut across and see the dye in the ring of xylem
12. wind blows away humid air around the leaf
    concentration gradient of water vapour stays steep
    so vapour diffuses out faster
13. hollow with no end walls and no cytoplasm, so water flows freely
    lignin makes the walls strong
    waterproof so water does not leak out
14. in summer it stores sucrose as starch
    in spring starch is changed to sucrose
    sucrose is sent to the growing shoots

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