

The need for transport and transport in plants

Revision notes · Why large organisms need transport systems, how xylem and phloem work, and how water is absorbed and lost by plants.

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. **Biology only** is not in the Double Award and is only examined on Paper 2.

The need for transport and transport in plants Spec 2.51-2.58B

Why multicellular organisms need transport systems Spec 2.51, 2.52

Every cell needs a supply of oxygen and dissolved food molecules, and must get rid of waste such as carbon dioxide. In a unicellular (single-celled) organism these substances move in and out by **diffusion** across the cell surface.

This works because a single cell has a **large surface area compared with its volume**. No part of the cell is far from the surface, so the diffusion distance is short and diffusion is fast enough to meet the cell's needs.

Multicellular organisms

A multicellular organism is much bigger. Its surface area : volume ratio is **small**, and most of its cells are deep inside the body, far from the outside world. Diffusion over such long distances is far too slow to supply every cell with enough oxygen and food, or to remove waste quickly enough.

Multicellular organisms therefore need a **transport system**. In humans this is the blood in the circulatory system. In flowering plants it is the xylem and phloem.

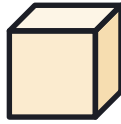
surface area : volume ratio = surface area ÷ volume

Surface area : volume ratio of a cube

A cube-shaped block of tissue has sides of 3 cm. Calculate its surface area : volume ratio.

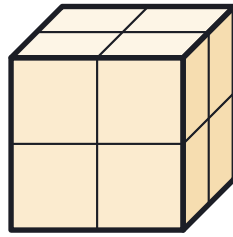
1. A cube has 6 faces. Area of one face = $3 \times 3 = 9 \text{ cm}^2$.
2. Surface area = $6 \times 9 = 54 \text{ cm}^2$.
3. Volume = $3 \times 3 \times 3 = 27 \text{ cm}^3$.
4. Ratio = 54 : 27. Divide both sides by 27.

Answer: 2 : 1



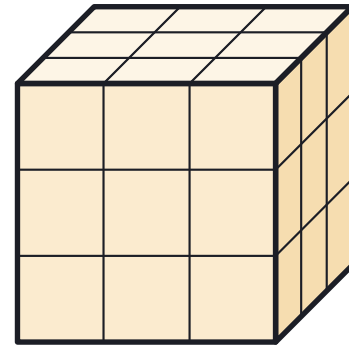
1 cm

surface area = 6 cm^2
 volume = 1 cm^3
 surface area : volume
 = 6 : 1



2 cm

surface area = 24 cm^2
 volume = 8 cm^3
 surface area : volume
 = 3 : 1



3 cm

surface area = 54 cm^2
 volume = 27 cm^3
 surface area : volume
 = 2 : 1

As the cube gets bigger, its surface area : volume ratio gets smaller.

Substances that a transport system carries

Substance	Direction	Reason
Oxygen	Into cells	Used in aerobic respiration to release energy
Carbon dioxide	Out of cells	Waste product of respiration
Digested food (glucose, amino acids)	Into cells	Source of energy and materials for growth and repair
Urea	Out of cells	Waste product made in the body, removed in urine

Exam tip: Do not just say that large organisms 'need more oxygen'. Link the idea: small surface area : volume ratio, so a long diffusion distance, so diffusion alone is too slow.

Xylem and phloem Spec 2.53, 2.54

Xylem and phloem are the two transport tissues in a flowering plant. They run together through the roots, stem and leaves.

Xylem

The xylem carries water and mineral ions from the roots to the other parts of the plant, such as the stem and leaves. It is made of dead cells joined end to end.

- The cells are dead with no cytoplasm, and the end walls between them have broken down. This makes a continuous hollow tube that water can flow through easily.
- The walls are strengthened with lignin. This is strong and waterproof, so it stops the tubes collapsing and helps to support the plant.

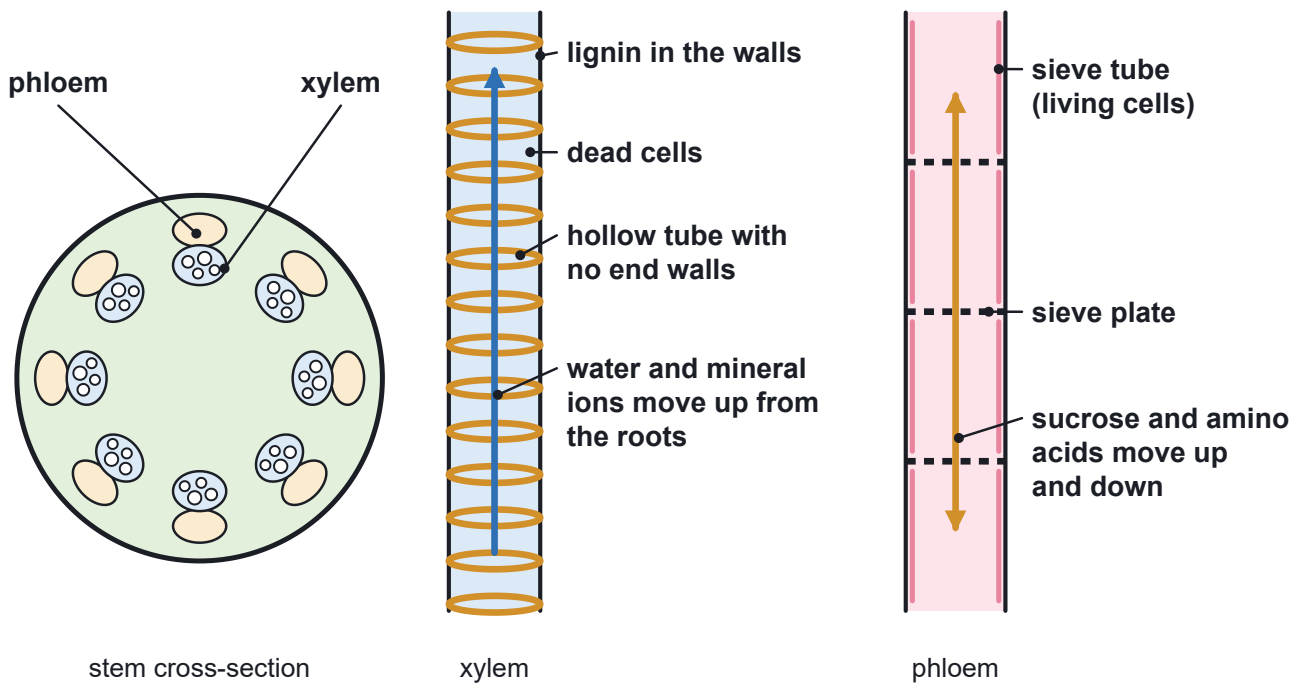
Phloem

The phloem carries sucrose and amino acids between the leaves and other parts of the plant. Sucrose is made from the glucose produced in photosynthesis. Phloem is made of living cells, and the substances can move up or down the plant, depending on where they are needed.

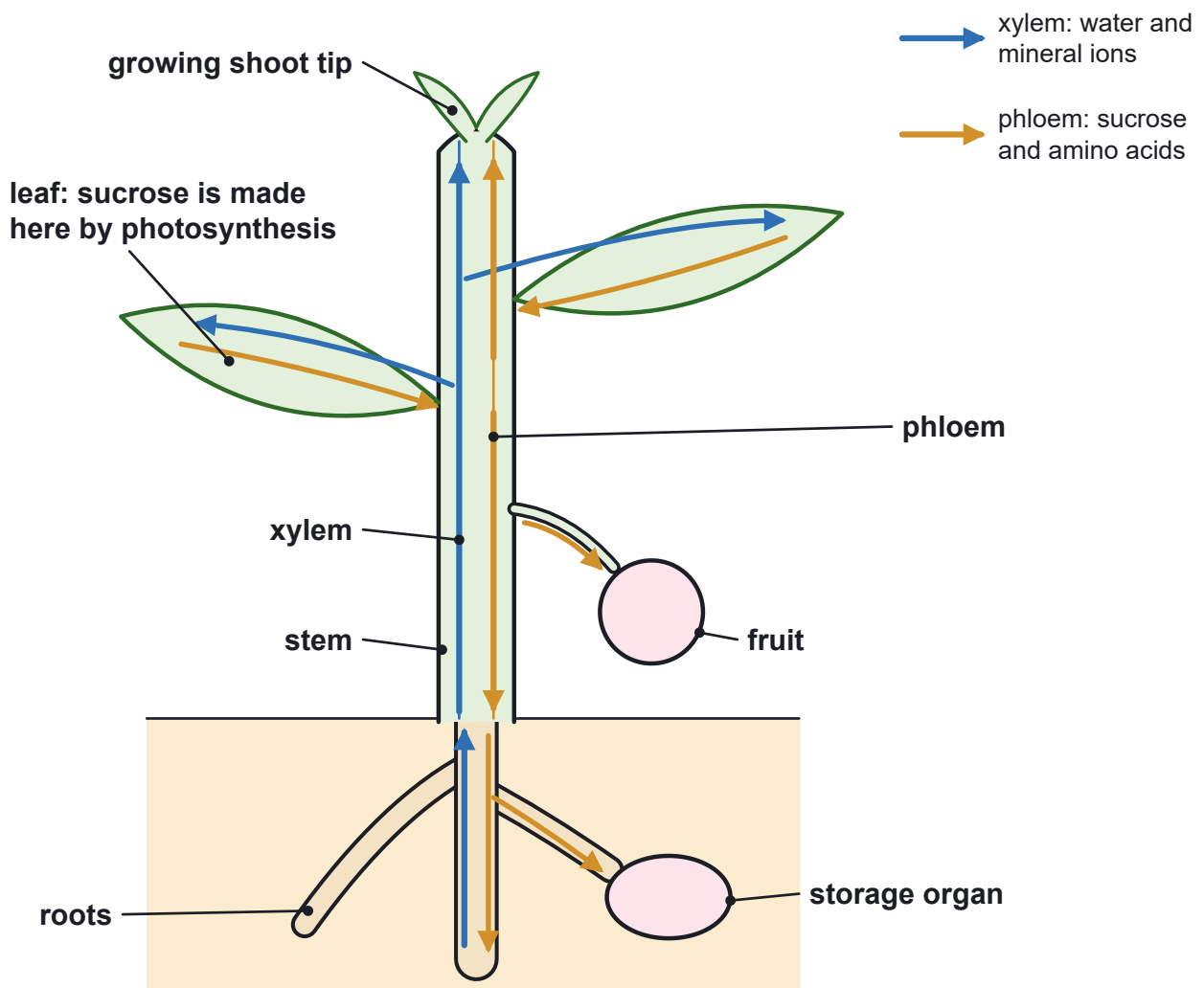
- Sucrose and amino acids travel from the leaves to growing tips, roots, flowers, fruits and storage organs.

- The phloem tubes (sieve tubes) are made of living cells joined end to end. Their end walls have small holes (sieve plates), so the solution can flow from one cell to the next.

Xylem and phloem compared		
	Xylem	Phloem
Substances carried	Water and mineral ions	Sucrose and amino acids
Direction	Roots to the rest of the plant (upwards)	Between the leaves and other parts, up or down
Cells	Dead, hollow tubes	Living cells
Cell walls	Strengthened with lignin	Sieve plates in end walls



Xylem: dead, hollow tubes strengthened with lignin. **Phloem:** living sieve tubes with sieve plates.



Xylem carries water and mineral ions **up** the plant. Phloem carries sucrose and amino acids **up or down** to where they are needed.

Common mistake: Do not mix the two up. Xylem = water and mineral ions, dead cells. Phloem = sucrose and amino acids, living cells.

Water uptake by root hair cells Spec 2.55B Biology only

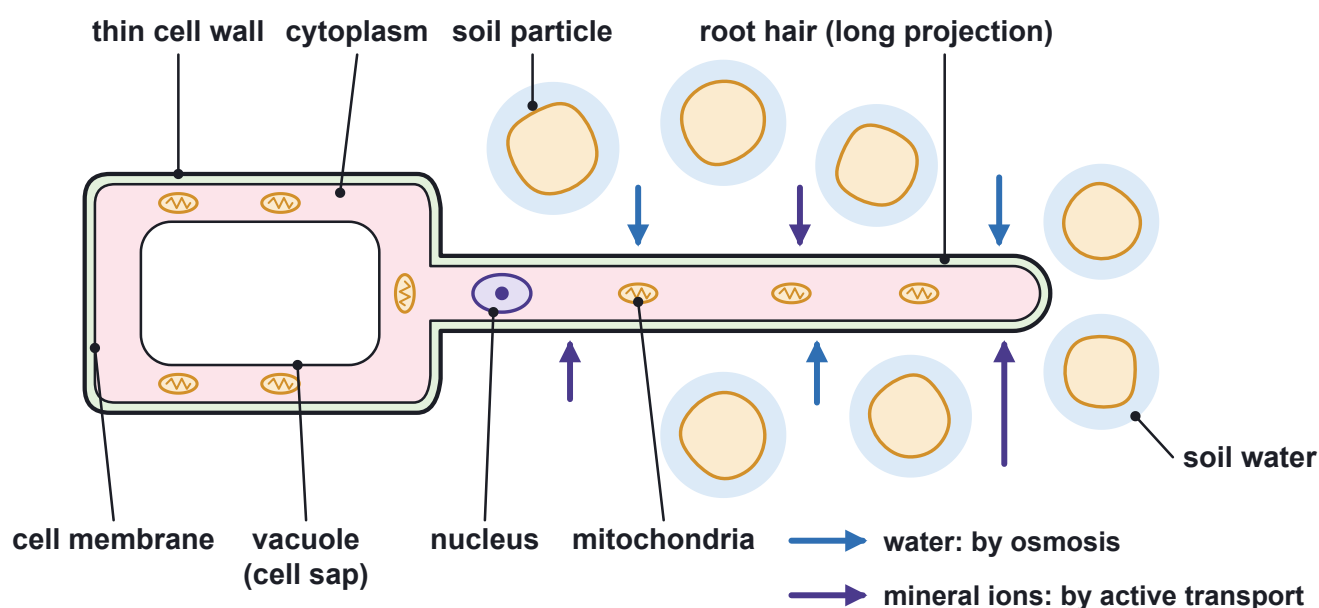
Root hair cells are found near the tips of roots. Each has a long, thin projection (the **root hair**) that reaches between the soil particles. They absorb water and mineral ions from the soil.

How water is absorbed

1. Soil water is a dilute solution, so it has a higher concentration of water molecules than the cell sap inside the root hair cell.
2. Water moves into the cell by **osmosis**: from the dilute solution outside to the more concentrated cell sap, through the partially permeable cell membrane.
3. The water then passes from cell to cell across the root into the xylem, which carries it up the plant.

Adaptations of a root hair cell	
Adaptation	How it helps
Long, thin projection (the root hair)	Large surface area, so more water can be absorbed
Thin cell wall and membrane	Short diffusion distance for water
Cell sap more concentrated than the soil water	Keeps a concentration gradient so water moves in by osmosis
Many mitochondria	Release energy for the active transport of mineral ions into the cell

Mineral ions, such as nitrate, are usually at a lower concentration in the soil than inside the cell. They are taken in by **active transport** against the concentration gradient, which needs energy from respiration.



A root hair cell: water enters by **osmosis**; mineral ions enter by **active transport** using energy from the mitochondria.

Exam tip: For an 'explain' question, link each adaptation to its function: 'the root hair gives a large surface area, so more water can be absorbed'.

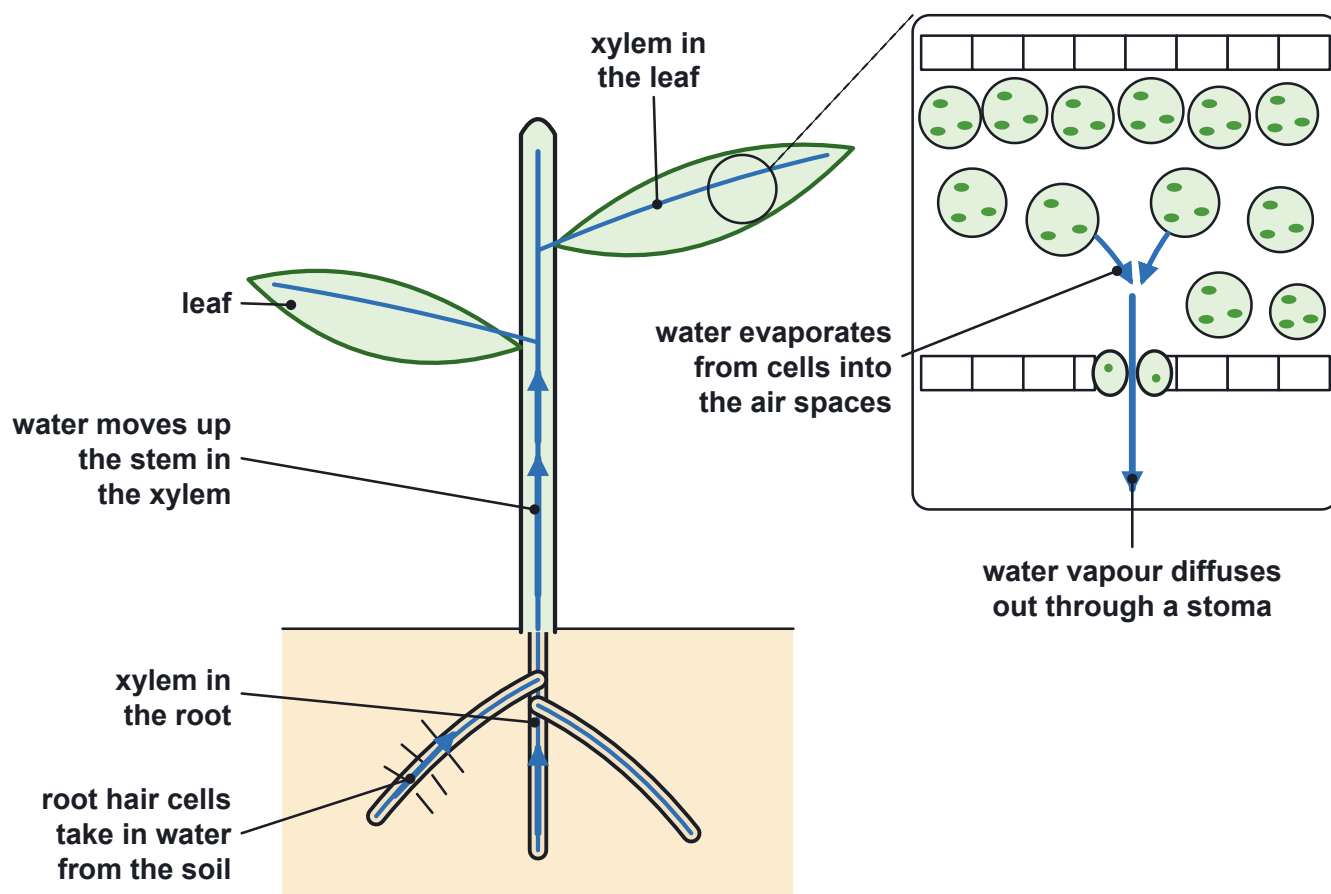
Transpiration Spec 2.56B Biology only

Transpiration The evaporation of water from the surface of a plant.

Most transpiration happens in the leaves. Water evaporates from the surface of the cells inside the leaf into the air spaces, then water vapour diffuses out through the **stomata** into the air.

1. Water is absorbed from the soil by the root hair cells.
2. Water moves up through the xylem to the leaves.
3. Water evaporates from the surface of the cells in the leaf into the air spaces.
4. Water vapour diffuses out of the leaf through the stomata.

As water leaves the leaf, more water is pulled up the xylem to replace it. This continuous flow is called the **transpiration stream**. It carries mineral ions from the roots to the leaves, and it supplies water for photosynthesis and keeps the cells firm.



The transpiration stream: water moves up the **xylem**, **evaporates** into the air spaces and **diffuses** out through the stomata.

Exam tip: Water is lost by evaporation and then diffusion. Do not say that water 'escapes' or 'leaks' from the leaf.

Factors affecting transpiration and the potometer Spec 2.57B, 2.58B Biology only

The rate of transpiration changes with the conditions around the leaves. You need to know the effect of **humidity**, **wind speed**, **temperature** and **light intensity**.

Factors affecting the rate of transpiration			
Factor	Change	Effect on rate	Reason
Temperature	Increase	Increases	Water evaporates faster and diffuses out of the leaf faster
Humidity	Increase	Decreases	The air already holds a lot of water vapour, so the concentration gradient is smaller and diffusion is slower
Wind speed	Increase	Increases	Moving air carries water vapour away from the stomata, keeping a steep concentration gradient
Light intensity	Increase	Increases	Stomata open wider in the light, so more water vapour can leave

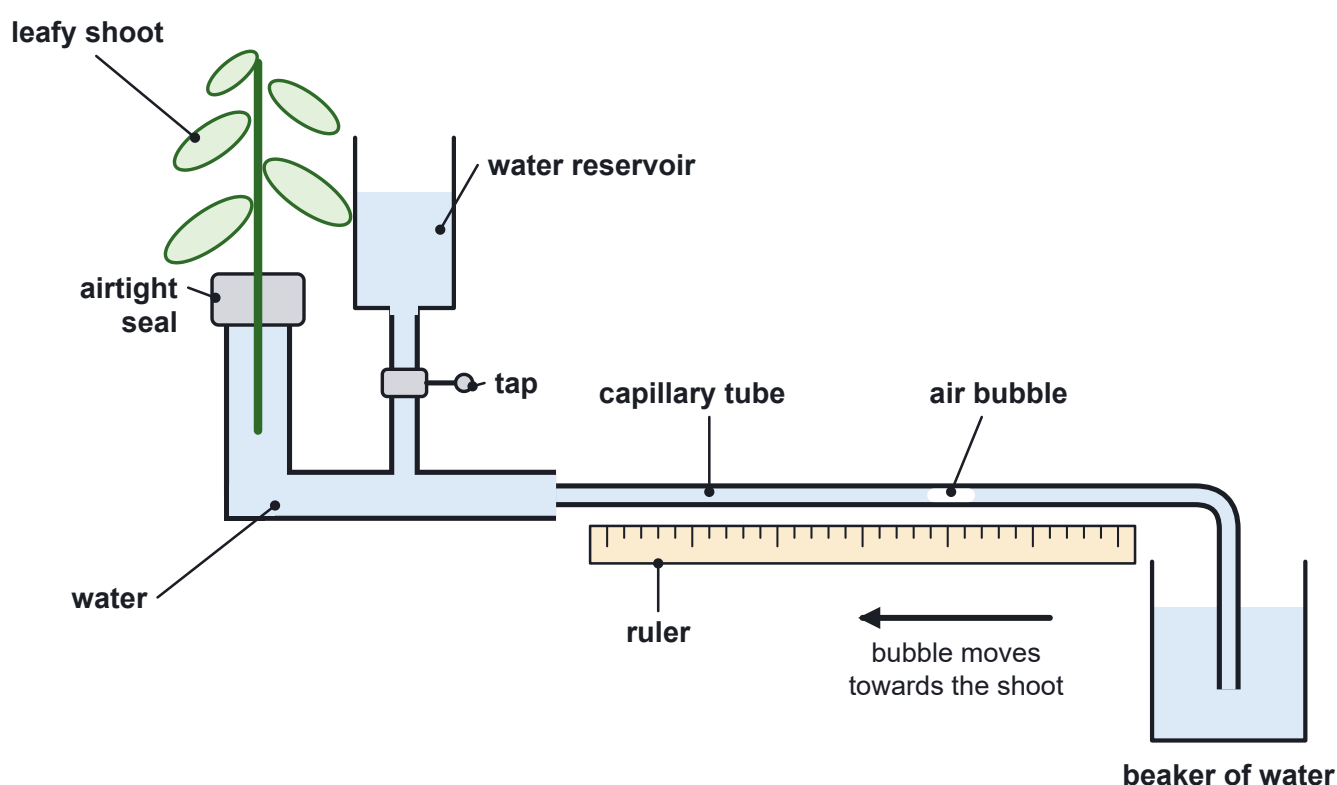
The opposite changes have the opposite effects. Low temperature, high humidity, still air and darkness all reduce the rate of transpiration.

Practical: investigating transpiration from a leafy shoot

A **potometer** measures how much water a cut shoot takes up. Almost all the water taken up is lost by transpiration, so uptake is used to measure the rate of transpiration.

1. Cut a leafy shoot under water, so no air enters the xylem, and fit it into the potometer under water.
2. Make sure the apparatus is full of water, with no air bubbles, and that the joints are airtight.
3. Dry the leaves, then introduce one air bubble into the capillary tube and record its starting position.
4. Measure the distance the bubble moves in a set time.
5. Change one factor (for example switch on a fan), keep the others the same and repeat. Calculate the mean of repeats.

Practical: Independent variable: one environmental factor, for example wind speed (fan distance), light (lamp distance), temperature or humidity (plastic bag over the shoot). Control the other factors, the same shoot size and the time. Safety: cut the shoot with care, and keep electrical equipment away from water. Expected results: the bubble moves further in a set time when it is warm, windy or bright, and less in humid air. You can also weigh the shoot and its container: the faster the mass falls, the higher the rate.



A potometer: the **distance the bubble moves** in a set time measures the rate of water uptake.

$$\text{rate of water uptake} = \text{distance moved by bubble} \div \text{time}$$

Rate of water uptake

An air bubble in a potometer moves 36 mm in 12 minutes. Calculate the rate of water uptake in mm per minute.

1. Rate = distance $\div$ time.
2. Rate = $36 \div 12$.

Answer: 3 mm/min

Volume of water taken up

The capillary tube has a cross-sectional area of 0.8 mm^2 . The bubble moves 40 mm in 10 minutes. Calculate the rate of water uptake in mm^3 per minute.

1. Volume = cross-sectional area $\times$ distance = $0.8 \times 40 = 32 \text{ mm}^3$.
2. Rate = volume $\div$ time = $32 \div 10$.

Answer: $3.2 \text{ mm}^3/\text{min}$

Maths skill: Give the unit with every rate. Repeat readings and find the mean to reduce the effect of random errors.

Quick check

1. Why can a unicellular organism rely on diffusion?
2. Which tissue carries water and mineral ions from the roots?
3. Which substances does phloem transport?
4. **Biology only** Define transpiration.
5. **Biology only** How does an increase in humidity affect the rate of transpiration?

Quick check answers

The need for transport and transport in plants

1. It has a large surface area compared with its volume, so diffusion distances are short.
2. Xylem.
3. Sucrose and amino acids.
4. The evaporation of water from the surface of a plant.
5. It decreases the rate, because the concentration gradient of water vapour is smaller.