Plant organ system

4.2.3.2 · Biology · revision notes

How the roots, stem and leaves work together as an organ system to transport water, mineral ions and sugars: root hair cells, xylem, phloem, transpiration, translocation, and the role of stomata and guard cells. Expect 'explain' questions on the factors that affect transpiration and calculations of transpiration rate from potometer data.

Key facts

- Roots + stem + leaves = the plant transport organ system
- Xylem: water and mineral ions, roots → leaves; hollow tubes strengthened by lignin
- Transpiration = loss of water vapour from the leaves
- Guard cells: turgid → stoma opens; flaccid → stoma closes
- Grade 7+ only Volume of water in a potometer tube = $\pi r^2 \times$ distance moved by the bubble
- Root hair cells: water by osmosis; mineral ions by active transport
- Phloem: dissolved sugars, leaves → rest of plant (translocation); pores in the end walls
- Faster transpiration: higher temperature, lower humidity, more air movement, higher light intensity
- Rate of transpiration = volume of water lost ÷ time

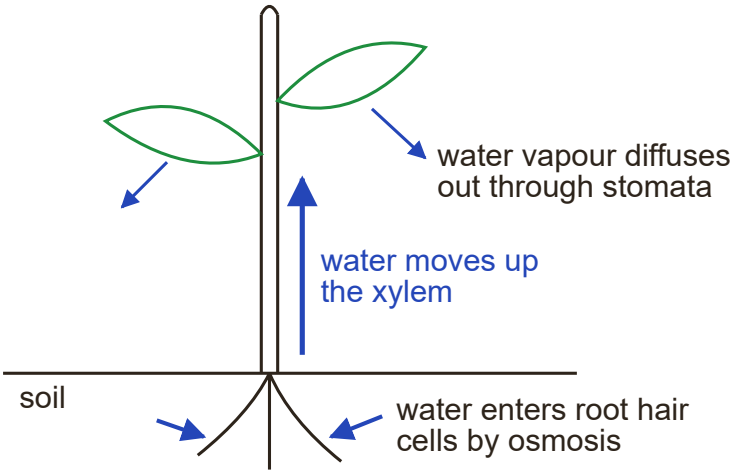
Notes

Roots, xylem and phloem

- The roots, stem and leaves form a plant **organ system** for transporting substances around the plant.
- **Root hair cells** have a long, thin extension that gives a large surface area. They absorb **water by osmosis** and **mineral ions by active transport**, which needs energy from respiration, so they have many mitochondria.
- **Xylem** transports water and mineral ions from the roots to the stems and leaves. It is made of hollow tubes of dead cells strengthened by **lignin**, suited to carrying water in the transpiration stream.
- **Phloem** transports dissolved sugars from the leaves to the rest of the plant, for immediate use or for storage. This is **translocation**. Phloem is made of tubes of elongated living cells, and cell sap moves from one cell to the next through pores in the end walls.

Transpiration

- **Transpiration** is the loss of water vapour from the leaves.
- Water evaporates from the surfaces of cells inside the leaf, and the water vapour diffuses out through the stomata. Water is drawn up the xylem to replace it. This flow is the **transpiration stream**.

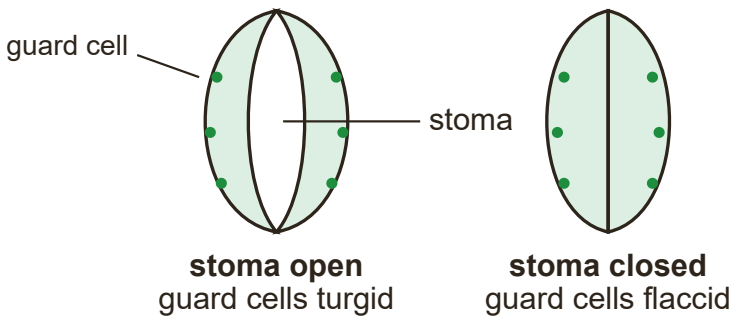


The transpiration stream. The arrows show the movement of water.

- **Temperature** up → faster: water molecules have more energy, so they evaporate and diffuse faster.
- **Humidity** up → slower: there is more water vapour in the air, so the concentration gradient is smaller.
- **Air movement** up → faster: water vapour is blown away from the leaf, keeping the concentration gradient steep.
- **Light intensity** up → faster: more stomata open to let in carbon dioxide for photosynthesis, so more water vapour escapes.

Stomata and guard cells

- Stomata and guard cells control **gas exchange** and **water loss**.
- When the plant has plenty of water, the guard cells take in water, become **turgid** and bend apart, opening the stoma. When the plant is short of water, they lose water, become **flaccid** and the stoma closes, reducing water loss. Grade 7+ only

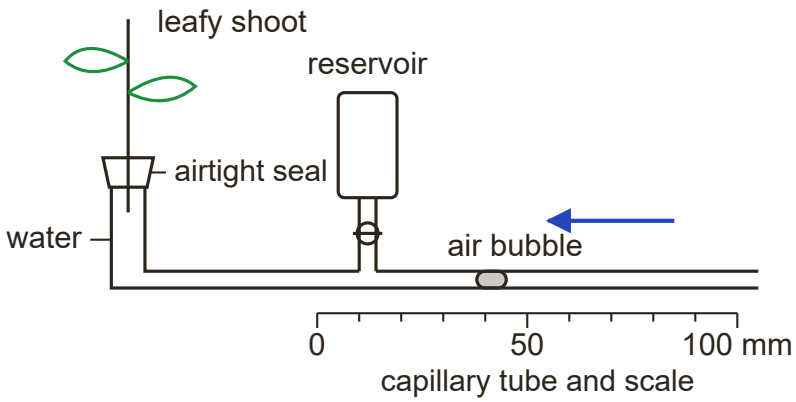


Guard cells control the size of the stoma.

- Stomata usually close in the dark, when no carbon dioxide is needed for photosynthesis, which saves water.

Practical work

- Rate of transpiration = volume of water lost ÷ time. A **potometer** measures water *uptake*, which is close to, but not exactly, the water lost.



A potometer. The distance the bubble moves in a set time shows the rate of water uptake.

- Cut the shoot and fit it into the potometer under water so no air gets in, and seal the joints so they are airtight. Record the distance the bubble moves in a set time.
- Change one factor, e.g. a fan for air movement or a lamp at different distances for light intensity, keep the others the same, and repeat to calculate a mean.
- Stomata distribution: paint clear nail varnish on a leaf surface, peel it off with clear tape, and count the stomata in several fields of view under a microscope. Calculate the mean.
- Most leaves have far more stomata on the lower surface, which is shaded and cooler, so less water is lost.

How to answer each type of question

Explain the effect of a factor on transpiration 2 to 3 marks **Grade 5**

1. Say whether the rate increases or decreases.
2. Explain with evaporation, diffusion and the concentration gradient of water vapour.
3. For light, link to more stomata opening for photosynthesis.

Example. Explain why a plant loses water more quickly on a windy day than on a still day.

Model answer. The wind blows water vapour away from the surface of the leaf (1). This keeps a steep concentration gradient of water vapour between the air spaces in the leaf and the air outside (1), so water vapour diffuses out through the stomata faster (1).

Calculate the rate of transpiration

2 to 4 marks | Grade 7

1. Distance rate = distance moved by the bubble ÷ time.
2. Volume = $\pi r^2 \times$ distance (use the radius, not the diameter, and square it).
3. Give the unit, e.g. mm per minute or mm^3 per minute.

Example. A student used a potometer. The air bubble moved 45 mm in 5 minutes. The capillary tube has a radius of 0.5 mm.
(a) Calculate the rate at which the bubble moved, in mm per minute.
(b) Calculate the volume of water taken up by the shoot in 5 minutes. Use: volume = $\pi r^2 \times$ distance. Give your answer to 3 significant figures.

Model answer.

(a) 45 ÷ 5 = 9 mm per minute (1)

(b) $\pi \times 0.5^2 \times 45$ (1) = 35.3 mm^3 (1)

Explain how root hair cells, xylem or phloem are adapted

2 to 4 marks | Grade 5

1. Give a feature of the cell or tissue.
2. Link it to its job: absorbing, transporting water or transporting sugars.

Example. Explain how root hair cells are adapted to absorb water and mineral ions from the soil.

Model answer. Root hair cells have a long, thin extension that gives a large surface area (1), so more water can be absorbed by osmosis (1). They have many mitochondria (1), which release energy from respiration for the active transport of mineral ions (1).

Explain how guard cells control water loss

3 marks | Grade 7

1. Say what happens to the guard cells (lose water, become flaccid).
2. Say what happens to the stomata (they close).
3. Say the effect: less water vapour is lost (but less carbon dioxide can get in, so photosynthesis slows).

Example. On a hot, dry day, a plant runs short of water and its stomata close.
Explain how the stomata close and how this helps the plant.

Model answer. The guard cells lose water and become flaccid (1), so the stomata close (1). Less water vapour diffuses out of the leaf, so less water is lost by transpiration (1).

Compare xylem and phloem

2 marks | Grade 5

1. Compare what each carries, and then how each is built.
2. Use 'whereas' so each point covers both tissues.

Example. Give **two** differences between xylem and phloem.

Model answer. Xylem transports water and mineral ions, whereas phloem transports dissolved sugars (1). Xylem is made of hollow tubes strengthened by lignin, whereas phloem is made of elongated cells with pores in the end walls (1).

Don't lose marks

- Saying water enters root hair cells by diffusion or active transport. Water moves in by osmosis; mineral ions move in by active transport.
- Saying phloem carries water, or xylem carries sugars.
- Saying transpiration is the loss of 'water' from the plant in general. It is the loss of water vapour from the leaves.
- Saying higher humidity increases transpiration. It decreases it, because the concentration gradient is smaller.
- Saying a potometer measures water loss. It measures water uptake, and some water taken up is used by the plant.
- Using the diameter instead of the radius, or forgetting to square it, in potometer volume calculations.

More tips

Memory tricks

- Transpiration is fastest in the conditions that dry washing on a line fastest: warm, dry, windy and sunny.
- Humidity is the odd one out: more humidity means slower transpiration.
- Turgid guard cells swell and bow apart, like two bent sausages, opening the stoma.
- Root hair cells: Water by Osmosis, Minerals by Active transport.
- Potometer check: as the shoot takes up water, the bubble moves towards the plant.

Exam technique

- For factor questions, state the effect (increase or decrease), then explain it using the concentration gradient or the stomata.
- In calculations, check the units (mm, mm^3, minutes, hours) and give the unit with your answer.
- Keep transpiration (water vapour, xylem) and translocation (sugars, phloem) separate: examiners do not accept them swapped.
- When describing a transpiration graph, quote values from it and say where the rate changes or levels off.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Name the parts of the plant transport system

The roots, stem and leaves form an organ system; xylem carries water and phloem carries sugars.

Grade 4

Define transpiration and translocation

Transpiration is the loss of water vapour from the leaves; translocation is the movement of dissolved sugars through the phloem.

Grade 5

Describe how root hair cells absorb substances

They take up water by osmosis and mineral ions by active transport, helped by their large surface area.

Grade 5

Compare the structure of xylem and phloem

Xylem is hollow tubes strengthened by lignin; phloem is tubes of elongated cells with pores in the end walls.

Grade 5

Explain factors affecting the rate of transpiration

Higher temperature, lower humidity, more air movement and higher light intensity all increase the rate.

Grade 5

Calculate the rate of transpiration

Rate = volume (or mass) of water lost or taken up ÷ time, e.g. from a potometer.

Grade 7

Explain how guard cells control water loss

Guard cells become turgid to open the stomata and flaccid to close them, balancing gas exchange against water loss.

Grade 7

Explain how water moves through the plant

Water evaporates from leaf cells and diffuses out through the stomata, and more water is drawn up the xylem to replace it.

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