TRANSPIRATION

Content Statements:

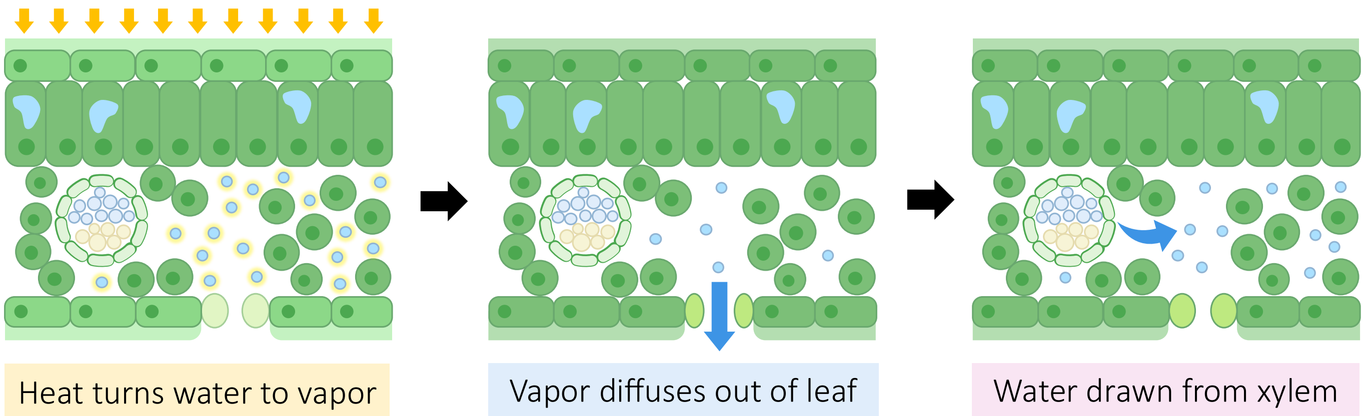
B3.1.9	Transpiration as a consequence of gas exchange in a leaf
B3.1.10	Stomatal density
B3.2.7	Transport of water from roots to leaves during transpiration
B3.2.8	Adaptations of xylem vessels for transport of water

TRANSPIRATION

Transpiration describes the loss of water vapour from the stems and leaves of a plant. The removal of water from leaves (via evaporation) and the uptake of water by the roots (via osmosis) will result in a **hydrostatic pressure gradient** that functions to draw water molecules against gravity up the xylem vessels (mass flow).

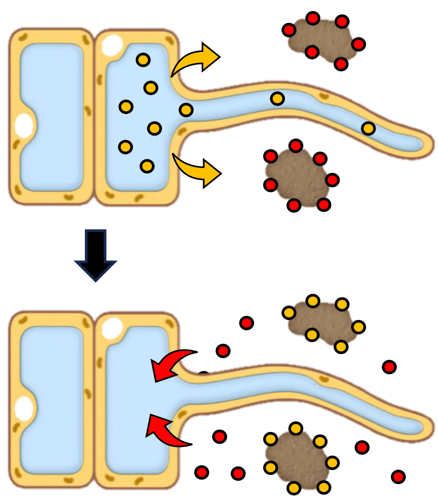
EVAPORATION

When light is absorbed by leaves (as part of photosynthesis), the energy may also convert water within the spongy mesophyll into vapour (**evaporation**). This vapour will then diffuse out of the leaf via the **stomata**, lowering the hydrostatic pressure in the tissue. This **negative pressure** potential generates tension, which causes more water to be drawn out of the xylem and through the cell walls by capillary action. **Guard cells** may occlude stomatal pores in order to regulate the loss of water vapour and hence control transpiration.



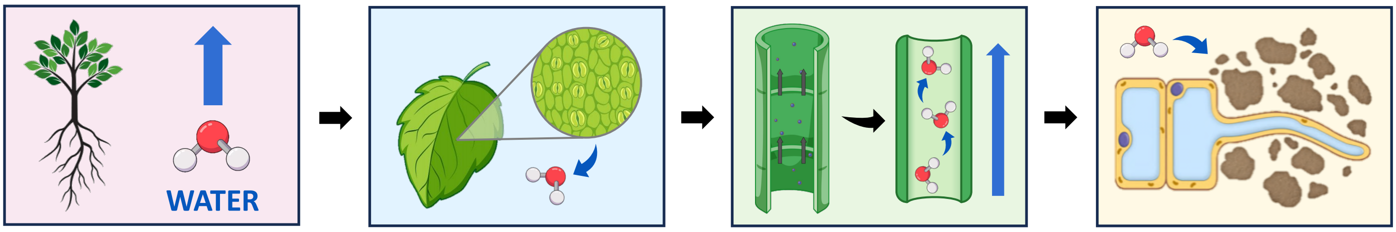
ROOT UPTAKE

Roots will absorb water from within the soil via **osmosis**. This is facilitated by the movement of **mineral ions** that are attached to negatively charged clay particles. Root cells will actively expel H^+ ions (**protons**) stored within the central vacuoles. These protons then displace the mineral ions on the clay particles, causing them to passively diffuse into the root cells (**indirect active transport**). This creates a hypertonic environment within the root cells that draws water via osmosis (moves to a high solute concentration). The root cells may possess **aquaporins** to optimise water uptake and have cellular protrusions (root hairs) to increase surface area.



MASS FLOW

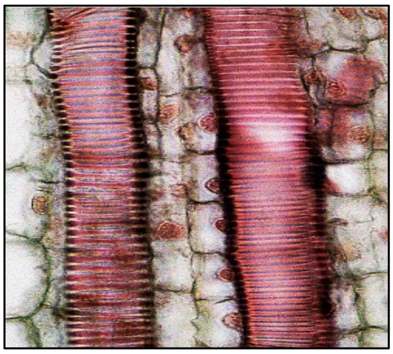
The difference in hydrostatic pressure between the roots and leaves creates a tension force that draws the water up the stem and against gravity. The polarity of water makes it **cohesive** (associates with other water molecules) and **adhesive** (can associate with the xylem wall). Consequently, water moves in a continuous, unidirectional column within the xylem – from the roots to the leaves. Over 95% of all water absorbed by roots is evaporated to enable transpiration, only a fraction is retained by the plant for use in cell functions.



Transpiration → **Leaves:** Evaporation → **Stem:** Mass Flow → **Roots:** Osmosis

XYLEM VESSELS

The xylem vessels possess several adaptations to support the transport of water. The xylem vessels are lined by a layer of **dead cells**, which are fused together to form a continuous hollow tubing that lacks protoplasm. This ensures the unimpeded movement of water in one direction only. The cell wall contains numerous **pores** that allow water to be transferred in and out of the xylem. The walls also have thickened cellulose and are reinforced by **lignin**, providing mechanical strength and rigidity. Xylems are composed of either **tracheids** (all vascular plants) or **vessel elements** (only certain vascular plants). Tracheids are tapered cells that exchange water via pores, while vessel elements have fused cells for faster transfer.



Xylem (light microscopy)

STOMATA

The amount of water lost from the leaves (transpiration rate) is regulated by the opening and closing of stomata. **Guard cells** flank the stomata and can occlude the opening by becoming increasingly flaccid in response to cellular signals. When a plant starts to wilt from water stress, dehydrated mesophyll cells release the plant hormone **abscisic acid** (ABA). This acts to trigger the efflux of potassium from guard cells, decreasing water pressure within the cells (they lose turgor). A loss of turgor makes the stomatal pore close, as the flaccid guard cells block the opening (lowering transpiration). Variations in stomatal density may exist in different types of plants due to genetic factors or exposure to climate conditions (e.g. humidity vs aridity).

Stomata and Guard Cells

TRANSPIRATION RATE

Transpiration is an inevitable consequence of gas exchange in a leaf, but the *rate* of transpiration can be influenced by a number of different abiotic conditions – including temperature, light, wind and humidity.

- **Temperature:** High temperatures will increase the vaporisation of water, leading to greater diffusion.
- **Sunlight:** Light stimulates the opening of stomata, as gas exchange is necessary for photosynthesis.
- **Wind:** The flow of air functions to remove the water vapour surrounding the leaf, increasing diffusion.
- **Humidity:** A higher concentration of water vapour in the air will decrease diffusion from the leaves.