PLANT TRANSPORT

Content Statements:

D2.3.8	Water potential as the potential energy of water per unit volume
D2.3.9	Movement of water from high to lower water potential
D2.3.10	Contributions of solute potential and pressure potential to water potential of cells with walls
D2.3.11	Water potential and water movements in plant tissue
B3.2.17	Generation of root pressure in xylem vessels by active transport of mineral ions
B3.2.18	Adaptations of phloem sieve tubes and companion cells for translocation of sap

WATER POTENTIAL

Water potential (ψw) is the **potential energy of water** per unit volume (it is measured in kilopascals / kPa). Water potential cannot be measured absolutely and is always stated relative to *pure water* at atmospheric pressure and a temperature of 20°C – the water potential under these baseline conditions is always 0 kPa.

Water potential is influenced by two main factors – solutes and pressure. The **solute potential** represents the effect of any dissolved solutes on the water potential of a solution (also called the *osmotic potential*). As solutes form polar associations with water, water has less potential energy for movement as the energy is being utilised to form hydrogen bonds. Solute potential is 0 kPa in pure water and negative in a solution. The **pressure potential** represents the effect of hydrostatic pressure on water potential (also called *turgor potential*). Higher pressures expose water to greater rates of collision, facilitating the transfer of potential energy to kinetic energy. Pressure potential is usually positive in plants and roughly 0 kPa in animal cells.

Water Potential (ψw)	=	Solute Potential (ψs)	+	Pressure Potential (ψp)	Solutes *lower* the ψw Pressure *raises* the ψw

WATER MOVEMENT

Water molecules move from an area of *higher water potential* to an area of *lower water potential*. This is because the water has more potential energy in regions of higher water potential and thus has a greater capacity for movement (kinetic energy). Plants cells will gain or lose water according to the relative water potentials of the internal and external environments – animal cells do not tend to experience significant water movement as they have less capacity to retain their structure (due to the absence of a rigid **cell wall**).

In **hypertonic solutions**, plant cells will lose water and *plasmolyse*. The external solution has a lower water potential (due to the solute potential being negative) which causes water to move out of the cell. This will cause the pressure potential within the cell to decrease as there are less water molecules exerting pressure on the cell membrane. This causes the cell membrane to retract from the cell wall until pressure equalises.

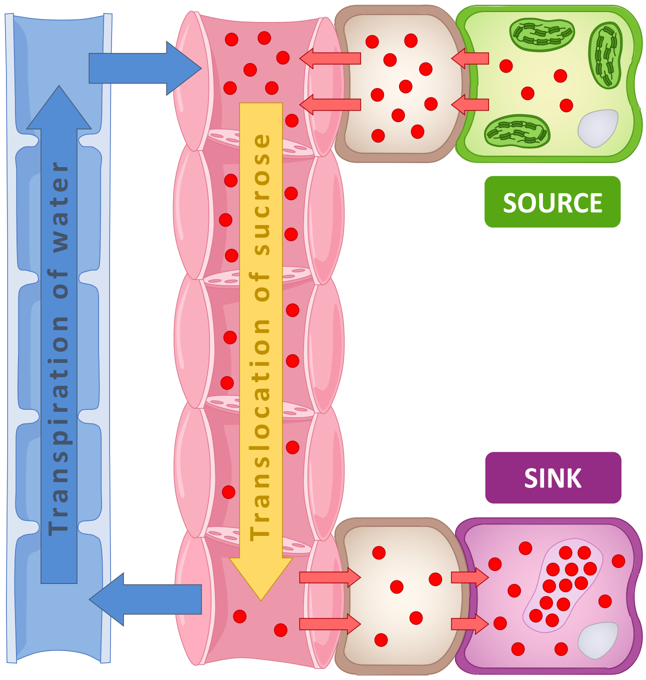
In **hypotonic solutions**, plant cells gain water and become *turgid*. The external solution has a higher water potential (due to having a lower solute concentration) which causes water to enter the cell. This will cause the pressure potential to increase as the increased cytoplasmic volume pushes the cell membrane against the cell wall. Eventually, the internal and external water potentials become equal and water uptake stops.

TRANSPIRATION

Plants can manipulate the water potential within tissues in order to facilitate movement of water between different parts of a plant. Transpiration typically involves the generation of a negative hydrostatic pressure in the leaves via the action of **evaporation**. This negative pressure creates tension within the **xylem vessels** to draw water up the stems via *capillary action*. However, evaporation is greatly reduced in humid climates and in winter (before leaf buds have opened on deciduous plants). Under these conditions, plants must rely on a positive pressure potential in the roots to generate *mass flow*. Plants control the uptake of water into roots by regulating the movement of mineral ions via **active transport**. As mineral ions move into the roots, water will follow via osmosis. The movement of water from the root tissue to the xylem vessels is mediated by **aquaporins**, allowing the plant to control the root pressure and regulate the overall rate of transpiration.

TRANSLOCATION

Translocation is the movement of organic compounds (such as sugars or amino acids) from sources to sinks. A **source** is where the organic compounds are formed (e.g. leaves). A **sink** is where organic compounds are delivered for further use (e.g. roots, fruits and seeds). Organic compounds are transported in the phloem as **sap**. Companion cells actively load compounds into a phloem at the source, which makes sap hypertonic. This causes water to be drawn from xylem (osmosis). The influx of water creates **hydrostatic pressure** that forces the phloem to move to areas of low pressure. At the sink, solutes within the phloem are unloaded by companion cells. This makes a sap solution more hypotonic, causing the water to leave a phloem and return to a xylem, lowering pressure in the phloem.



PHLOEM STRUCTURE

Phloem sieve tubes are primarily composed of two types of cells – sieve element cells and companion cells. The sieve element cells collectively form the sieve tubes, while companion cells provide metabolic support.

Sieve element cells are connected by porous **sieve plates** at their transverse ends, to enable the rapid flow of solutes between cells. Sieve elements have **no nuclei** and **reduced cytoplasm** to maximise the space for translocation. They also have thick and **rigid cell walls** to withstand the high levels of hydrostatic pressure.

Companion cells facilitate the loading and unloading of solutes at sources and sinks. They possess a dense cytoplasm with **many mitochondria** (to fuel active transport) and are connected to the sieve element cells via **plasmodesmata** (microscopic channels in cell walls enabling the continuous movement of cytoplasm).

Phloem Features:

- Transports organic compounds
- Composed of living cells
- End walls flank cells (porous)
- Movement is bi-directional

Xylem Features:

- Moves water and mineral ions
- Composed of dead cells (fused)
- No end walls between cells
- Movement is uni-directional