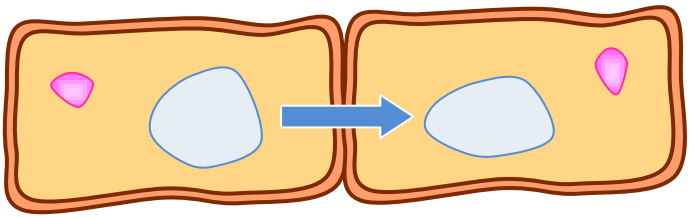
2.12 Water Uptake and Movement Up the Stem

Water movement between plant cells and the uptake of water from the roots to the leaves

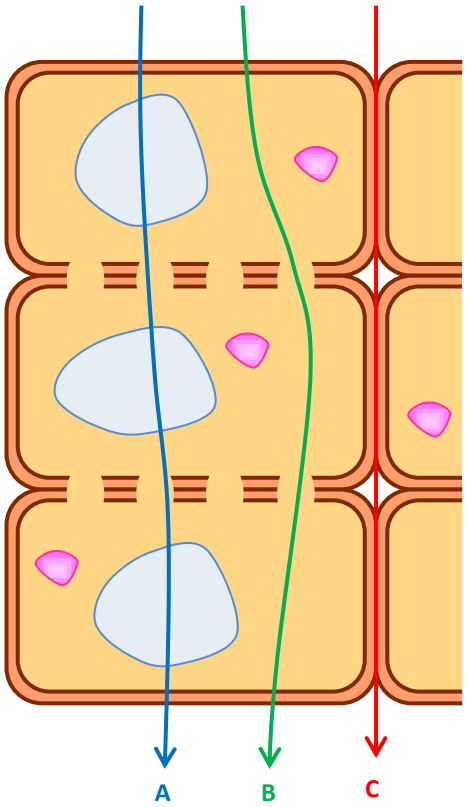
Water Movement Between Cells

Water molecules can move between adjacent cells. A water molecule moves from a cell with a higher **water potential** (less negative) to one with a lower water potential (more negative). For example:



Ψ = -600 kPa **Ψ = -1100 kPa**

There are three possible ways in which water molecules can travel between cells:



The **vacuolar pathway** (**A**) is one route water can take. Here, the water molecules enter the cytoplasm through the plasma membrane, and travel across the cytoplasm, and through the vacuole, back through some cytoplasm, onto the next vacuole, etc
[cytoplasm – vacuole – cytoplasm]

The **symplast pathway** (**B**) is a second possible route. The water travels only through adjoining cells by their cytoplasm (not vacuoles), via **plasmodesmata** (strands of cytoplasm which connect two different cells' cytoplasm)
[cytoplasm – cytoplasm – cytoplasm]

The **apoplast pathway** (**C**) is the other route. The cellulose cell walls have many water-filled spaces between them which water can travel across. In this pathway, the water molecules do not cross any plasma membranes, meaning that dissolved mineral ions and salts can be carried with it
[cell wall – cell wall – cell wall]

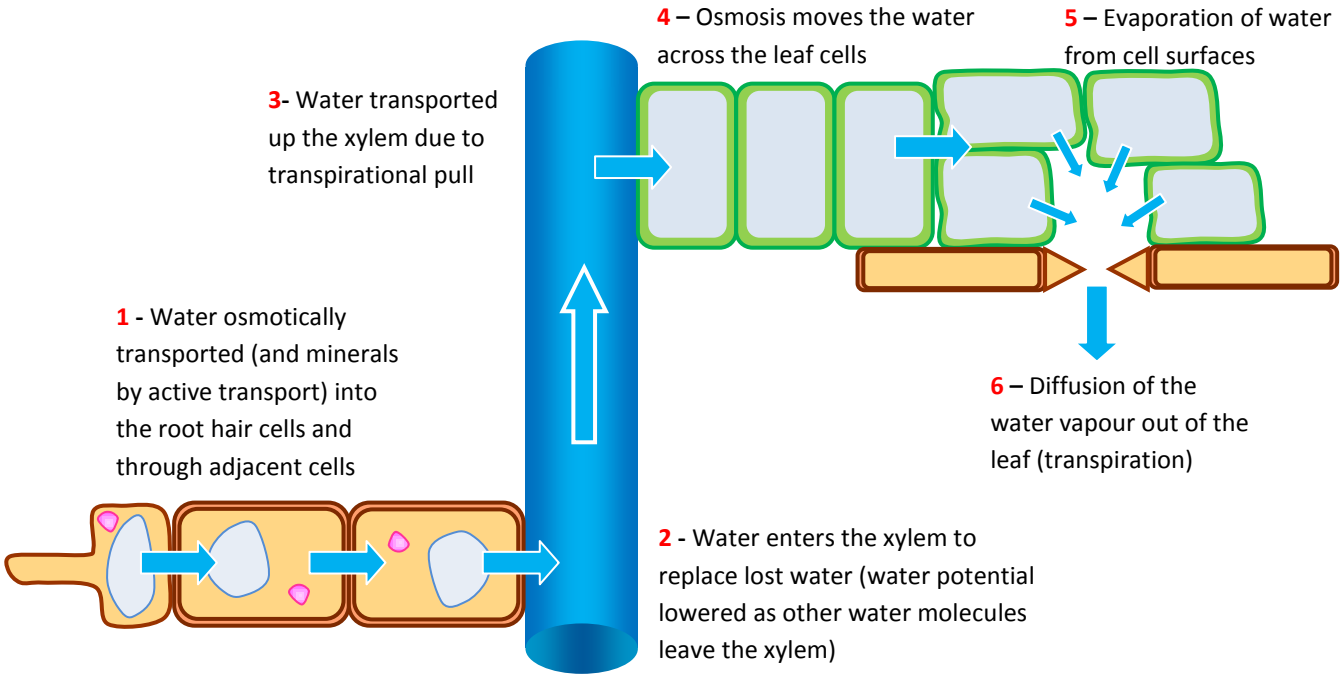
Water moving by the apoplast pathway is forces to travel through the cytoplasm of the endodermis, because the endodermis cells have a waterproof layer in their cell walls called **suberin**. This is organised in bands called **Casparian strips**.

Uptake of Water Through the Roots

Water enters root hair cells by **osmosis**. The water potential of root hair cells is lower than the surrounding water. The water can then move across the root via osmosis, down the concentration gradient, to the **endodermis**.

The endodermal cells pump minerals into the xylem using **active transport**. This lowers the water potential in the xylem and causes water to follow by osmosis.

The water is then pulled up the xylem by the **transpirational pull** generated by the water leaving the xylem and then transpiring from the leaves.



The Casparian Strip

The **endodermis** is a layer of cells which surrounds the xylem. Many of these cells have a waterproof layer in their cell walls which appears in bands. This band is called the **Casparian strip**. This blocks the apoplast pathway, because it means that the water cannot travel along cell walls, so water is forced to follow the symplast pathway.

The purpose of the Casparian strip is to ensure that the water carrying the salts and dissolved mineral ions has to travel through the plasma membranes to the cellular cytoplasm. To allow this, there are **transport proteins** (see 1.8 Movement Across Cell Membranes) in the membranes. Certain substances can be *actively transported* into the xylem from adjacent cells, including nitrate. This decreases the water potential of the xylem, meaning there is a steep water potential gradient from the cells surrounding the xylem to the xylem itself, therefore forcing water to move from those cells into the xylem. This is another result of the Casparian strip blocking the apoplast pathway.

Movement of Water up the Stem

There are three processes which aid the movement of water up the stem:

1 **Root pressure** – the action of the endodermis moving minerals into the xylem by active transport drives water into the xylem (by osmosis), which in turn pushes water up the xylem as new water enters the vessel

2 **Transpirational pull** – the loss of water from the leaves must be replaced by water coming up the xylem. Water molecules are attracted to each other by the forces of **cohesion**. These forces are strong enough to hold the molecules together in a long chain or column. As the molecules at the top of the column are lost, the whole chain is pulled up as one lot, creating the transpirational stream.

3 **Capillary action** – the same forces also attract the water molecules to the sides of the xylem – this is called **adhesion**. Because the xylem are very narrow, these forces can pull the water molecules up the sides of the vessel

Leaving the Leaf

Most of the water which leaves the leaf exits through **stomata**. These are tiny pores in the epidermis. A tiny amount also leaves through the waxy cuticle. Water evaporates from the cells immediately below the guard cells, lowering the water potential in those cells, causing water from neighbouring cells to enter them by osmosis.