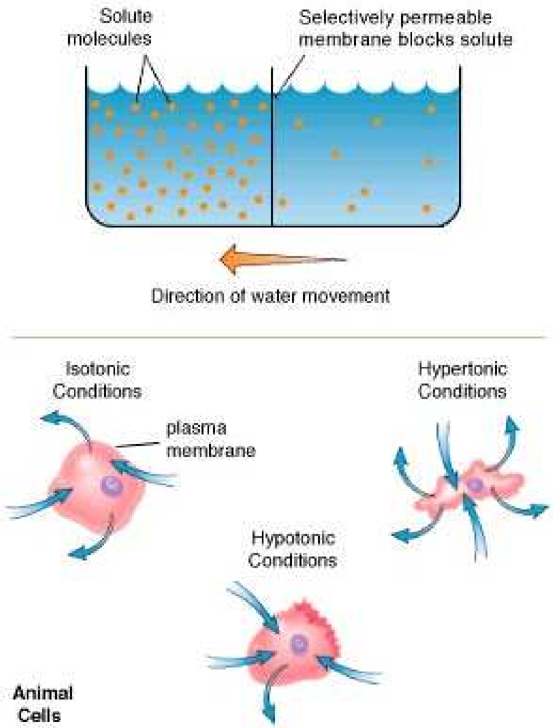
Describe the movement of water and solutes in plants

During the process of osmosis, water molecules move from an area that is hypotonic to an area that is hypertonic. A hypotonic area is one in which has less solute and a hypertonic area is one which has more solute.



Plant cells, such as the ones in the epidermis and cortex regions of the roots of the plant, all have living contents, which are enclosed by a cell surface membrane and a thick, quite inelastic cellulose cell wall. The cell wall has special properties, which help the cells resist during the osmotic uptake of water. If a plant cell is placed in distilled water, it won't swell up and burst like for example, a red blood cell, but it will take in water until the pressure that the wall exerts stops any further intake and expansion. When a plant reaches this condition it is said to be fully turgid. This turgor is essential for support in the plant, as the plant would wilt if it lost water.

The term water potential is used to describe the force acting on water molecules in a solution, when separated from pure water by a membrane, which only allows water to pass through it. This is a measure of the potential of water molecules to move from a region of a certain water molecule concentration to another region of lower water molecule concentration. Water will move from a region of higher water potential to one of lower water potential. It is measured in terms of pressure and the units are either kPa (kilopascals) or MPa (megapascals). The symbol for water potential is Ψ (Greek letter psi). Pure water has the highest water potential (0). More negative water potentials indicate more hypertonic solutions. This change on water potential caused by a solute being there is called the solute potential and its symbol is Ψ_s.

When placed in distilled water, the plant cells will tend to take in water; this is due to plant cells containing various solutes, such as sugars, which exert a solute potential. The cell wall opposes this uptake of water with an inward pressure. The term used to describe this is pressure potential and its symbol is Ψ_p it is also given a positive value and this is due to the fact that it goes against the solute pressure.

The following equation also allows us to express the relationship between water potential, solute potential and pressure potential in terms of the water status of the cell:

$$\Psi = \Psi_s + \Psi_p$$

Water potential = solute potential + pressure potential

Due to osmosis, in plant cells, the water moves from an area of high water potential to an area of low water potential, along a water potential gradient.

In a cell that is fully turgid the water potential is zero as the solute and pressure potential cancel each other out. If a turgid cell is placed into a concentrated sugar solution, water from the cell will leave it, due to the more negative solute pressure of the sugar solution compared to the water potential of the cell. As the water leaves the cell, the volume of the cell decreases, and then eventually the cell surface membrane starts to separate from the cellulose cell wall. This process is called plasmolysis. Something called incipient plasmolysis will occur at the point where the cell surface membrane is just about to lose contact with the cell wall. No more pressure is exerted on the cell wall after this (the pressure potential is 0). Total plasmolysis will occur when the cell has lost the maximum amount of water and the cell membrane has left the cell wall entirely. A vacuole in the cell would have almost completely disappeared.

Water is taken up by the younger parts of the roots, usually in the region of the root hairs. These root hairs greatly increase the SA for water uptake and they are long projections from the epidermal cells, which extend among soil particles. The solute concentrations are very low in the water of most soils, so the Ψ of this water is close to zero. The Ψ_s's of plant cells are usually around –500 and –3000 kPa, so therefore, water will be taken up by osmosis, due to there being a water potential gradient between root hair cells and soil water.

DIAGRAM

There are three paths for the water to move across the cortex of the root from the epidermis to the central tissues. These three ways are:

- Apoplast pathway: in which water passes through the continuous system of adjacent cell walls.
- Symplast pathway: in which water moves from cell to cell, through the cytoplasm (the cytoplasm of adjacent cells in the cortex is in contact via the plasmodesmata, which are fine-channels through the cell walls).
- Vacuolar pathway: in which water moves from vacuole to vacuole.

DIAGRAM

However, when water reaches the endodermal cells its movement is stopped by a waterproof layer in the cell walls, called the Casparian strip. This is impregnated with suberin, a waxy compound, which is impermeable to water.

Therefore, water is prevented from passing around the endodermal cells through the cell walls, but instead it passes through the cell surface membrane and cell contents.