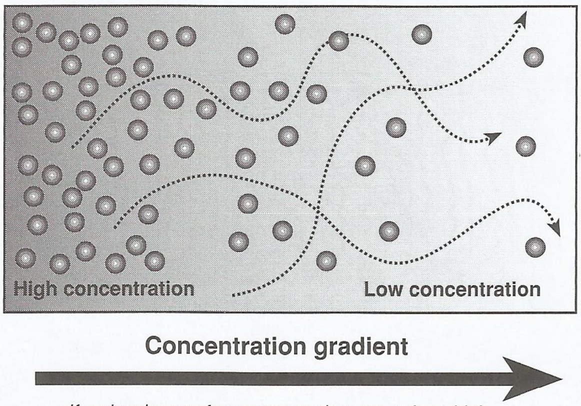
Passive Transport Processes

The molecules that make up substances are constantly moving about in a random way. This random motion causes molecules to disperse from areas of high to low concentration; a process called **diffusion**. The molecules move down a **concentration gradient**. Diffusion and osmosis (diffusion of water molecules across a partially permeable membrane) are **passive** processes, and use no energy. Diffusion occurs freely across membranes, as long as the membrane is permeable to that molecule (partially permeable membranes allow the passage of some molecules but not others). Each type of molecule diffuses down its own concentration gradient. Diffusion of molecules in one direction does not hinder the movement of other molecules. Diffusion is important in allowing exchanges with the environment and in the regulation of cell water content.

Diffusion is the movement of particles from regions of high to low concentration (down a **concentration gradient**), with the end result being that the molecules become evenly distributed. In biological systems, diffusion often occurs across partially permeable membranes.



If molecules are free to move, they move from high to low concentration until they are evenly dispersed.

Factors affecting rates of diffusion

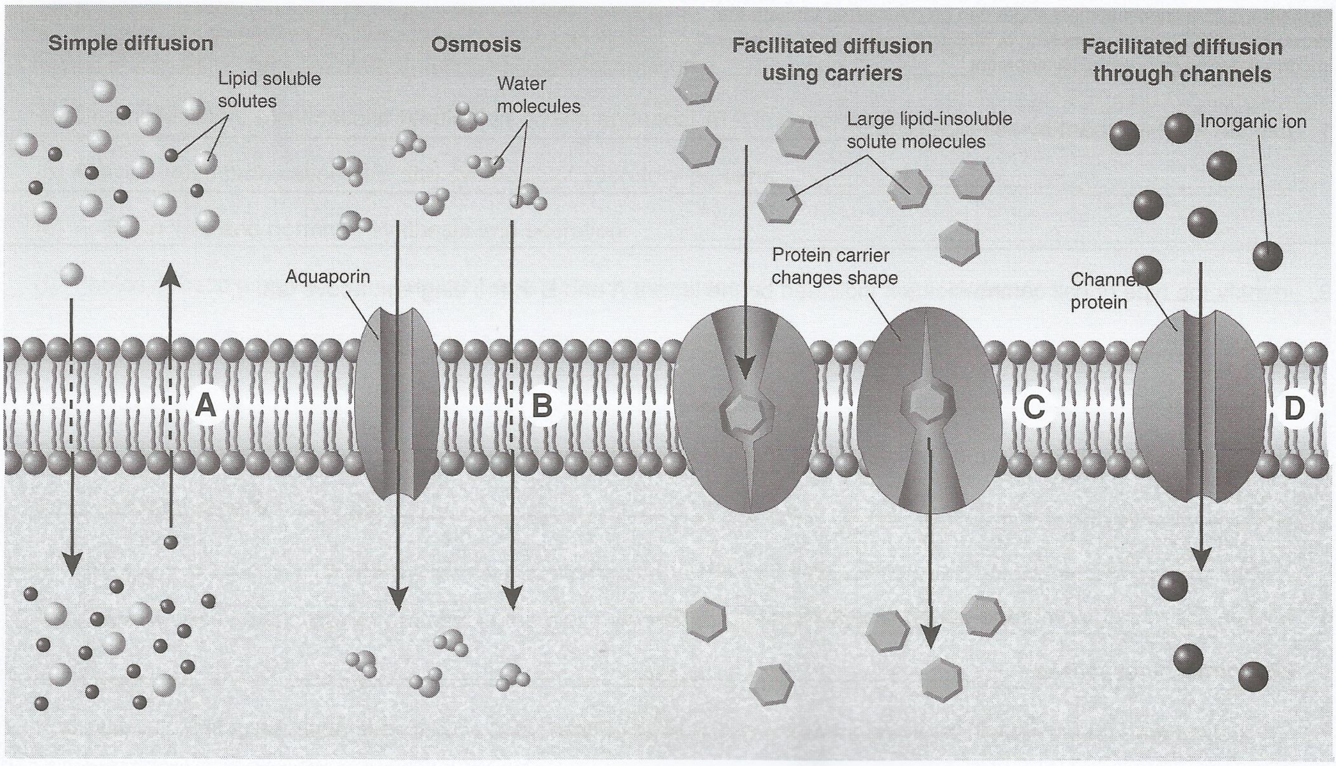
Concentration gradient:	Diffusion rates will be higher when there is a greater difference in concentration between two regions.
The distance involved:	Diffusion over shorter distances occurs at a greater rate than diffusion over larger distances.
The area involved:	The larger the area across which diffusion occurs, the greater the rate of diffusion.
Barriers to diffusion:	Thicker barriers slow diffusion rate. Pores in a barrier enhance diffusion.

FICK'S LAW

$$\frac{\text{Surface area of membrane} \times \text{Difference in concentration across the membrane}}{\text{Length of the diffusion path (thickness of the membrane)}}$$

These factors are expressed in **Fick's law**, which governs the rate of diffusion of substances within a system. Temperature also affects diffusion rates; at higher temperatures molecules have more energy and move more rapidly.

Diffusion Through Membranes



A: Some molecules (e.g. gases and lipid soluble molecules) diffuse directly across the plasma membrane. Two-way diffusion is common in biological systems, e.g. at the alveolar surface of the lung, CO_2 diffuses out and oxygen diffuses into the blood.

B: Osmosis describes the diffusion of water across a partially permeable membrane (in this case, the plasma membrane). Some water can diffuse directly through the lipid bilayer, but movement is also aided by specific protein channels called **aquaporins**.

C: A lipid-insoluble molecule is aided across the membrane by **carrier mediated facilitated diffusion**. This involves a transmembrane carrier protein specific to the molecule being transported (for example, glucose transport into red blood cells).

D: Small polar molecules and ions diffuse rapidly across the membrane by **channel-mediated facilitated diffusion**. Special channel proteins (sometimes called ionophores) create hydrophilic pores that allow some solutes, usually inorganic ions, to pass through.

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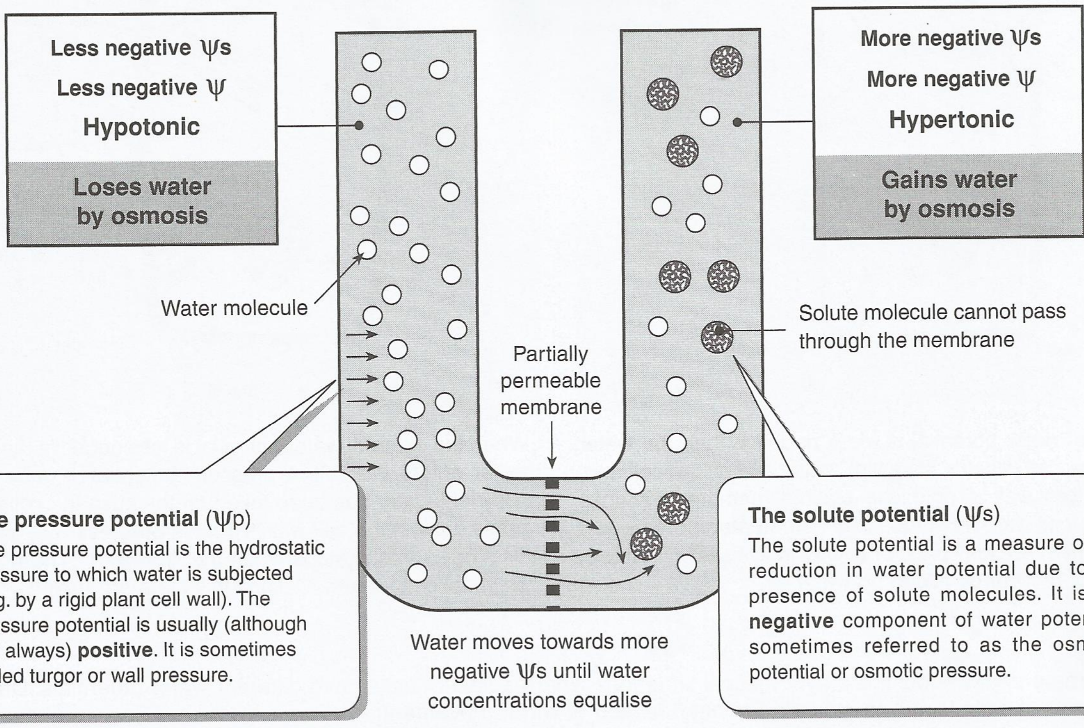
Osmosis and Water Potential

Osmosis is the term describing the diffusion of water down its concentration gradient across a partially permeable membrane. It is the principal mechanism by which water enters and leaves cells in living organisms. The direction of this movement can be predicted on the basis of the water potential of the solutions involved. The water potential of a solution (denoted by ψ) is the term given to the tendency for water molecules to enter or leave a solution by osmosis.

Pure water has the highest water potential, set at zero. Dissolving any solute in water lowers ψ (makes it more negative). Water always diffuses from regions of less negative to more negative water potential. Water potential is determined by two components: the **solute potential**, ψs (of the cell sap) and the **pressure potential**, ψp, expressed by:

$$\psi cell = \psi s + \psi p$$



The pressure potential (ψp)
The pressure potential is the hydrostatic pressure to which water is subjected (e.g. by a rigid plant cell wall). The pressure potential is usually (although not always) **positive**. It is sometimes called turgor or wall pressure.

The solute potential (ψs)
The solute potential is a measure of the reduction in water potential due to the presence of solute molecules. It is the **negative** component of water potential, sometimes referred to as the osmotic potential or osmotic pressure.

1. Describe two properties of an exchange surface that would facilitate rapid diffusion rates:

   (a) ______________________ (b) ______________________

2. Describe two biologically important features of diffusion:

   (a) ______________________

   (b) ______________________

3. Describe how facilitated diffusion is achieved for:

   (a) Small polar molecules and ions: ______________________

   (b) Glucose: ______________________

4. Explain how concentration gradients across membranes are maintained: ______________________

5. Explain the role of aquaporins in the rapid movement of water through some cells: ______________________

6. (a) State the water potential of pure water at standard temperature and pressure: ______________________

   (b) Explain what happens if a cell takes up sucrose by active transport: ______________________

   (c) Describe a situation where this occurs in plants: ______________________

Cell Membranes

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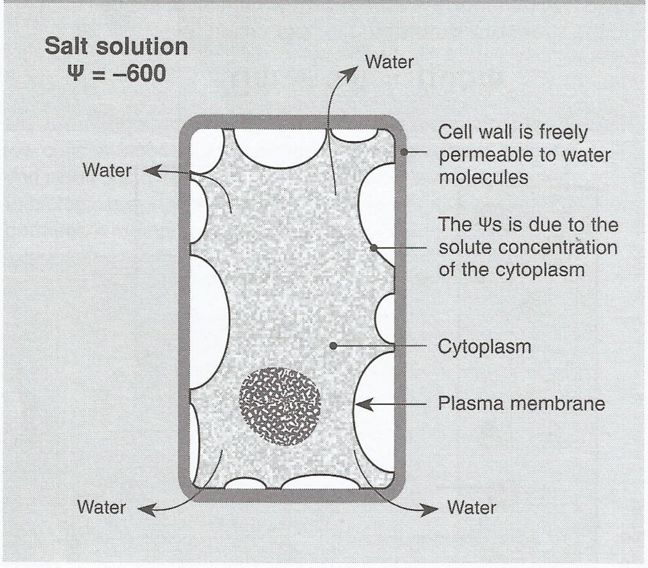
Water Relations in Plant Cells

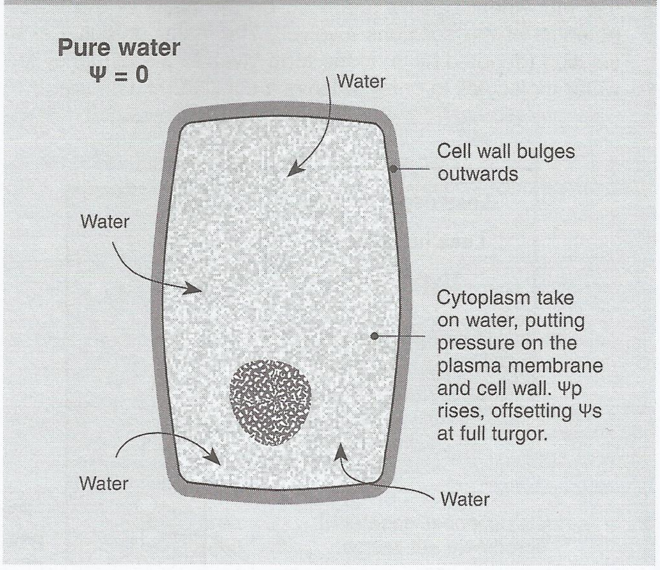
The plasma membrane of cells is a partially permeable membrane and osmosis is the principal mechanism by which water enters and leaves the cell. When the external water potential is the same as that of the cell there is no net movement of water. The diagram below illustrates two different situations: when the external water potential is less negative than the cell and when it is more negative than the cell.

Plasmolysis in a Plant Cell



When external water potential is more negative than the water potential of the cell (Ψcell = Ψs + Ψp), water leaves the cell and, because the cell wall is rigid, the plasma membrane shrinks away from the cell wall. This process is termed **plasmolysis** and the cell becomes flaccid (Ψp = 0). Full plasmolysis is irreversible; the cell cannot recover by taking up water.

Turgor in a Plant Cell



When the external water potential is less negative than the Ψcell, water enters the cell. A pressure potential is generated when sufficient water has been taken up to cause the cell contents to press against the cell wall. Ψp rises progressively until it offsets Ψs. Water uptake stops when the Ψcell = 0. The rigid cell wall prevents cell rupture. Cells in this state are **turgid**.

7. The diagrams below show three hypothetical situations where adjacent cells have different water potentials. Draw arrows on each pair of cells (a)-(c) to indicate the net direction of water movement:

(a)

A	B
ψs = –400 kPa	ψs = –500 kPa
ψp = 300 kPa	ψp = 300 kPa
ψ = –100 kPa	ψ = –200 kPa

(b)

A	B
ψs = –500 kPa	ψs = –600 kPa
ψp = 100 kPa	ψp = 100 kPa
ψ = –400 kPa	ψ = –400 kPa

(c)

A	B
ψs = –600 kPa	ψs = –500 kPa
ψp = 200 kPa	ψp = 300 kPa
ψ = –400 kPa	ψ = –200 kPa

8. Fluid replacements are usually provided for heavily perspiring athletes after endurance events. Suggest what the water potential of these drinks should be, relative to the body fluids, and explain your answer:

9. (a) Explain the role of pressure potential in generating cell turgor in plants:

(b) Explain the purpose of cell turgor to plants:

10. Explain how animal cells differ from plant cells with respect to the effects of net water movements:

11. Describe what would happen to an animal cell (e.g. a red blood cell) if it was placed into:

(a) Pure water:

(b) A solution of lower (more negative) water potential:

(c) A solution of higher (less negative) water potential:

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