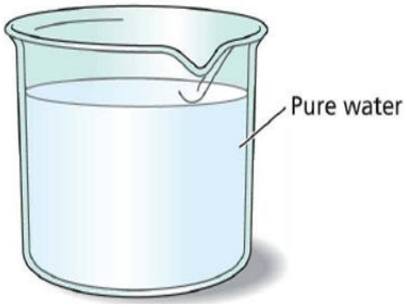
Core Course XII: Plant Physiology

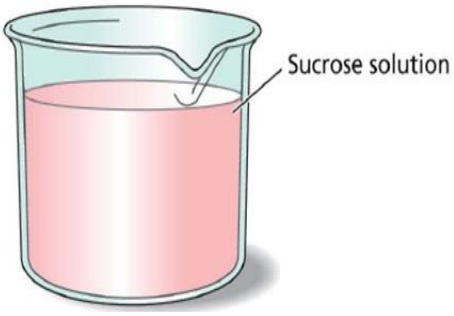
Course Code: BOTACOR12T

Only solvent



(Maximum DP)

Solvent + solute= solution



(A deficit in DP develops)

Diffusion

Diffusion Is the Movement of Molecules by Random Thermal Agitation:

Water molecules in a solution are not static; they are in continuous motion, colliding with one another and exchanging kinetic energy. The molecules intermingle as a result of the random thermal agitation. This random motion is called diffusion.

Definition: The tendency of the particles (molecules, atoms, ions etc.) of gases, liquids and solids to get evenly distributed throughout the available space due to random kinetic motion is called **diffusion**.

- It is the net movement of anything (for example, atom, ions, molecules) from a region of higher concentration to a region of lower concentration.
- This is driven by a gradient in concentration.

In the 1880s the German scientist **Adolf Fick** discovered that the rate of diffusion is directly proportional to the concentration gradient ($\Delta cs/\Delta x$) —that is, to the difference in concentration of substance *s* between two points separated by the distance.

In symbols, we write this relation as **Fick's** first law:

$$\boldsymbol{J_s = -D_s \frac{\Delta cs}{\Delta x}}$$

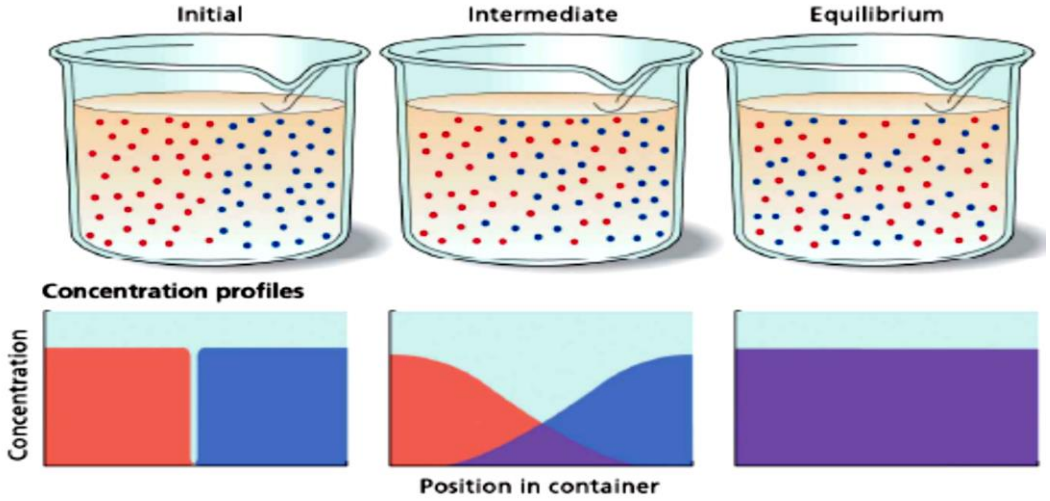
The rate of transport, or the **flux density** (*J*s), is the amount of substance *s* crossing a unit area per unit time (e.g., *J*s may have units of moles per square meter per second [mol m−2 s−1]).

The **diffusion coefficient** (*D*s) is a proportionality constant that measures how easily substance*s* moves through a particular medium.

The diffusion coefficient is a characteristic of the substance (larger molecules have smaller diffusion coefficients) and depends on the medium (diffusion in air is much faster than diffusion in a liquid, for example). The negative sign in the equation indicates that the flux moves down a concentration gradient.

- The diffusion of the gases, sometimes results in the development of a pressure which may be defined as **diffusion pressure,** more precisely as **chemical potential**.

- Pure solvent shows maximum diffusion pressure i.e. zero. With the addition of solute particle the chemical potential of the solvent decreases and a **diffusion pressure deficit (DPD)** results.
- The movement of the molecules depends upon kinetic energy during diffusion. The movement of molecules occurs from its higher energy towards its lower energy. The diffusion of one substance is independent of the other
- The magnitude of the pressure is inversely proportional to the average distance between the molecules or directly proportional to the concentration of diffusible particles, i.e., higher the concentration of the particles, the greater their diffusion pressure.
- It is also directly proportional to the absolute temperature, i.e., the average energy of a particle in a homogeneous substance rises as the temperature increases but is constant for various substances at a given temperature. The particle velocities in gases can be easily calculated, but it is much more difficult to obtain values for liquids and solids.



Diffusion is of immense significance in plant-water relations:

- Evaporation, a diffusion process, is the overall driving force for most water movement through the plant.
- All living cells exist in an aqueous environment and are separated by a differentially permeable membrane which allows only certain substances to pass but not all.
- The movement of substances in and out of the cell through the membrane is a matter of diffusion.
- The phenomenon of diffusion is directly or indirectly involved in all physiological processes.
- All the aerial intake of different gases, i.e., CO_2 and O_2 from the atmosphere as well as the movement of gases through intercellular spaces of the tissue takes place by this process.
- Absorption of water and minerals from the soil by the higher plants also takes place by the diffusion phenomenon although a more complicated mechanism is involved in their absorption and accumulation by the root hairs.

- The loss of molecules from the plant body is also a diffusion process. Thus transpiration and loss of CO_2 and O_2 take place by diffusion.

Factors affecting the rate of diffusion:

✓ **Temperature:**

The rate of diffusion is directly proportional to the temperature, it means rate of diffusion increases with rise in temperature. Diffusion stops approximately at 0ºC.

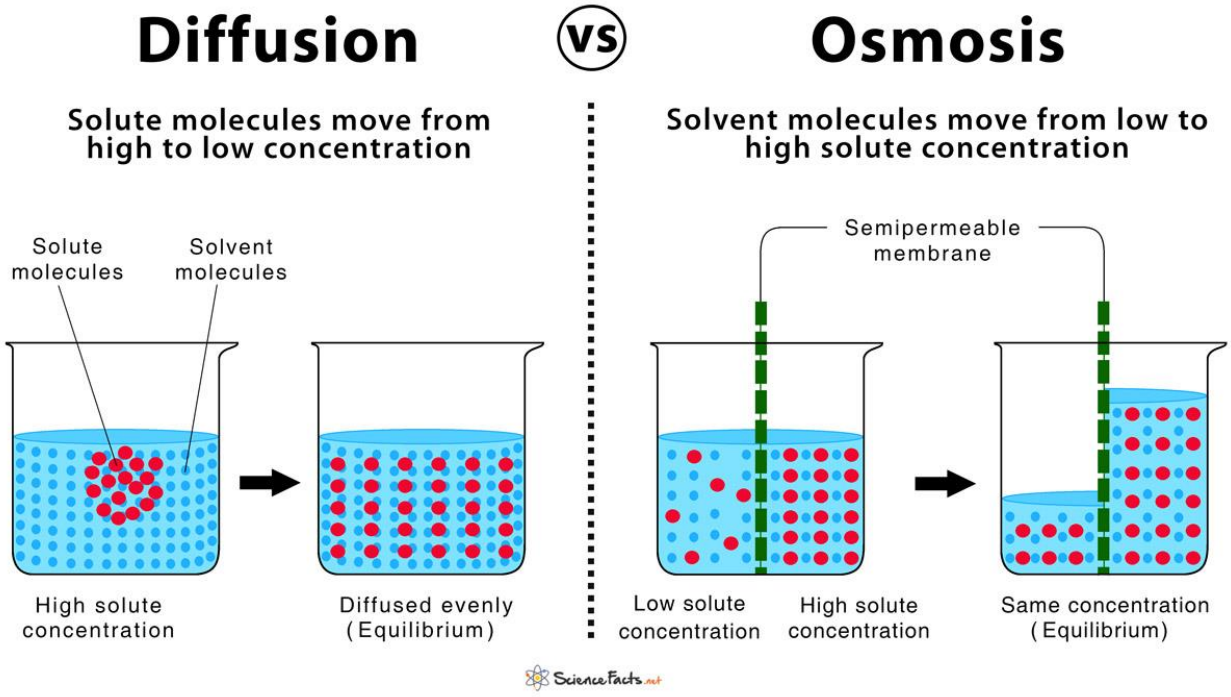
✓ **Density:**

Rate of diffusion is inversely proportional to square root of its relative density. It means rate of diffusion lowers down with increasing density.

Rate of diffusion $\alpha = 1/\sqrt{}$density

Pressure-Driven Bulk Flow Drives Long-Distance Water Transport:

A second process by which water moves is known as **bulk flow** or **mass flow**. Bulk flow is the concerted movement of groups of molecules en masse, most often in response to a pressure gradient. Among many common examples of bulk flow of water moving through a garden hose, a river flowing, and rain falling.



Osmosis:

Definition: Osmosis is movement of solvent or water molecules from the region of their higher diffusion pressure or free energy to the region of their lower diffusion pressure or free energy across a semi-permeable membrane.

✓ Osmosis was discovered by **Abbe Nollet.** The detailed explanation of osmosis has been given by **Traube**.

- ✓ Movement of water into the cell during the osmosis is called **endosmosis**. When the water moves out of the cell it is called **exosmosis.**
- ✓ Osmosis is the net movement of water molecules across a partially-permeable membrane. Water molecules move randomly with a certain amount of **kinetic energy.**

Osmotic Pressure :

- ✓ The term **'osmotic pressure'** is misleading. It is in fact an irrational statement. No isolated solution can possess an osmotic pressure since the phenomenon is only demonstrable in a system in which pure solvent and solution are separated by a semi-permeable membrane.
- ✓ An unconfined solution has an osmotic pressure although no pressure in the literal sense is exerted.
- ✓ Since the osmotic pressure is the pressure that must be imposed upon the solution to maintain its solvent in equilibrium with pure solvent at the same temperature, it is confusing to refer to this pressure as if it were exhibited by the solution.
- ✓ There appears to be a need for a new and agreed term to denote **'solute potential' (ψ_s)** or 'osmotic potential' of a solution, being equal in magnitude but opposite in sign to π.

Thus, $$\pi = - \psi_s$$

- ✓ The development of ψ_s in plant cells is of primary importance in determining their water relationships. The osmotic pressure of a solution is directly proportional to the concentration of solute in it.
- ✓ Osmotic pressure of a solution is measured by "**Osmometer**".
- ✓ The highest osmotic pressure is found in the **halophytes(*Atriplex confertifolia*** which is approximately 202.5 atmosphere). The lowest osmotic pressure is found in aquatic plants or **hydrophytes**. The osmotic pressure shows maximum variation in the plants cells.
- ✓ Generally osmotic pressure is less during the night and higher at noon in summer.
- ✓ The value of osmotic pressure depends upon the concentration of the solution. More solute present in the solution will increase the OP of the solution.

Factors affecting osmotic pressure:

- ✓ Concentration of the solute – The osmotic pressure of solution increases with increase in the concentration of solutes.
- ✓ Temperature – Osmotic pressure is proportional to the temperature. It means that osmotic pressure of solution increases by the increase in temperature.
- ✓ Dissociation of solutes into ions (ionization) also increases the OP of solution.

Significance:

- Root hairs absorb water from the soil through the process of osmosis.
- The cell to cell movement of water in plant and distribution of water in plant takes place through the phenomenon of osmosis.

- Turgidity is developed by the process of endosmosis which helps to maintain a definite shape of leaves, stem and flowers. Turgidity also provides mechanical strength to the plants.
- The opening and closing of stomata also depends upon the process of osmosis.
- The leaves of ***Mimosa pudica*** ("Touch me not") are dropping down only by contact and dehiscence of fruits and sporangium are dependent upon turgor changes after osmosis.
- The resistance is increased due to high osmotic concentration against the dry climate and cold temperature (below 0ºC).
- The growth of the young cells depends on the result of osmosis. The other daily activities also take place by osmosis and plasmolysis.
- The fresh water growing plants and animals either wilt or die when they are keeping in marine water.
- Bacteria and fungi of meat and fishes are destroyed by the addition of excess salt.
- Fungi and bacteria of jam, jelly, sweet pickles etc. are destroyed by sugar solution of high concentration.
- Weeds can be destroyed by applying saline water into the roots.

Differences between diffusion and osmosis:

Basis For Comparison	Diffusion	Osmosis
The Process	The movement of solutes existing in any state of solid, liquid or gas from a region of their higher concentration to the region of lower concentration, but without a semi-permeable membrane	The movement of solvent especially water from the region of high solute concentration to the region of low solute concentration, through a semi-permeable membrane
Medium	Takes place in any medium of solid, liquid, and gas	Takes place only in the liquid medium
Material	Applied to all states of solid, liquid, and gas	Applied only for the solvent part of the solution
Properties of Molecules	Depends on the size and electric charge of molecules	Depends on the particle concentration
Concentration Gradient	Moves along the concentration gradient	Moves down the concentration gradient
Semipermeable membrane (cell membrane)	The motion is direct and does not always require the semipermeable membrane or cell membrane	The motion is always through the semipermeable membrane or cell membrane

Rate of the process	Fast process	Slow process
Free energy	Only depends on the free energy of the substance	Depends on the rate of reduction of the free energy of one solvent
Example	The scent of perfume filling a whole room within seconds	Plant root hairs taking up water from the soil
Purpose and Significance in living organisms	1. Important in animals for producing energy for the cell, during respiration it helps in the exchange of gases 2. In plants, it helps in transpiration and photosynthesis	1. Important in animals for maintaining the water potential of the cell, transporting nutrients, and in cell-cell diffusion 2. In plants, it maintains turgidity, provides mechanical support, prevents excess water loss, and helps in the absorption of water from the soil

How are Diffusion and Osmosis Alike :

- Neither process can initiate unless there is a difference in the concentration of particles between two regions.
- The processes are complete only when the concentration of the particles becomes even in both regions (equilibrium).
- Both are spontaneous transport processes, which mean they do not require any input of extra energy to occur.
- In both, particles move from an area of higher concentration to lower concentration.