18. A cell with $\psi_s$ –1.0 MPa, $\psi_p$ 0.3MPa is immersed in a solution with Ψ – 4.0MPa .
(i) What is the water potential of the cell at equilibrium.
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(ii) What is the solute potential of the cell at equilibrium.
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(iii) What is the pressure potential of the cell at equilibrium.
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19. A cell at incipient plasmolysis with Ψs –2.0 Mpa plant cell with a vacuole is immersed in a solution of Ψ= –1.2 MPa .
(i) Calculate Ψ and Ψp of the cell at equlibrium.
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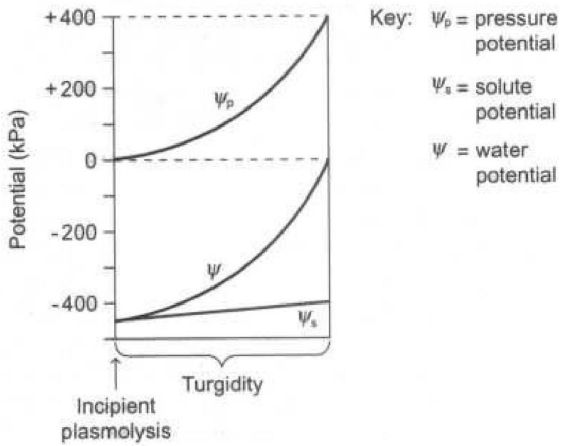
20. Following graph shows change of water potential of plasmolyzed cell from incipient plasmolysis.




(i) What is the solute potential of cell at incipient plasmolysis and turgid stage.
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(i) What is the nature of the immersed solution.
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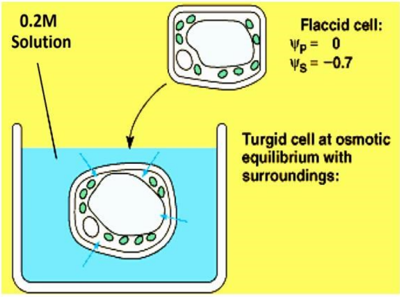
Biology
2025 REVISION
UNIT 04
WATER POTENTIAL

Sampath Lankadheera

16. Given vacuolated plant cell immersed in 0.2 M solution. 0.1M solution has following values for $\psi_s^{cell}$ = -0.23MPa




(i) Calculate the water potential of the cell at equilibrium.

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(ii) Calculate the pressure potential of the cell at equilibrium

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(iii) What can you say about the pressure potential of this cell compared to the cell immersed in pure water

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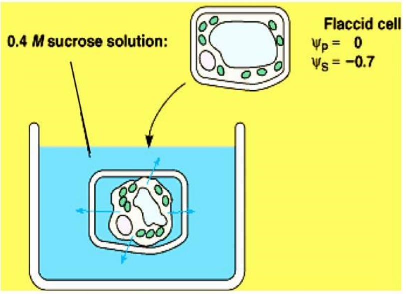
17. Given vacuolated plant cell immersed in 0.4 M solution. 0.1M solution has following values for $\psi_s^{cell}$ = -0.23MPa




(i) Calculate the water potential of the cell at equilibrium.

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(iii) Calculate the pressure potential of the cell at equilibrium.

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(iv) Calculate the solute potential of the cell at equilibrium

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(ii) Calculate the water potential of the cell at equilibrium.
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(iii) What is the change of water potential of the pure water at equilibrium.
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(iv) Calculate the pressure potential of the cell at equilibrium
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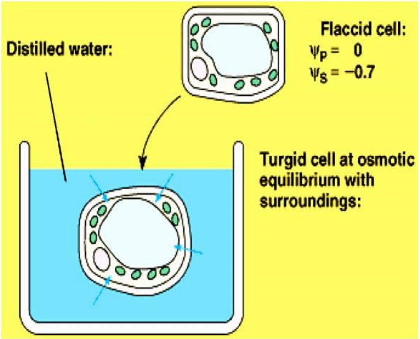
15. Given vacuolated plant cell immersed in distilled water.




(i) Calculate water potential of the cell before immersed in distilled water.
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(ii) Calculate the water potential of the cell at equilibrium.
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(iii) What is the change of water potential of the pure water at equilibrium.
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(iv) Calculate the pressure potential of the cell at equilibrium
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## Acquisition of water and minerals

### Need for transport

As land plants evolved and increased in number, competition for light, water and nutrients also increased. As a result, the size and complexity of plant body increased. Therefore the simple ways of transportation of water and material became inadequate leading to the evolution of vascular tissues, consisting of xylem and phloem to carryout long distance transport in plants.

e.g. the xylem transports water and minerals from roots to shoots.

the phloem transports products of photosynthesis from where they are made or stored to where they are needed.

**Methods of water and solutes movement**

Both active and passive transport mechanisms occur in plants

- Active transport
- Passive transport
  - Diffusion
  - Osmosis
  - Imbibitions
  - Facilitated diffusion
  - Bulk flow- long distance

(Diffusion, Osmosis, Imbibitions, Facilitated diffusion – Short distance)

Passive transport occurs spontaneously, and it does not require metabolic energy (ATP).

Movement of some materials across membranes takes place using ATP and that process is called an active transport.

**Diffusion**

Molecules have an energy called thermal energy, due to their constant motion. One result of this motion is diffusion.

In the absence of other forces, the movement of molecules of a substance from a place where it is more concentrated to place where it is less concentrated, due to random motion of molecules is called diffusion.

The motion of a molecule is random, but movement of a population of molecules by diffusion is directional.

Therefore, diffusion takes place according to a concentration gradient, spontaneously and not using metabolic energy (ATP).

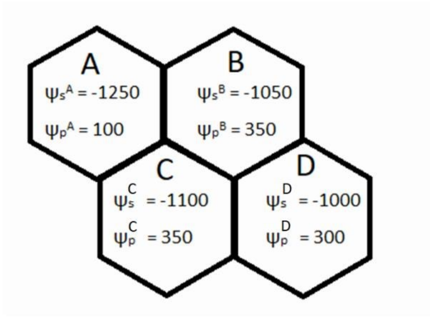
Diffusion takes place across the membrane also, if the membrane is permeable to those molecules.

e.g. Water and soluble materials can diffuse through the cellulose cell wall

$O_2$ and $CO_2$ can diffuse through the plasma membrane



12. Following table shows solute potential and pressure potential of 4 cells in KPa.




(i) Calculate the water potential of above cells.

(ii) Show the direction of flow of water in those cells on the diagram.

(iii) Calculate the water potential of cells at equilibrium.

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(iv) What is the pressure potential of cells at equilibrium

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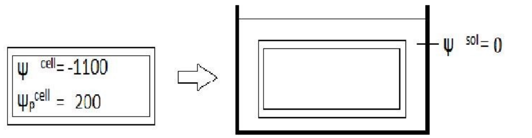
13. If the concentration of NaCl inside plant cell at incipient plasmolysis is 0.15M, which way will the water flow if the cell is placed in the 0.1 M solution? What is the pressure potential of the cell at equilibrium.

14. Water potential and pressure potential of a cell is given.




(i) Calculate solute potential of the cell before immersed in pure water.

(iv) What are pressure potential values at equilibrium.

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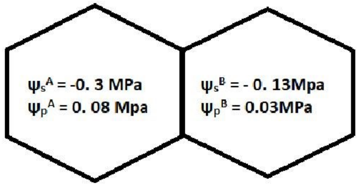
10. Following diagram shows two adjoining turgid plant cells.




(i) What is the direction of flow of water.

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(ii) What is the water potential of cell after reaching to the equilibrium.

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(iii)What are solute potential values at equilibrium

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(iv) What are pressure potential values at equilibrium.

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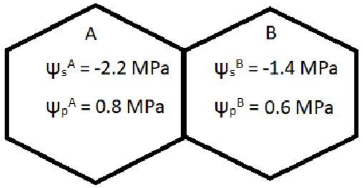
11. Following diagram shows two adjoining turgid plant cells.




(i) What is the direction of flow of water.

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(ii) What is the water potential of cell after reaching to the equilibrium.

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(iii) What are solute potential values at equilibrium

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(iv) What are pressure potential values at equilibrium.

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**Osmosis**

Osmosis is a special type of diffusion. The diffusion of free water molecules across a selectively permeable membrane is called osmosis.

Free water is water molecules that are not bound to solutes or surfaces.

**Imbibition**

The physical adsorption of water molecules by hydrophilic materials is called imbibition.

e.g. adsorption of water molecules by the cellulose cell walls.

**Facilitated diffusion**

Movement of water and hydrophilic solutes across the membranes passively with the help of transport protein that span the membrane is called facilitated diffusion.

Transport proteins are very specific. They transport some substances but not the others. This movement also takes place along concentration gradient and it is a passive movement.

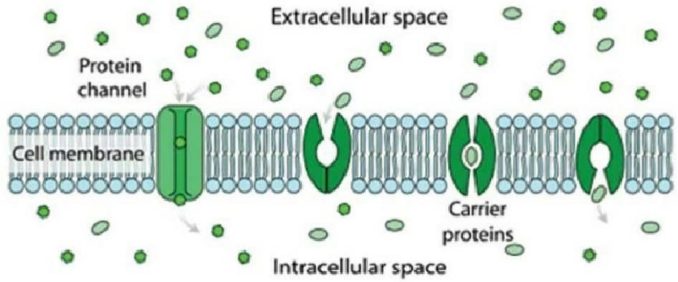


*Fig 4.15 -The process of facilitated diffusion*

**Bulk flow**

Bulk flow is the movement of liquid and the materials (entire solution) in response to pressure gradient. Always the bulk flow transports materials from higher pressure to lower pressure region.

It is a long-distance transport method. This flow does not occur through the membranes and occurs at much greater speed than diffusion. This method of transport is independent of solute concentration gradient.

**Concept of water potential**

The physical property that predicts the direction in which water will flow governed by solute concentration and applied pressure is called water potential. Water potential is related to potential energy of water molecules.

Any system that contains water has a water potential. Free water moves from regions of higher water potential to regions of lower water potential, if there is no barrier to its flow.

Water potential is denoted by Ψ. Ψ is measured in a unit of megapascal (MPa). Arbitrary the Ψ of pure water in a container open to the atmosphere under standard conditions (at sea level and room temperature) is 0 MPa.

Both solute concentration and physical pressure can affect water potential; as expressed in the water potential equation.

$\Psi = \Psi s + \Psi p$

Ψ= water potential

Ψs= solute potential

Ψp= pressure potential

**Solute potential**

Solute potential (Ψs) is directly proportional to the molarity of a solution. (Ψs is also called osmotic potential. Solutes affect the direction of osmosis.)
The solutes in plants are typically mineral ions and sugars.

Ψ of pure water is 0 MPa.

When solutes are added, they bind water molecules and reduce free water molecules, reducing capacity of the water to move and do work.

In this way an increase in solutes has a negative effect on water potential. Therefore, Ψs of a solution is always expressed as a negative number. As the solute concentration increases, Ψs will become more negative.

e.g: Ψs of the 0.1M sugar solution is -0.23MPa

**Pressure potential**

Pressure potential (Ψp) is the physical pressure on a solution. Ψp can be positive or negative relative to atmospheric pressure.

e.g: Ψp of a xylem vessel is usually less than -2 MPa as xylem vessels are under tension (negative pressure)

Ψp of a living cell is a positive value because living cell is usually under positive pressure due to osmotic uptake of water.

The cell contents press the plasma membrane against the cell wall. Then press against the protoplast, producing a pressure called turgor pressure. When turgor pressure increases, the Ψ of cell also increases.



6. You are given a solution with 0.1M concentration. $\psi_s = -0.23$Mpa.
Calculate $\psi_s$ of 0.15M, 0.20M, 0.25M, 0.30M Solutions.

7. The solute potential of a 0.1 M solution of distilled water and sucrose at $20^0$ C at standard atmospheric pressure is —0.23 MPa. If we continue adding sucrose to the solution until it reaches a concentration of 0.75 M at $20^0$ C at standard atmospheric pressure. What is the water potential, solute potential and pressure potential of final solution?

8. Following diagram shows water potential values of near by cells.


(i) What is the direction of flow of water.

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(ii) What is the water potential of cell after reaching to the equilibrium.

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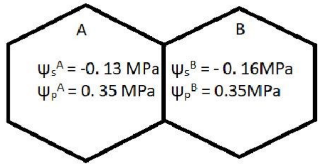
9. Following diagram shows water potential values of 2 near by cells.




(i) What is the direction of flow of water.

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(ii) What is the water potential of cell after reaching to the equilibrium.

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(iii) What are solute potential values at equilibrium

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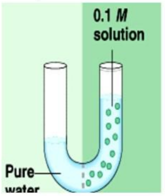
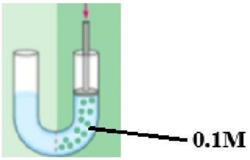
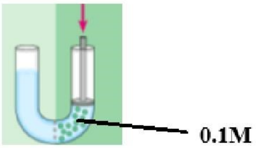
1. $\psi = \psi_s + \psi_p$. If a 0.1M solution has following values for $\psi_s^{cell} = -0.23$MPa, Then calculate $\psi$ solution. What is the direction of water flow.



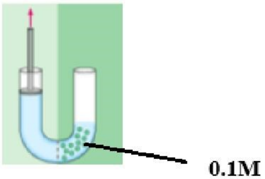

2. What is the water potential of the 0.1M solution when physical pressure increase to $\psi_p = 0.23$MPa. What is the direction of water flow. 0.1M solution has following values for $\psi_s^{cell} = -0.23$MPa




3. What is the water potential of 0.1M solution of above system when physical pressure increase to $\psi_p = 0.30$MPa of the solution. What is the direction of water flow. 0.1M solution has following values for $\psi_s^{cell} = -0.23$MPa




4. What is the water potential of 0.1M solution, when physical pressure decrease to $\psi_p = -0.30$ MPa of pure water. What is the direction of water flow. 0.1M solution has following values for $\psi_s^{cell} = -0.23$MPa




5. $\psi_s$ of a cell is – 0.65MPa. Water potential ($\psi$) of the cell is – 0.175 MPa. Find the $\psi_p$ of the cell.



**Water potential of a cell**

Cell is a system containing water. Therefore, it has a water potential. The protoplast is an aqueous system and it contains solutes. Therefore, it has a solute potential ($\Psi$s) which is negative. Because of $\Psi$s, $\Psi$ of the cell is decreased.

Due to the turgor pressure internal pressure of protoplast increases and increases pressure potential ($\Psi$p) of the cell. Because of $\Psi$p, $\Psi$ of cell increased.

Therefore, water potential ($\Psi$) of a cell is given by the following equation.

$\Psi = \Psi s + \Psi p$

**Entry of water into vacuolated cell across the cell membrane**

If a cell is placed in a solution, direction of water movement depends on the water potential of external solution and protoplast.

Take a fully flaccid cell; (as a result of water losing)

The $\Psi$p of that cell is 0;

$\Psi p = 0$ ;$\Psi s = \Psi$

$\Psi$s of pure water is 0 and addition of solutes will increase the negative value of $\Psi$s or become more negative. Suppose this flaccid cell is placed in a solution of higher solute concentration (more negative solute potential) than the cell itself, since the external solution has a lower (more negative) water potential, water diffuse out of the cell. The protoplast of the cell shrinks and pulls away from the cell wall. This process is known as plasmolysis.

Suppose this flaccid cell is placed in pure water ($\Psi$=0 MPa). The cell has a lower water potential than the pure water as it contains solutes. Therefore, water enters the cell by osmosis. Then the protoplast of the cell begins to swell and press the plasma membrane against the cell wall. The partially elastic cell wall, exerting a turgor pressure, pushes back against pressurized protoplast. Therefore, $\Psi$p is increased gradually. The maximum value of $\Psi$p= $\Psi$s of the cell. Therefore, $\Psi$ becomes 0. This matches the water potential of extracellular environment, 0 Mpa. Then a dynamic equilibrium is formed and there is no further net water movement. If the cell has the maximum value for $\Psi$p, (it equal to the $\Psi$s of the cell) the cell is said to be in fully turgid state. (fully turgid or fully flaccid cells are not found in nature).

Therefore, if non-woody tissue is placed in a solution with higher water potential, it is stiffened and is very rigid. Therefore, turgor pressure helps support of non woody plants. Turgor pressure is also important in cell elongation. Loss of turgor results in wilting, a condition where leaves and stem droop.

**Movement of water and minerals from soil solution to plant root**

The cells near the root tips of the roots are important because most of the absorption of water and minerals occurs there. In this region, the epidermal cells are permeable cross the selectively permeable plasma membrane before entering the vascular tissue and keep unneeded and toxic materials out.

The endodermis also prevents solutes that have accumulated in the xylem from leaking back into the soil solution.

**Symplastic route**

The symplast consists of the entire mass of cytosol of all living cells in a plant, as well as plasmodesmata, the cytoplasmic channels that interconnect them.

In the symplastic route, water and solutes move along the continuum of cytosol. This route requires substance to cross a plasma membrane once, when they first enter the plant. After entering one cell, substances can move from cell to cell via plasmodesmata.

**Transmembrane route**

The transmembrane route requires repeated crossing of plasma membranes as water and solutes exit one cell and enter the next.

As the soil solution moves along the apoplast, some water and minerals are transported into the protoplast of the cells of the epidermis and cortex and then move via the symplast.

Some substances can use more than one route. The least resistence for the transport is found in apoplastic route. Therefore, more water use apoplastic route.

Finally, water and minerals enter into the tracheids and vessel elements of xylem. These waters conducting cells lack protoplasts when mature and therefore they are parts of the apoplast. Endodermal cells and living cells of the vascular tissues discharge minerals from their protoplast to their own cell walls. Both diffusion and active transport involve in transport of solutes from symplast to apoplast. Then water and minerals can enter the tracheids and vessel elements to the transport to shoot system by bulk flow only through the apoplast.

to water and many are differentiated to root hairs. Root hairs account for much of the absorption of water by roots, due to increase in surface area.

The root hairs absorb the soil solution, which consists of water molecules and dissolved mineral ions that are not bound tightly to soil particles. This absorption takes place across the plasma membrane. Water can enter root hair by osmosis, a passive movement along the concentration gradient.

But in the root hairs concentration of mineral ions is greater than that of soil solution. K+ concentration in the root hair is hundreds of time greater than in the soil solution. Therefore, mineral ions transport occurs against concentration gradient, by an active transport.

The soil solution is also absorbed into hydrophilic walls of the epidermal cells and passes freely along the cell walls and the extracellular spaces into the root cortex.

**Radial transport**

Transport of water and minerals entered from soil to root cortex into the xylem of the root is known as radial transport.

The endodermis, the innermost layer of cells in the cortex, functions as the last check point for selective passage of the minerals from the cortex into the vascular cylinder. All materials which enters root through cell walls and extracellular spaces should cross the membranes of endodermis. Therefore, unwanted materials can be selectively excluded.

Three routes are used in the radial transport. They are:

1. apoplastic route
2. symplastic route
3. transmembrane route

**Apoplastic route**

The apoplastic route consists of everything external to the plasma membrane of living cells and includes cell walls, extracellular spaces and the interior of dead cells such as vessel elements and tracheids.

Water and solutes move along continuum of the cell walls and extracellular spaces and it is known as apoplastic route.

Uptake of soil solution by the hydrophilic walls of root hairs provides access to the apoplast. Water and minerals then can diffuse into cortex along this matrix of walls and extracellular spaces.

Endodermis blocks apoplastic route by a barrier located in the transverse and radial walls of endodermal cells, called the casparian strips. It is a belt made of suberin which is impervious to water and mineral salts. Thus water and minerals cannot cross the endodermis and enter the vascular cylinder via apoplast. Therefore, water and minerals