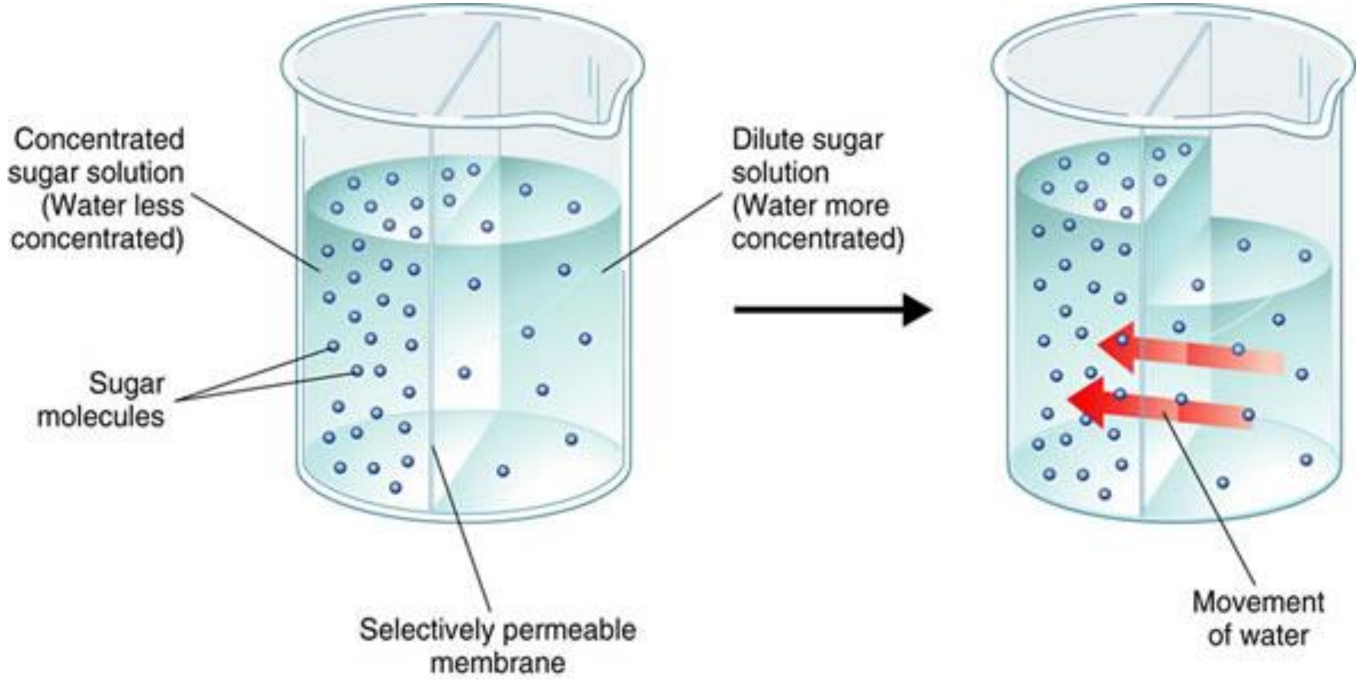
Water Potential - AP

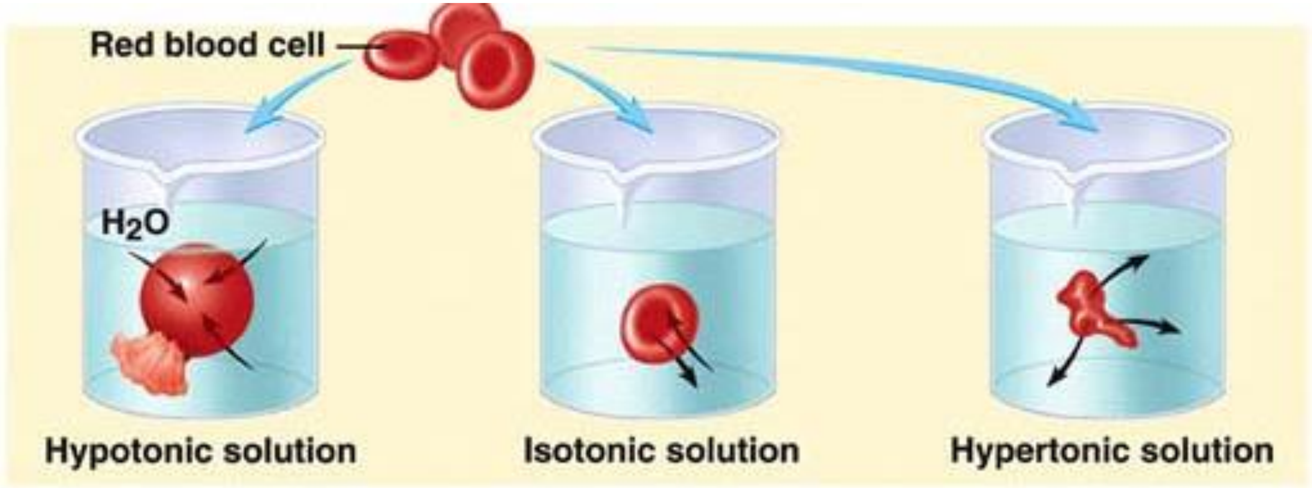
SBI4UP

Remember . . . Osmosis

Osmosis: net movement of water across a selectively permeable membrane. Water moves with its concentration gradient.



Remember . . . Osmosis in an Animal Cell

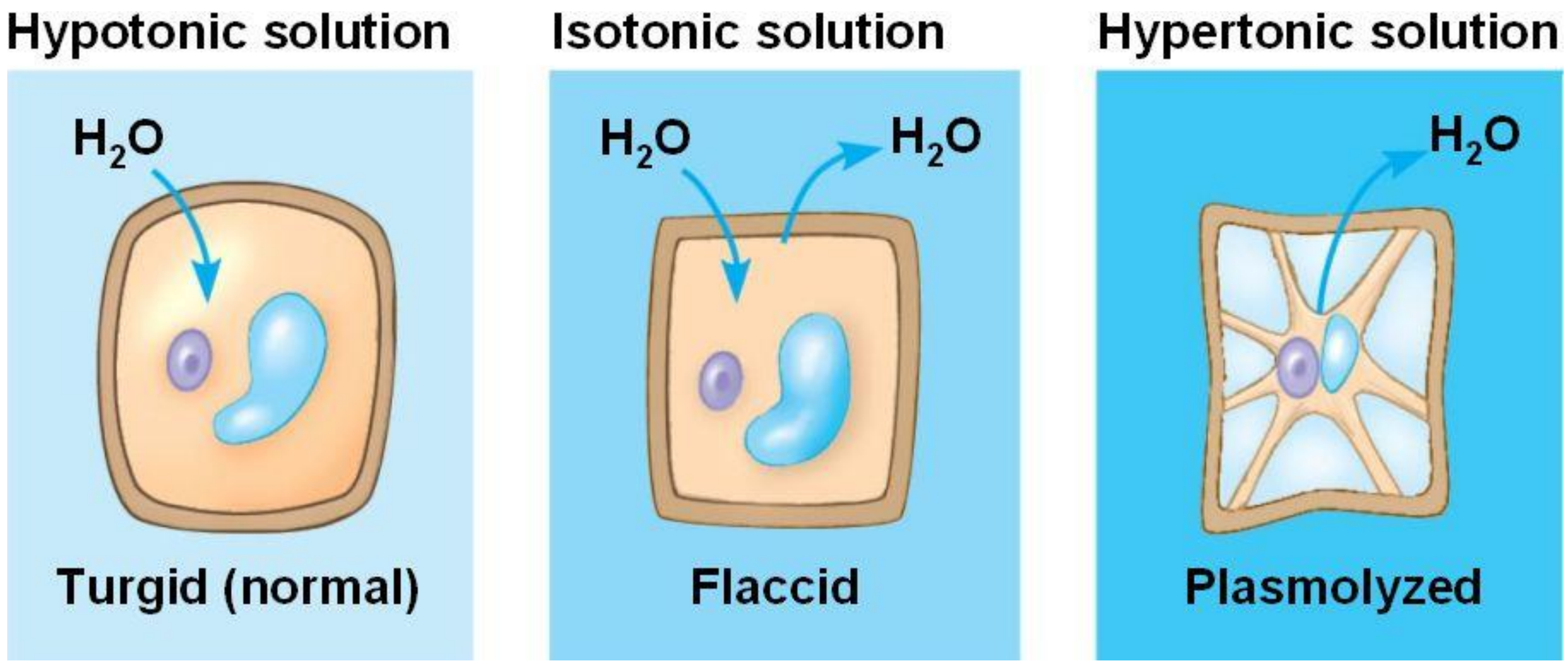


(a) A hypotonic solution with a low solute concentration results in swelling (*black arrows*) and lysis (*puff of red in the lower left part of the cell*) of a red blood cell placed into the solution.

(b) An isotonic solution with a concentration of solutes equal to that inside the cell results in a normally shaped red blood cell. Water moves into and out of the cell in equilibrium (*black arrows*), but there is no net water movement.

(c) A hypertonic solution, with a high solute concentration, causes shrinkage (crenation) of the red blood cell as water moves out of the cell and into the hypertonic solution (*black arrows*).

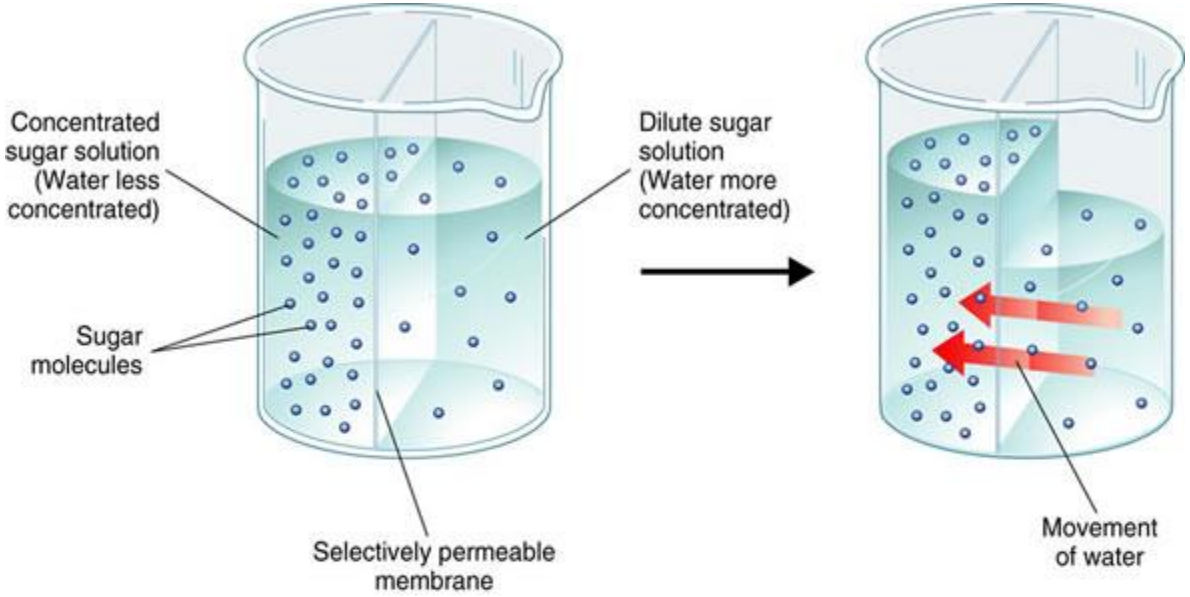
Remember . . . Osmosis in a Plant Cell



Water Potential

<u>Water potential:</u> Is a measurement that combines the effects of solute concentration and pressure to determine the direction of movement of water.
It is measured in ***Megapascals (Mpa or bars)***

*Water flows from regions of high water potential **(Ψ)** to regions of low water potential **(Ψ)***



All three forms of potentials must be considered when determining the direction in which water will move.

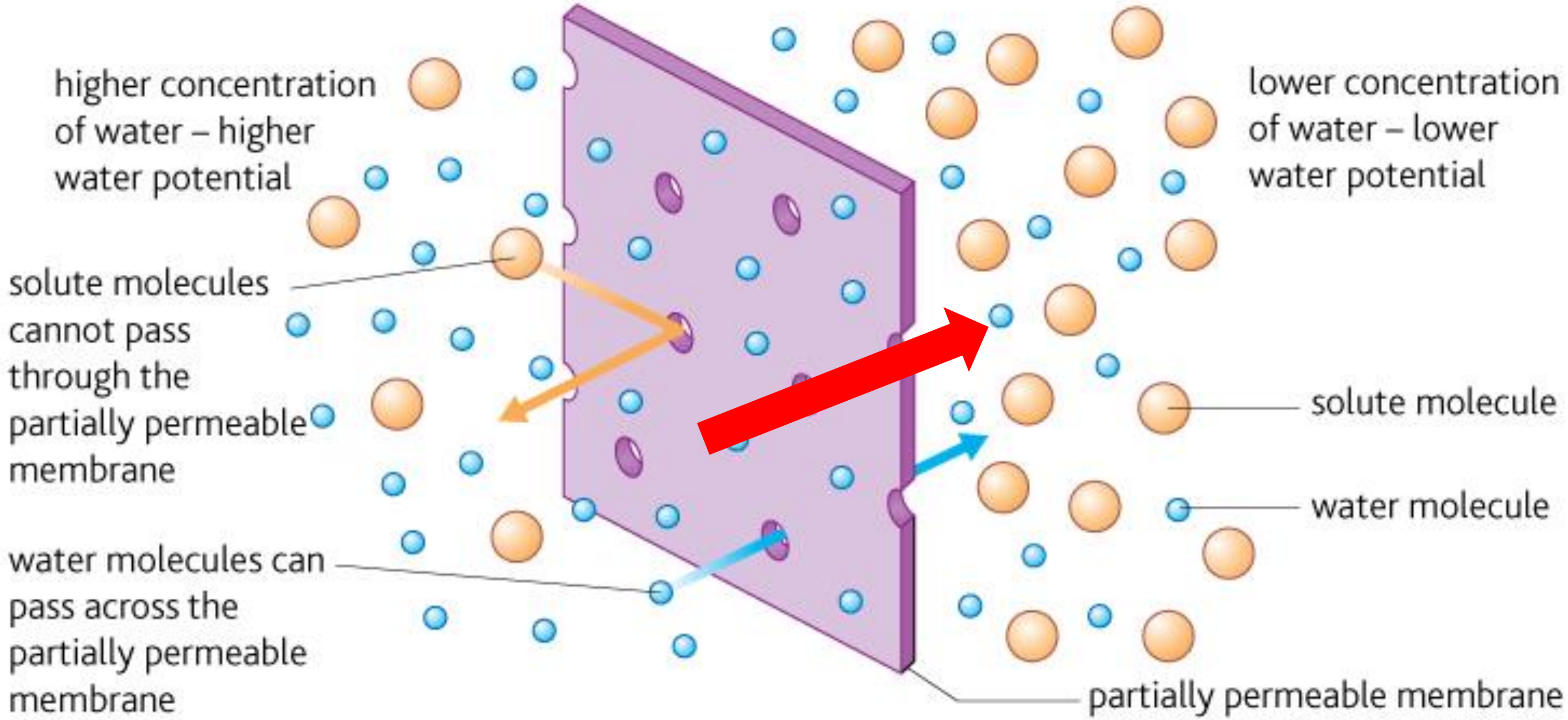
Key Terms

Water potential (Ψ):

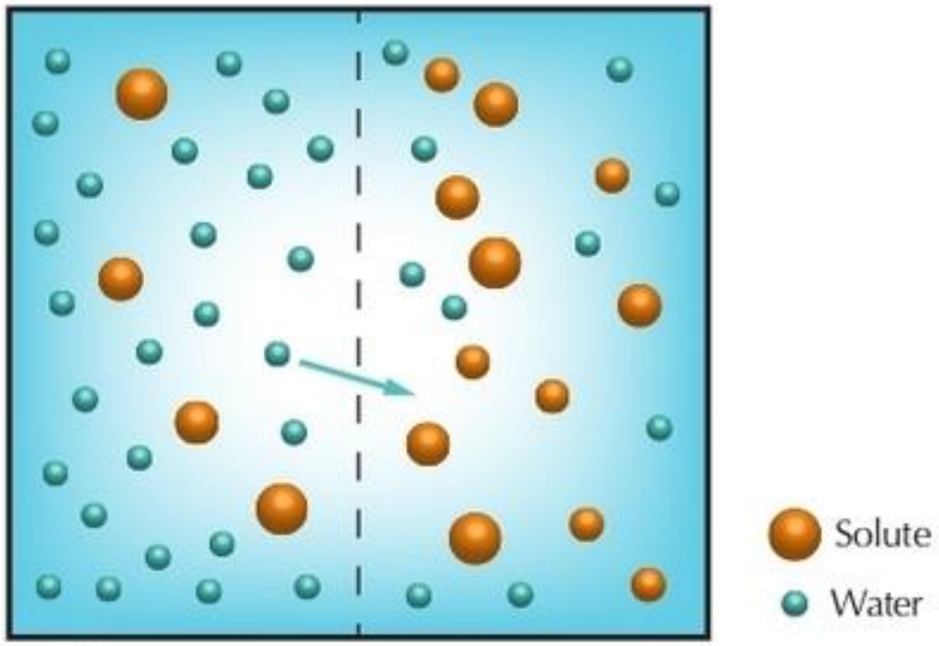
Solute potential (Ψ_s):

Pressure potential (Ψ_p):

Movement of Water & Water Potential *(Ψ)*



Water and Solute Potential (Ψ & Ψ_s)



A B

Determine which side of the container has a high water potential (Ψ).

Determine which side of the container has a high solute potential (Ψ_s).

Water and Solute Potential (Ψ & Ψ_s)

In the following table, identify whether the cell has a high/low Ψ and a high/low Ψ_s

Why is Ψ_p not considered for animal cells?

<table>
<tr><th>HYPERTONIC</th><th>HYPOTONIC</th><th>ISOTONIC</th></tr>
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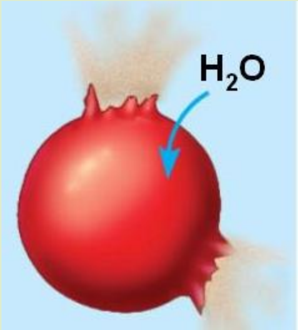
<td>
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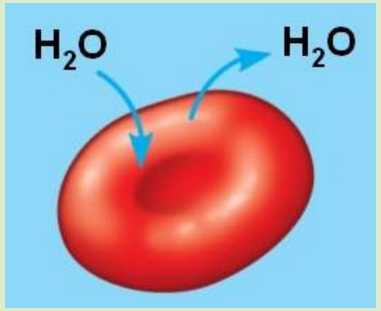
<td>
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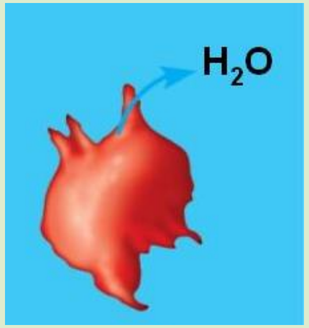
<td>
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<tr>
<td>Ψ in cell:
Ψ_s in cell:
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</table>

Water and Solute Potential (Ψ & Ψ_s)

Hypotonic Solutions:

- The Ψ (water potential) is ***high***, thus there is ***more free energy*** available
- The water molecules are not clustered due to the ***low solute concentration***
- Thus, Ψ_s is low

Hypertonic Solutions:

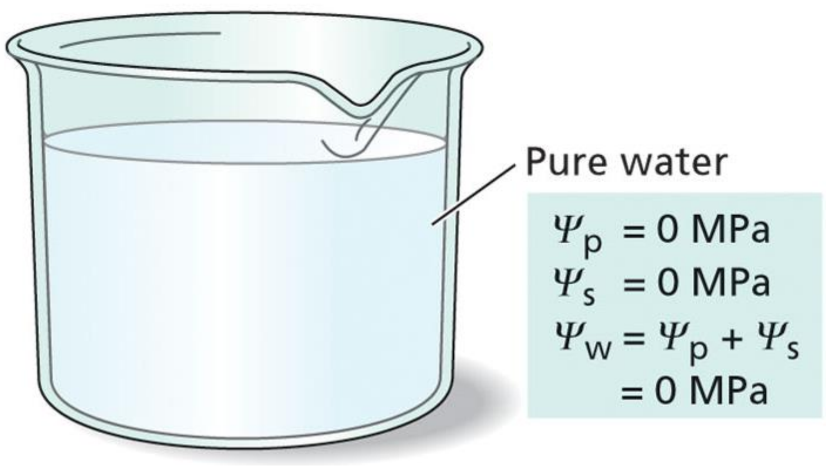
- The Ψ (water potential) is ***low***, thus there is ***less free energy*** available
- The water molecules are clustered due to the ***high solute concentration***
- Thus, Ψ_s is ***high***

Water and Solute Potential (Ψ & Ψ_s)

Isotonic Solutions:

- The Ψ (water potential) is ***zero***
- The pressure potential (Ψ_p) and solute potential (Ψ_s) are also ***zero***
- There is not pressure exerted from the external environment or solutes

Pure water



One may calculate the Ψ of a solution by using the following formula:

$$\Psi = \Psi_p + \Psi s$$

1) ***Addition of solutes:***

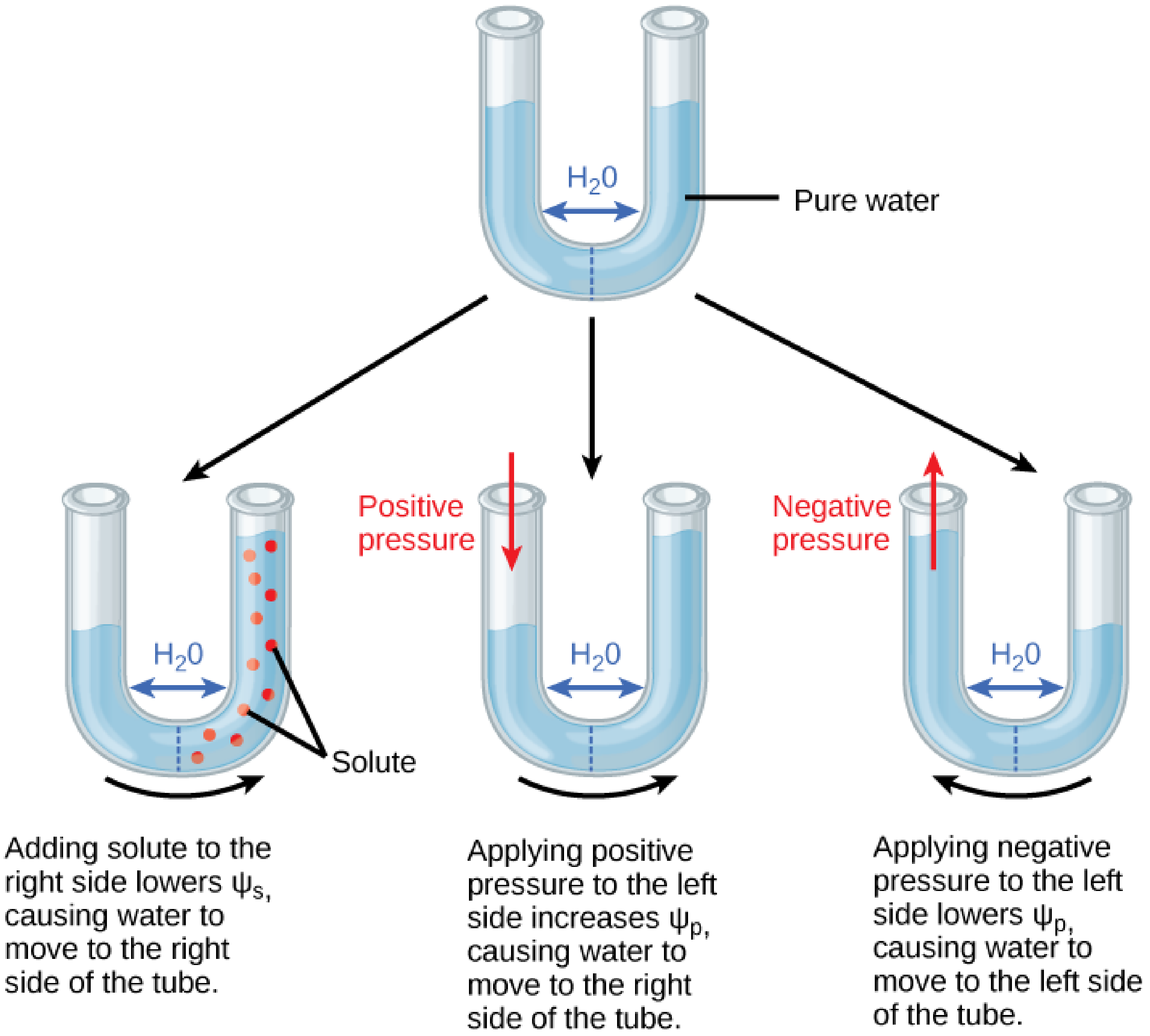
- Reduces water potential

2) ***Application of physical pressure***

- Increases water potential

3) ***Negative pressure***

- Decreases water potential

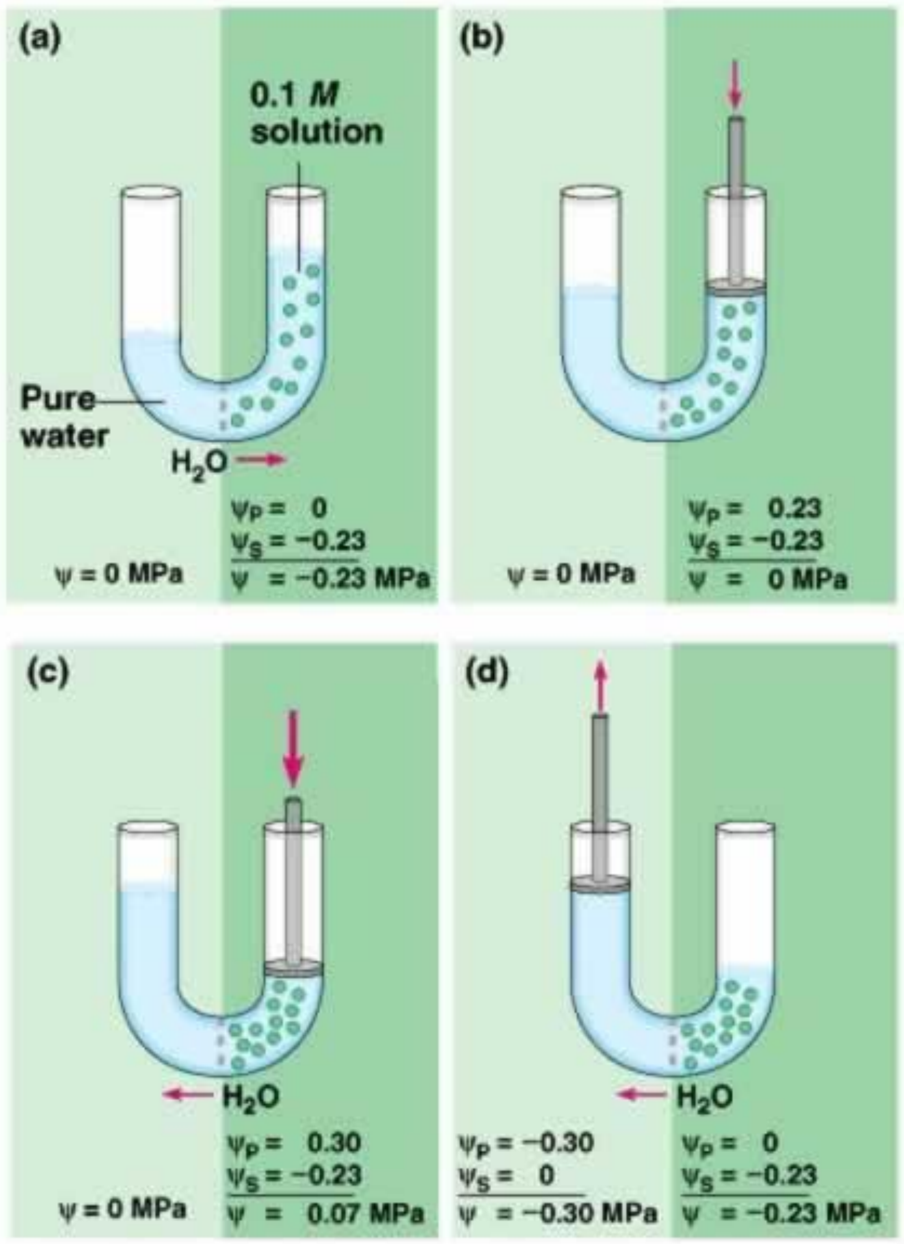


Addition of solute

Water moves towards the solute concentration

Positive pressure equivalent to solute pressure

Water has no net movement



Positive pressure that exceeds solute pressure

Water moves away from pressure and solute concentration

Negative pressure

Moves towards the negative pressure

Solute Potential (Ψ_s)

Considering that water potential (Ψ) is affected by solute potential (Ψ) , one must be able to calculate the value of (Ψ) to:

- Determine the water potential and consecutively the movement of water
- Calculate the amount of pressure being applied into the system.

EQUATION

$$\Psi s = - iCRT$$

i **:** ionization constant

C: molar concentration (mol/L)

R: pressure concentration (0.0831 L·bars/mol· K)

T: Temperature in Kelvin (273 + n ^{o}C)

Water Potential and Plant Cells

1) <u>To survive:</u>

- Plants must balance water uptake and loss

2) <u>Osmosis:</u>

- Determines the net uptake or water loss by a cell
- Is affected by solute concentration and pressure

How Solutes and Pressure Affect Water Potential

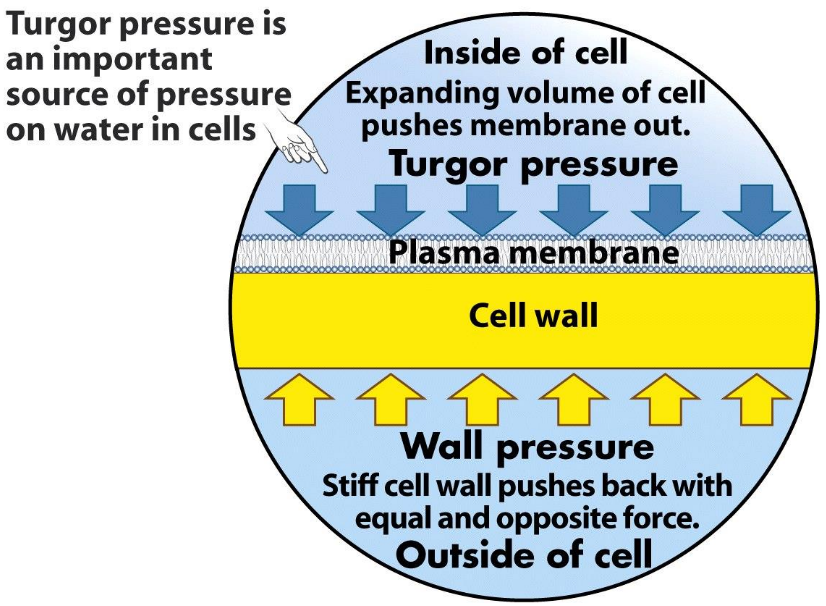
Both ***pressure*** and ***solute concentration*** can affect water potential.

Pressure potential:

- Is the physical pressure on a solution

Turgor Pressure: *pushes the plasma membrane against the cell wall of plant. This is caused by the flow of water from an area of low solute concentration outside the cell into the cell's vacuole, which has a higher solute concentration*

Pressure potential is the tendency of water to move in response to pressure.

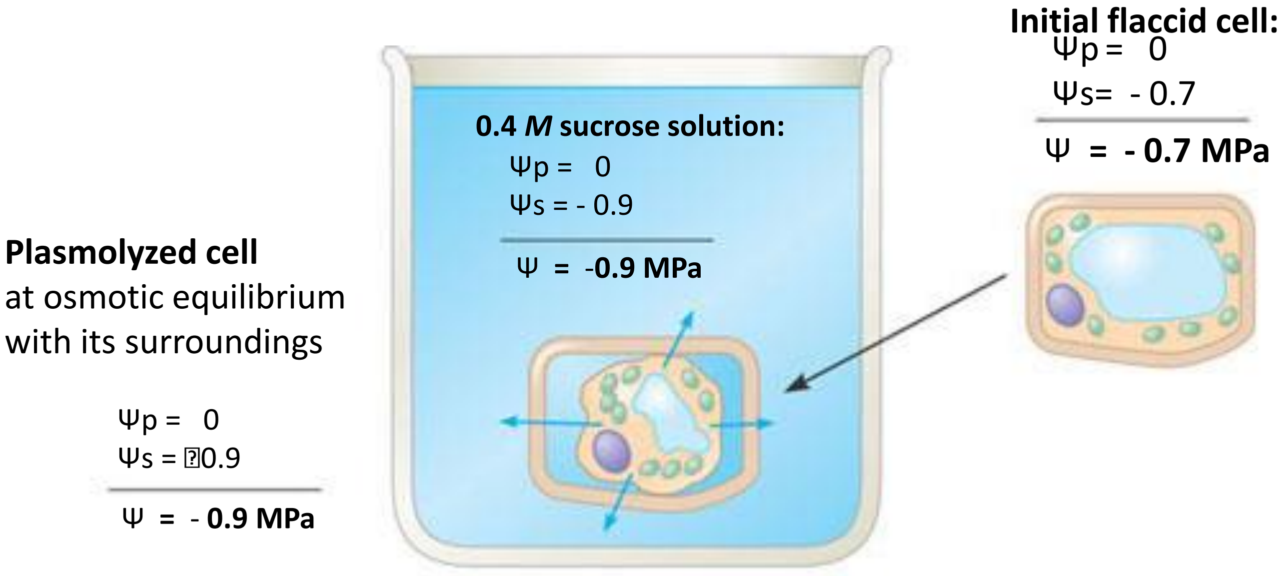


Water Potential in Plant Cells

Water potential can affect uptake and loss of water by plant cells

If a flaccid cell is placed in an environment with a higher solute concentration

- The cell will lose water and become plasmolyzed



Flaccid cells always have a pressure potential of zero.

Water Potential in Plant Cells

If the same flaccid cell is placed in a solution with a lower solute concentration

- The cell will gain water and become turgid

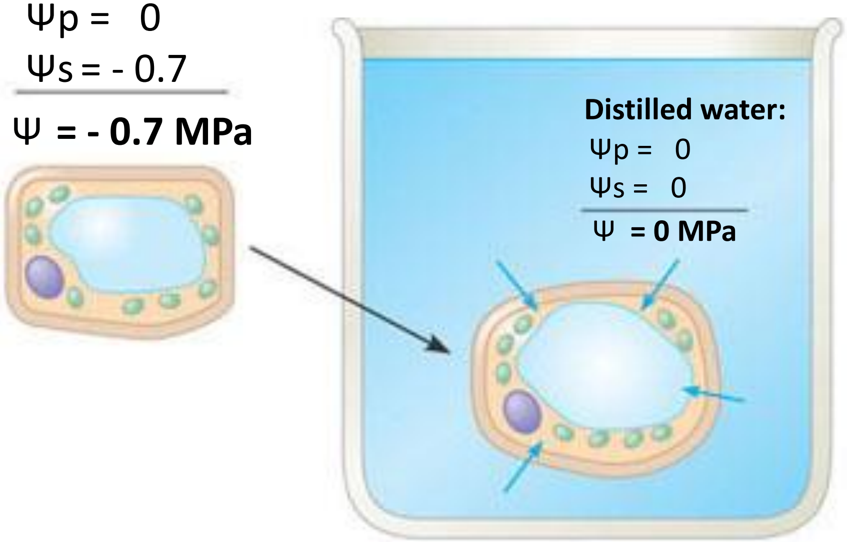
Turgid cells have a larger positive pressure potential because the water pressed on the cell wall and the cell wall presses back with an equal positive force.

Initial flaccid cell:

$\Psi p = 0$

$\Psi s = -0.7$

$\Psi = -0.7$ MPa



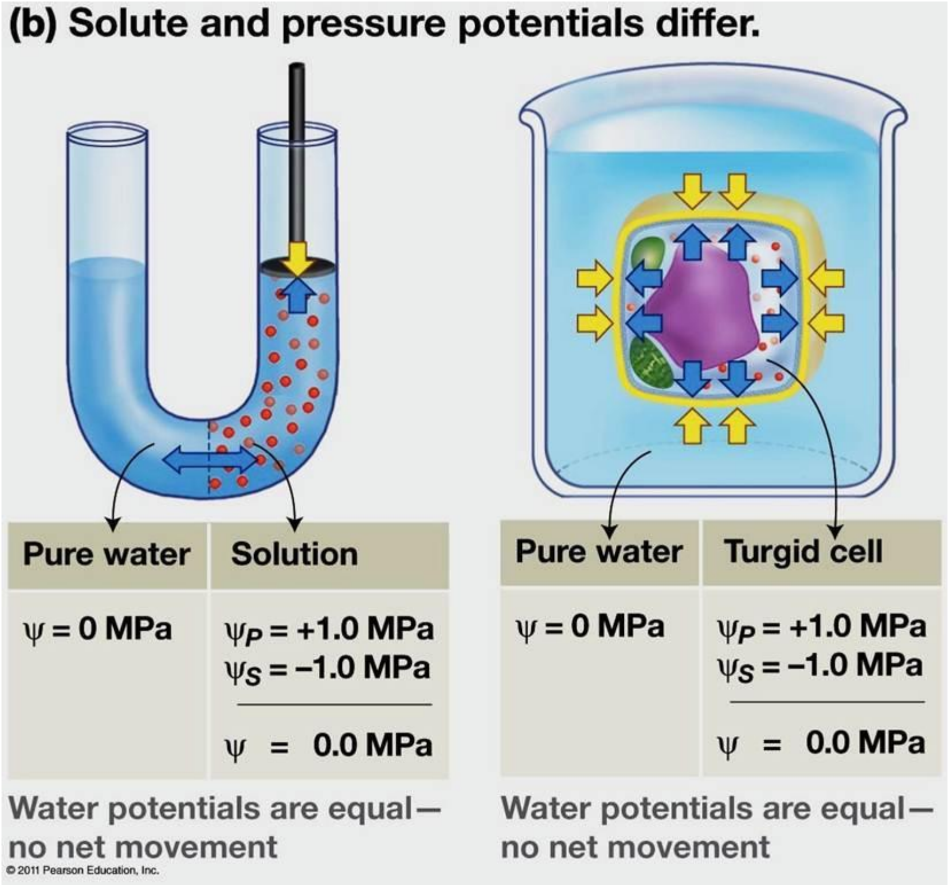
Turgid cell
at osmotic equilibrium
with its surroundings

$\Psi p = 0.7$

$\Psi s = -0.7$

$\Psi = -0$ MPa

Water Potential in Plant Cells



As water enters the cell, the cell wall exerts pressure and the water potential inside the cell also increases.

*Eventually **equilibrium** is reached and not further net movement of water occurs.*

Finding the Pressure the Cell Walls Exerts at Equilibrium

1) Flaccid potato cell containing 0.3 M solutes. Find the water potential and assume that room temperature is 22 ^{o}C.

Show your work:

Finding the Pressure the Cell Walls Exerts at Equilibrium

2) If this cell is then put into a beaker of 0.1 M sucrose what will happen?

Show your work:

Finding the Pressure the Cell Walls Exerts at Equilibrium

- Water potential (Ψ) of sucrose solution will still be approximately -2.45 bars

(the pressure and 0.1 M concentration will have remained nearly constant)

- At equilibrium the water potentials of the sucrose and cell contents will be the same. Thus, Ψ_{cell} = -2.45 bars

- Ψ_{solute} of the cell will still be – 7.35 bars since it will not have been diluted appreciably.

IN CELL: $\Psi = \Psi_p + \Psi_s$

-2.45 bars = Ψ_p + (-7.35 bars)

Ψ_p = 4.9 bars

No net movement of water because the water potential inside and outside of the cell are equal. The solute concentration is NOT equal. This phenomenon occurs due to the combination of the water potential and pressure potential of the cell.

Checking for Understanding

1. If a plant cell's Ψ_P = 2 bars and its Ψ_S = -3.5 bars, what is the resulting Ψ?

Show your work:

Checking for Understanding

2. The plant cell from the previous question is placed in a beaker of sugar water with Ψ_S = -4.0 bars. In which direction will the net flow of water be?

Show your work:

Checking for Understanding

3. The original cell from question # 1 is placed in a beaker of sugar water with Ψ_S = -0.15 MPa (megapascals). We know that 1 MPa = 10 bars. In which direction will the net flow of water be?

Show your work:

Checking for Understanding

4. The value for Ψ in root tissue was found to be -3.3 bars. If you place the root tissue in a 0.1 M solution of sucrose at 20°C in an open beaker, what is the Ψ of the solution, and in which direction would the net flow of water be?

Show your work:

Checking for Understanding

5. NaCl dissociates into 2 particles in water: Na+ and Cl-. If the solution in question 4 contained 0.1 M NaCl instead of 0.1 M sucrose, what is the Ψ of the solution, and in which direction would the net flow of water be?

Show your work: