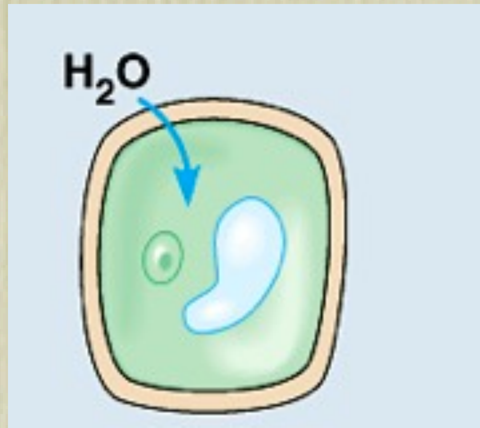
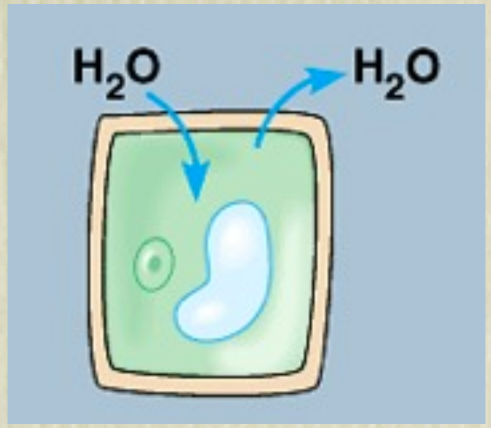
Why Does Water Move?

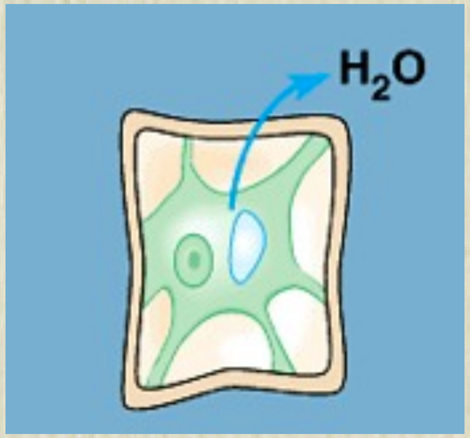
Water Movement



- **In and Out**
  - Water moves into cells
  - Water moves out of cells
  - Water moves into the roots of plants
  - Water moves out of the roots of plants



  - What are the forces that drive this movement?
  - Is it possible to quantify this process?



  - The good news is, “Yes!”
  - It revolves around a concept called **Water Potential**

Water Potential

- **Water Potential**
  - Measures the tendency of water to move from one place to another.
  - Very useful in understanding water movement in plants, animals, and the soil
  - Abbreviated by the Greek letter **ψ,** psi (pronounced: “sigh”)
- Key Ideas:
  - Water molecules move around randomly
  - When water is enclosed by a membrane the water molecules will hit the membrane, exerting pressure on it.
  - This **pressure** is known as **water potential**

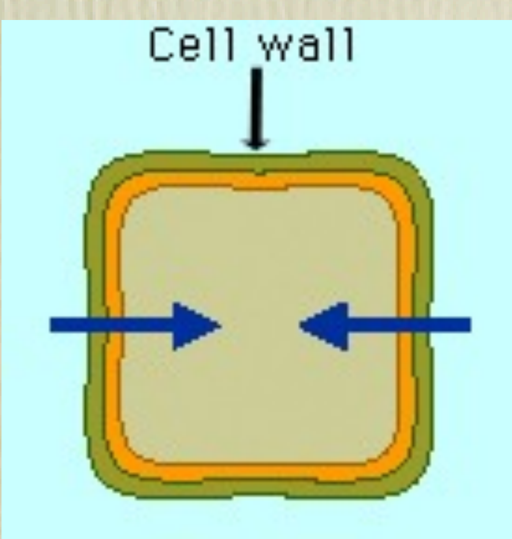
Water Potential- The Details

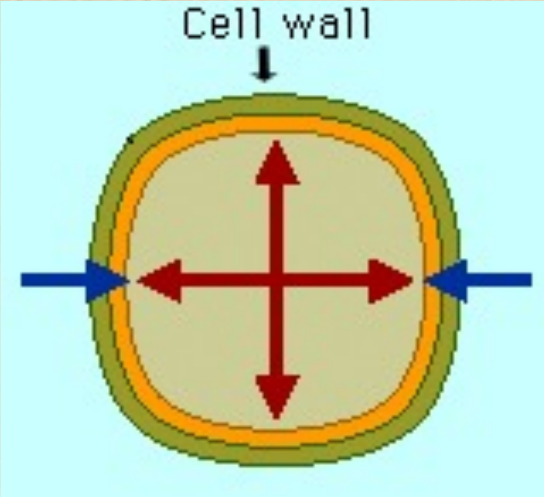
- It is measured in units of **pressure:**
  - Bar (bar)
  - Pascal (Pa)
- **Key Idea: Water** always moves from an area of **higher water potential** to **lower water potential**
- Two things determine **water potential (ψ)**
  - **Pressure Potential (ψ_p)**
  - **Solute Potential (ψ_s)**
- **It can be expressed in this formula:**
- **Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)**
- Let's take a look at these two factors in more detail, **pressure potential** and **solute potential. . .**

Pressure Potential (ψ_p)

Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)

- **Pressure Potential (ψ_p)**: How is it created? What is it?
  - A plant cell is surrounded by a rigid cell wall
  - When water enters the plant cell, its volume increases and the living part of the cell presses on the cell wall
  - The cell wall is rigid so **pressure** builds up inside the cell.
  - This tends to stop more water from entering the cell
  - This pressure, exerted by a plant cell wall that limits further water uptake, is called **pressure potential (ψ_p)**
  - If water is **not** in a cell, but in an **open container** the **pressure potential** = 0 bar, since no pressure can be exerted because the container is opened (i.e. nothing can "push back").





Solute Potential (ψ_s)

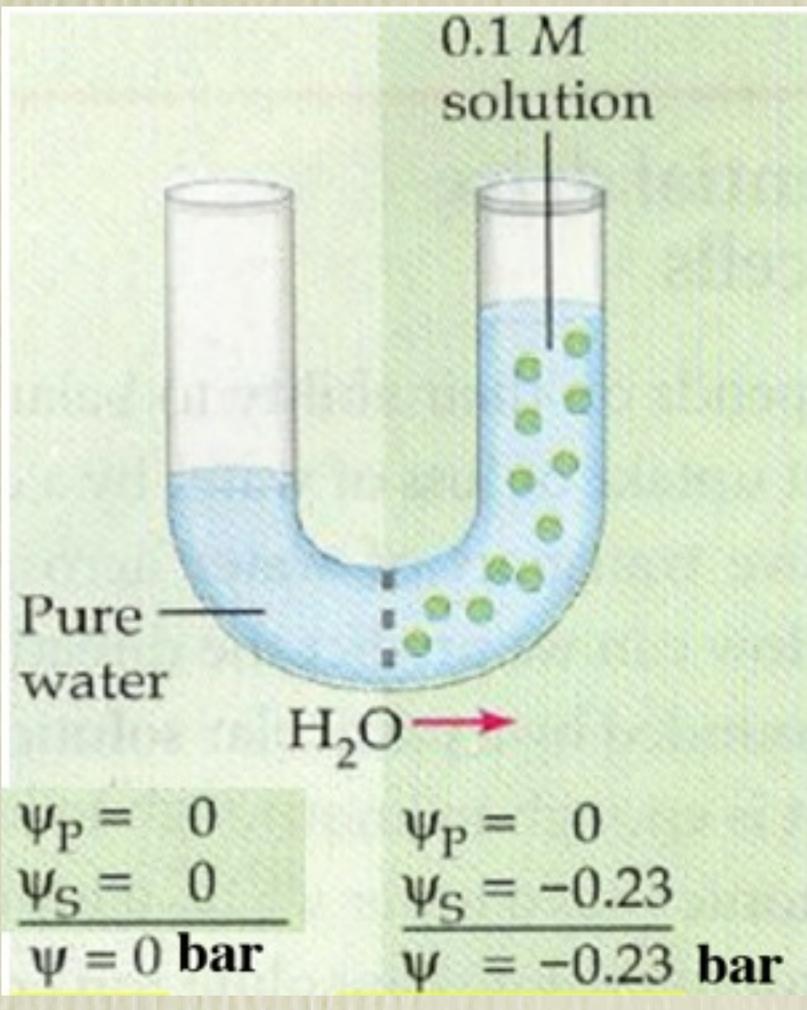
Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)

- **Solute Potential (ψ_s)**: How is it created? What is it?
  - The amount of solute in a solution effects the pressure.
    - **Pure water** has a **solute potential** = 0 bar, because there is no solute in the water.
    - Adding solute **lowers** the solute potential (i.e. it becomes more negative).
    - Therefore, solute potential is always zero or less than zero (a negative number). It is **never** positive.
- Let's put **pressure potential (ψ_p)** and **solute potential (ψ_s)** together and see how they influence **water potential (ψ)**, and therefore the movement of water into or out of a container.

Water Potential Problem (ψ)

Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)

- How to analyze a situation in which two containers are separated by a semipermeable membrane:

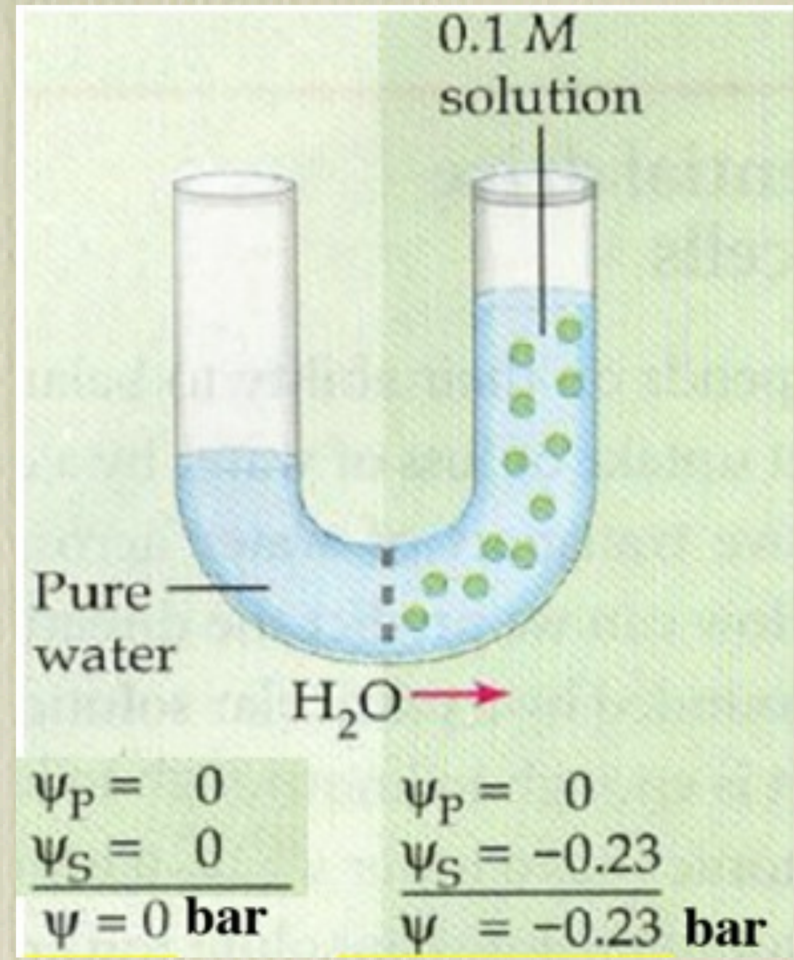


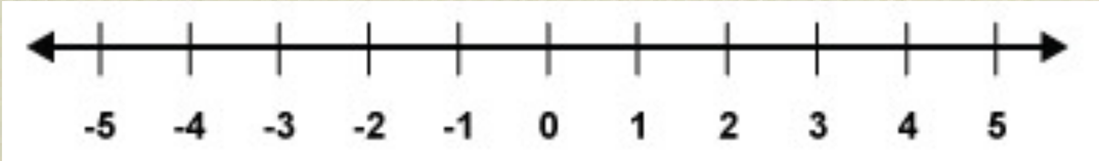
- **Left Side Container**
  - **Pressure Potential (ψ_p) = 0 bar**
    - Why? Because it is an open container and no pressure potential can be created in an open container.
  - **Solute Potential (ψ_s) = 0 bar**
    - Why? Because it is pure water and pure water has no solutes and therefore there is no solute pressure.
- How to calculate the **water potential** in the **left side container**
- **Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)**
- **Water Potential (ψ) = 0 bar - 0 bar = 0 bar**

Water Potential Problem (ψ)

Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)

- **Right Side Container**
  - **Pressure Potential (ψ_p) = 0 bar**
    - Why? It is an open container.
  - **Solute Potential (ψ_s) = -0.23 bar**
    - Why? Solutes have been added to the water creating a solute potential.
- **Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)**
- **Water Potential (ψ) = 0 bar - 0.23 bar = -0.23 bar**
- **Which way does the water move?**
- **Water** always moves from an area of **higher** **water potential** to **lower** **water potential**
- Look at the number line. What number is larger, **0 bar** or **-0.23 bar**?
  - **0 bar!** (this is the single most confusing thing about water potential problems so beware-using a number line helps, if you get confused)
- Therefore, water will move from the **0 bar** container to the **-0.23 bar** container (i.e. to the right).

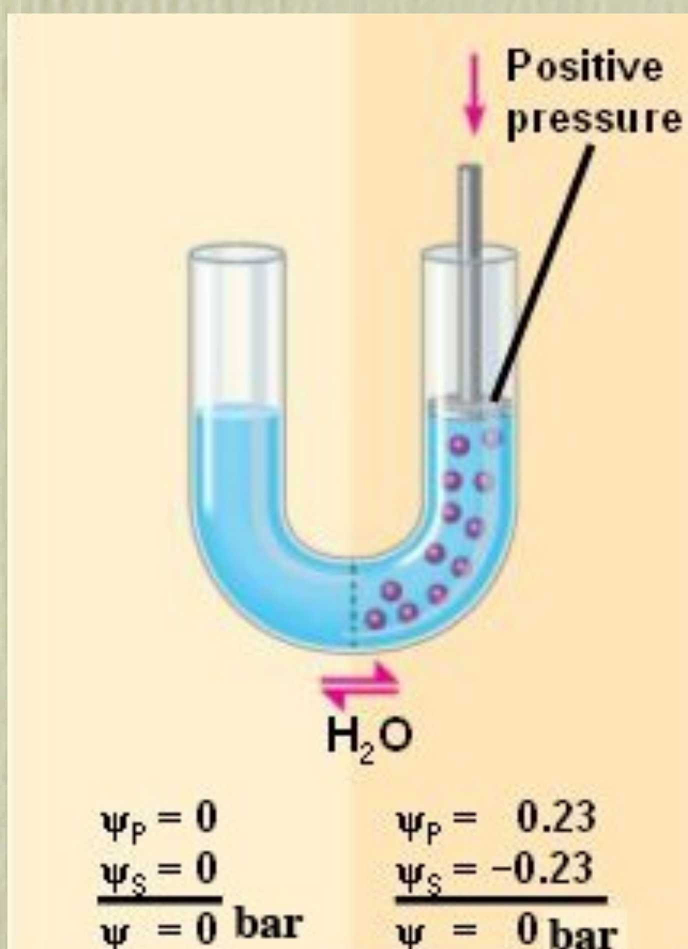




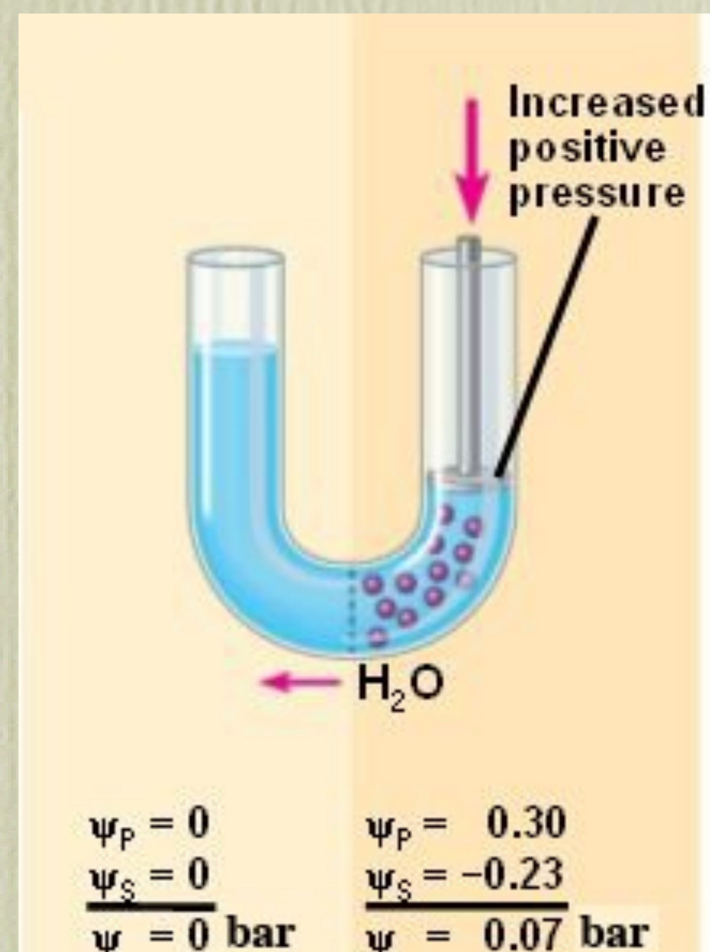
Water Movement

- The key idea to remember is that **water** always moves from an area of **higher <u>water potential</u>** to **lower <u>water potential</u>**
- We use the **Water Potential Equation** to determine which container has the higher or lower water potential, which will help us determine the direction of water flow. Let the equation guide your thinking in these 3 scenarios.

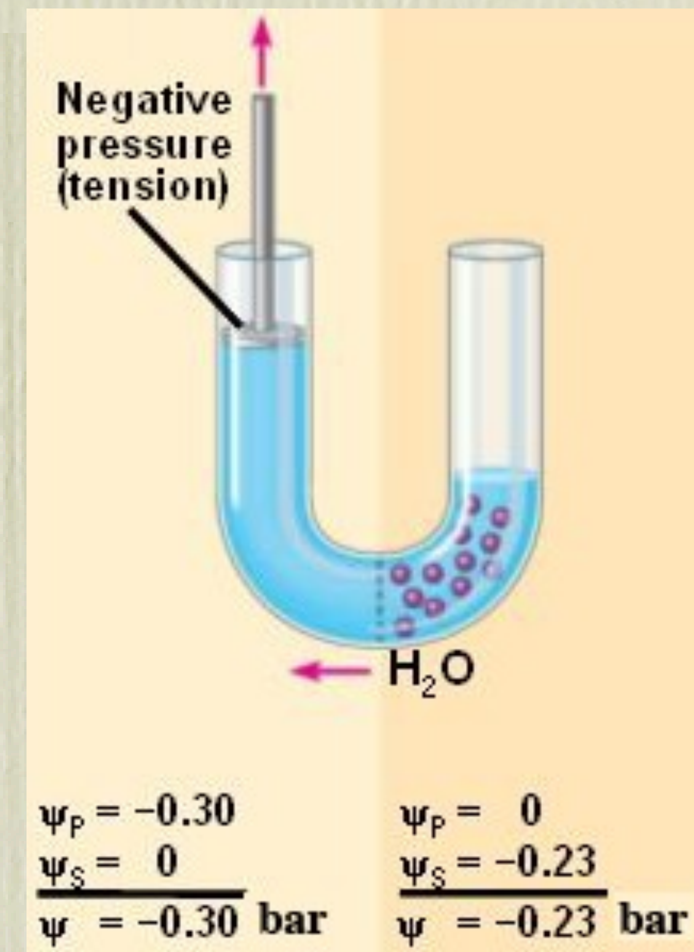
Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)



Scenario 1



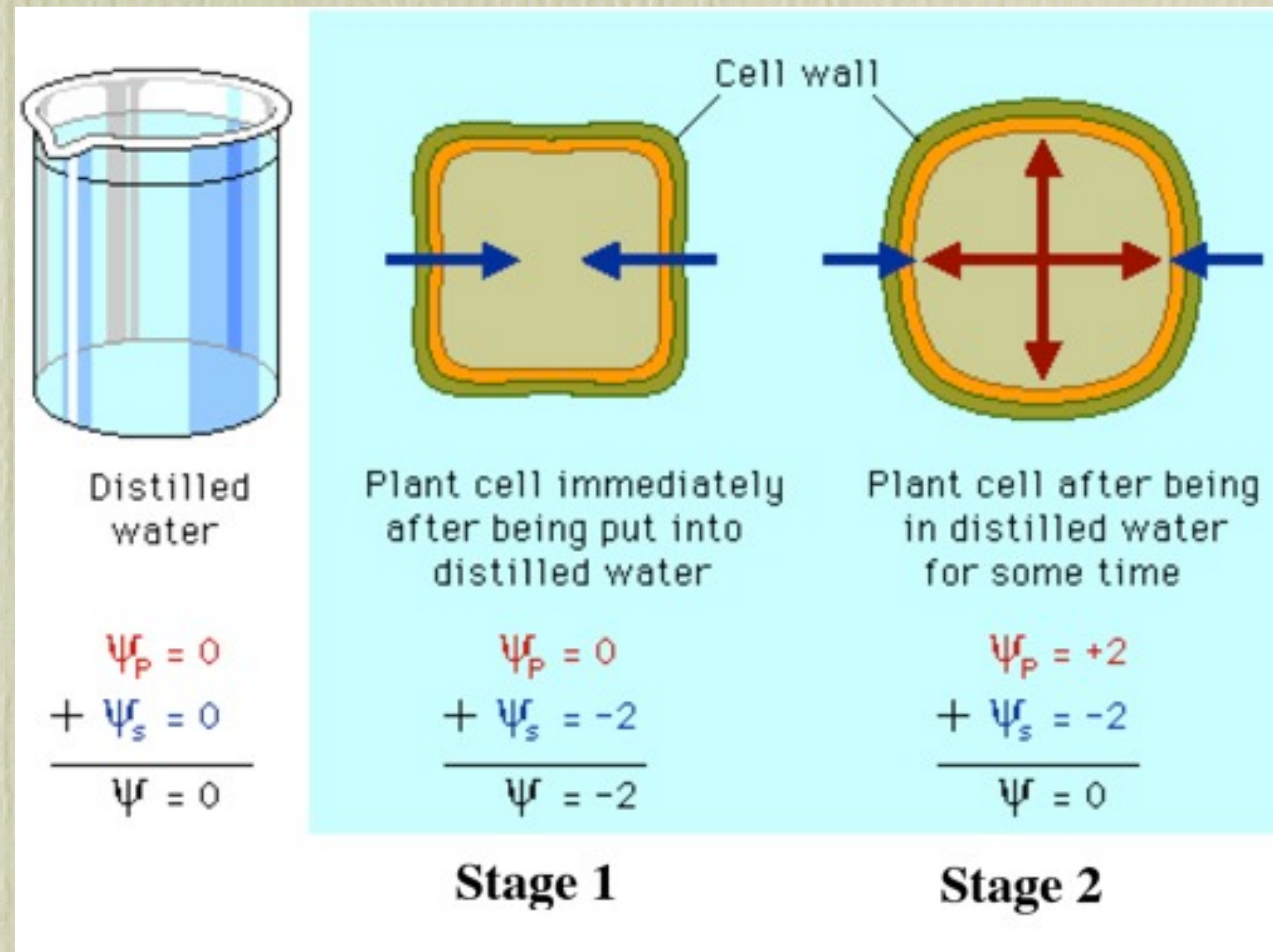
Scenario 2



Scenario 3

Plant Cell in Distilled Water

- Let's look at what happens when a plant cell is placed in distilled water
  - Use the Water Potential Equation to guide your thinking
  - **Water Potential (ψ) = Pressure Potential (ψ_p)** + **Solute Potential (ψ_s)**
  - The **Water Potential (ψ)** in the distilled water will be 0 bar.
  - In **Stage 1**, the plant cell has a **Solute Potential (ψ_s)** of - 2 bar, and a **Pressure Potential (ψ_p)** of 0 bar (no pressure potential has built up yet)
    - Therefore the **Water Potential (ψ)** is - 2 bar and water moves into the cell
  - In **Stage 2**, the plant cell has a **Solute Potential (ψ_s)** of - 2 bar (no solutes have been added or taken away from the cell), and a **Pressure Potential (ψ_p)** of 2 bar because the pressure potential has built up.
    - Therefore the **Water Potential (ψ)** is 0 bar and there is no net movement of water into or out of the cell.



Solute Potential (ψ_s) - Details

- Let's get quantitative with Solute Potential **(ψ_s)**
- Solute Potential **(ψ_s)** = -iCRT
  - i = the number of particles the molecule will make in water
    - For NaCl this would be 2 because it ionizes into Na^+ and Cl^-
    - For glucose this would be 1 because glucose does not ionize
  - C = the molar concentration of the solution
  - R = pressure constant = 0.0831 liter bar/ mole K
  - T = temperature in degrees Kelvin (273° + °C) of the solution
- Solute Potential **(ψ_s)** Example Problem: The molar solution of a sugar solution in a open container has been determined to be 0.3 M. Calculate the solute potential at 27°C. Round your answer to the nearest hundredth. Once you find the solute potential calculate the water potential.
  - Answer: Solute Potential **(ψ_s)** = -iCRT
  - **Solute Potential (ψ_s)** = - (1)(0.3 M)(0.0831 liter bar/ mole K)(300K) = -7.48 bar
- Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)
- **Water Potential (ψ)** = 0 bar - 7.48 bar = - 7.48 bar

Molarity- A Refresher

- In order to calculate Solute Potential (ψ_s) you may be expected to calculate the **molarity** of a solution. It may have been a while since you've calculated molarity so let's do a quick refresher.
- **Molarity**
  - A way of expressing concentration
  - Number of moles of solute dissolved in one liter of solution (moles/liter)
  - Formula for **Molarity= Moles of solute/liters of solution**
- Practice Problem: What is the molarity of a solution made by dissolving 2.5 g of NaCl in enough water to make 125 ml of solution?

$$\text{molarity} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

Molar Mass of NaCl

$$2.5\text{ g NaCl} \times \frac{1\text{ mole NaCl}}{58.5\text{ g NaCl}} = 0.0427\text{ mole}$$

$$\text{molarity} = \frac{0.0427\text{ mole NaCl}}{0.125\text{ L}}$$

$$= 0.34\ \underline{M}\text{ NaCl}$$

Summary

- Water is key to all living things and therefore understanding water movement is important is important in biology.
- If you want to be able to determine which way water moves (into or out of a cell or a container) you can use the **water potential equation** to guide your thinking:
  - Water Potential (ψ) = Pressure Potential (ψ_p) + Solute Potential (ψ_s)
- Things to remember about this equation:
  - The units used are units of pressure and will most likely be **bar** for the AP Bio test.
  - The **pressure potential** of an open container is 0 bar.
  - The **solute potential** of pure water is 0 bar.
    - Solute potential will always be 0 bar (pure water) or negative (if there is a solute).
  - If you need to calculate the **solute potential** use this equation:
    - Solute Potential **(ψ_s)** = -iCRT
  - After you have done all your calculations use this idea to guide your thinking about water movement:
    - **Water** always moves from an area of **higher** **<u>water potential</u>** to **lower** **<u>water potential</u>**