AP Biology Lab 1c Water Potential

In this part of the exercise you will use potato cores placed in different molar concentrations of sucrose in order to determine the water potential of potato cells. First, however, we will explore what is meant by the term "water potential."

Background:

$$\Psi = \Psi_p + \Psi_s$$

Water potential = Pressure potential + Solute potential

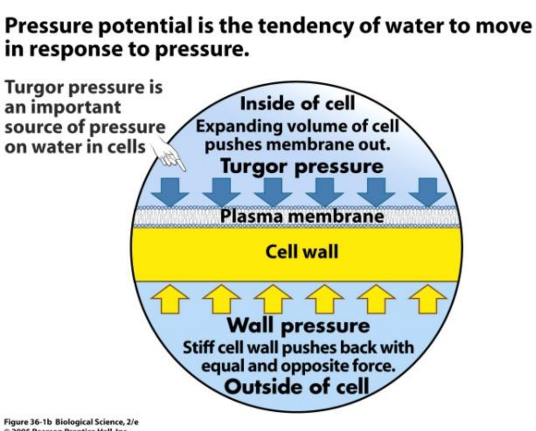
Botanists use the term water potential when predicting the movement of water into or out of plant cells. Water potential is abbreviated by the Greek letter psi (Ψ) and it has two components: a physical pressure component (pressure potential Ψ_p) and the effects of solutes (solute potential Ψ_s)

Water potential is affected by two physical factors.

- **One factor is the addition of solute which lowers the water potential.**
- **The other factor is pressure potential (physical pressure). An increase in pressure raises the water potential.**

By convention, the water potential of pure water at atmospheric pressure is defined as being zero (Ψ = 0).

Movement of H_2O into and out of a cell is influenced by the **solute potential** (relative concentration of solute) on either side of the cell membrane. If water moves out of the cell, the cell will shrink. If water moves into an animal cell, it will swell and may even burst. In plant cells, the presence of a cell wall prevents cells from bursting as water enters the cells, but pressure eventually builds up inside the cell and affects the net movement of water. As water enters a dialysis bag or a cell with a cell wall, pressure will develop inside the bag or cell as water pushes against the bag or cell wall. **It is important to realize that water potential and solute concentration are inversely related.** The addition of solutes lowers the water potential of the system. In summary, solute potential is the effect that solutes have on a solution's overall water potential.

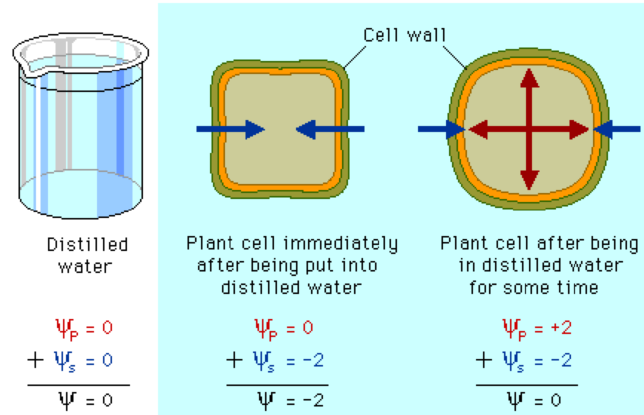


Movement of H_2O into and out of a cell is also influenced by the **pressure potential** (physical pressure) on either side of the cell membrane. Water movement is directly proportional to the pressure on a system. For example, pressing on the plunger of a water-filled syringe causes the water to exit via any opening. In plant cells this physical pressure can be exerted by the cell pressing against the partially elastic cell wall. Pressure potential is usually positive in living cells; in dead xylem elements it is often negative.

The water potential value can be positive, zero, or negative. Remember that water will move across a membrane in the direction of the lower water potential. An increase in pressure potential results in a more positive value and a decrease in pressure potential (tension or pulling) results in a more negative value. In contrast to pressure potential, **solute potential is always negative**; since pure water has a water potential of zero, any solutes will make the solution have a lower (more negative) water potential. **Generally, an increase in solute potential makes the water potential value more negative and an increase in pressure potential makes the water potential more positive.**

To illustrate the concepts discussed above, we will look at a sample system using Figure 1.2. When a solution, such as that inside a potato cell, is separated from pure water by a selectively permeable cell membrane, water will move (by osmosis) from the surrounding water where water potential is higher, into the cell where water potential is lower (more negative) due to the solute potential (Ψ_s). In Figure 1.2a the pure water potential (Ψ) is 0 and the solute potential (Ψ_s) is —3. *We will assume, for purposes of explanation that the solute is not diffusing out of the cell.*

By the end of the observation, the movement of water into the cell causes the cell to swell and the cell contents to push against the cell wall to produce an increase in pressure potential (turgor) (Ψ_p = 3). Eventually, enough turgor pressure builds up to balance the negative solute potential of the cell. When the water potential of the cell equals the water potential of the pure water outside the cell (v of cell = v of pure water = 0), a dynamic equilibrium is reached and there will be no *net* water movement (Figure 1.2b).



If you were to add solute to the water outside the potato cells, the water potential of the solution surrounding the cells would decrease. It is possible to add just enough solute to the water so that the water potential outside the cell is the same as the water potential inside the cell. In this case, there will be no net movement of water. This does not mean, however, that the solute concentrations inside and outside the cell are equal, because water potential inside the cell results from the combination of both pressure potential and solute potential (Figure 1.3).

If enough solute is added to the water outside the cells, water will leave the cells, moving from an area of higher water potential to an area of lower water potential. The loss of water from the cells will cause the cells to lose turgor. A continued loss of water will eventually cause the cell membrane to shrink away from the cell wall (plasmolysis).

Procedure: Day 1:

Work in groups. You will be assigned one or more of the beaker contents listed in Table 1.4. For each of these, do the following:

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Members						
0.0 *M*						
0.2 *M*						
0.4 *M*						
0.6 *M*						
0.8 *M*						
1.0 M						

\# - Instructions $Measure %Calculate

1. Pour 100 mL of the assigned solution(s) into a labeled 250-mL beaker. Slice a potato into discs that are slightly more than 3 cm thick.

2. Use a #2 cork borer (approximately 5 mm in inner diameter) to cut four potato cylinders. Using a razor, trim the cylinders to exactly 3cm in length. Do not include any skin on the cylinders. You need four potato cylinders for *each* beaker.
3. Keep your potato cylinders in a sealed vial until it is your turn to use the balance.
4. Determine the mass of the four potato cylinders and record their sum in Table 1.4. Put the four cylinders into the beaker of sucrose solution.
5. Cover the beaker with plastic wrap to prevent evaporation.
6. Place Beaker in Let it stand overnight.

Day 2:

7. Remove the cores from the beakers, blot them gently on a paper towel, and determine their total mass as you did yesterday.
8. Record the final mass in Table 1.4, calculate the Mass Difference and record.
9. Calculate the percentage change (Δm) using the following equation: $\Delta m = \left(\frac{M_f - M_i}{M_f}\right) X\ 100$
10. Record class data on the Spreadsheet in Google Docs (link on Site) and copy the results in Table 1.5.

$M_f = Final\ mass$
$M_i = Initial\ mass$

Table 1.4: Potato Core—Individual Data

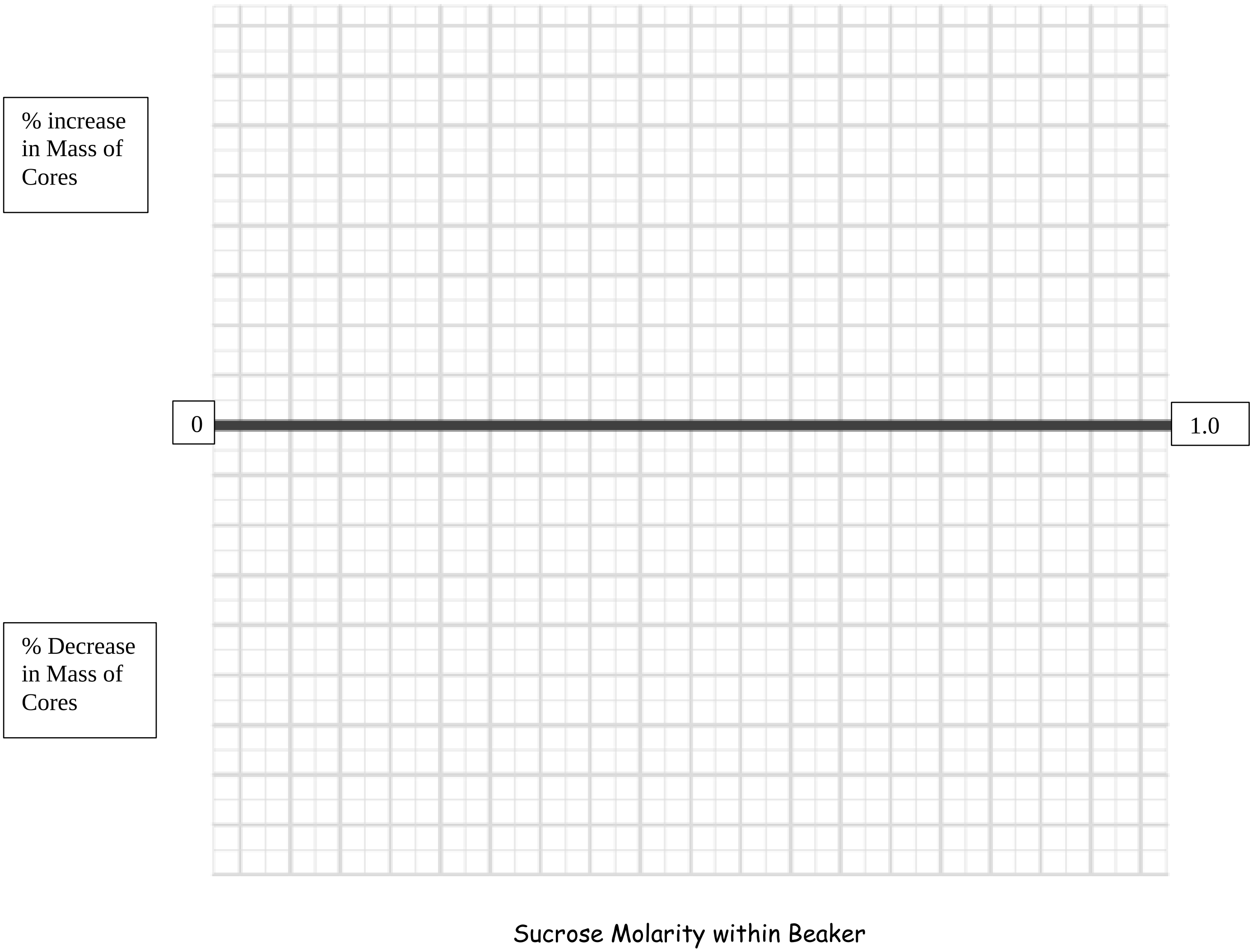
Contents in Beaker	Initial Mass	Final Mass	Mass Difference	Percent Change in Mass
a) 0.0 *M* Distilled Water				
b) 0.2 *M* Sucrose				
c) 0.4 *M* Sucrose				
d) 0.6 M Sucrose				
e) 0.8 *M* Sucrose				
f) 1.0 *M* Sucrose				

Table 1.5: Potato Core Results—Class Data

Contents of Beaker	Percent Change In Mass of Potato Cores							Total % change	Class Average
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7		
0.0 *M* Distilled Water									
0.2 *M* Sucrose									
0.4 *M* Sucrose									
0.6 *M* Sucrose									
0.8 *M* Sucrose									
***1.0 M* Sucrose**									

11. Graph the class average for the percentage change in mass.

Graph 1.2: Percent Change in Mass of Potato Cores at Different Molarities of Sucrose



10. Determine the molar concentration of the potato core. This would be the sucrose molarity in which the mass of the potato core does not change. To find this, follow your teacher's directions to draw the straight line on Graph 1.2 that best fits your data. **The point at which this line crosses the x-axis represents the molar concentration of sucrose with a water potential that is equal to the potato tissue water potential.** At this concentration there is no net gain or loss of water from the tissue. Indicate this concentration of sucrose in the space provided below.

Molar concentration of sucrose = ___________

AP Biology Lab 1c: Calculation of Water Potential from Experimental Data

i =	The number of particles the molecule will make in water; for NaCl this would be 2; for sucrose or glucose, this number is 1
C =	Molar concentration (from your experimental data)
R =	**Pressure constant = 0.0831 liter bar/mole K**
T =	Temperature in degrees Kelvin = 273 + °C of solution

1. The **solute potential** of this sucrose solution can be calculated using the following formula:

<u>Solute potential (Ψ_s) = –iCRT</u>

The units of measure will cancel as in the following example:

- A 1.0 M sugar solution at 22 °C under standard atmospheric conditions

$\psi_s = -i\ (C)(R)(T)$

$$\psi_s = -(1)\left(1.0\ \frac{\cancel{\text{mole}}}{\cancel{\text{liter}}}\right)\left(0.0831\ \frac{\cancel{\text{liter}}\ \textbf{bar}}{\cancel{\text{mole K}}}\right)(295\ \cancel{\text{K}})$$

Ψs = -24.51 bars

1. In an open system with only atmospheric pressure, the same amount of force is acting on both the beaker and the cells in it. That allows us to assume that the **pressure potential (ψ_p) of any open system is Zero**. Knowing the solute potential of the solution (ψ_s) and knowing the pressure potential of the solution is zero (ψ_p = 0) allows you to calculate the water potential of the solution. The water potential will be equal to the solute potential of the solution.

$\psi = \psi_p + \psi_s$
$\psi = 0 + \psi_s$
$\Psi = \Psi_s$

The water potential of the solution at equilibrium will be equal to the water potential of the potato cells. What is the water potential of the potato cells? Show your calculations here.

2. Water potential values are useful because they allow us to predict the direction of the flow of water. Suppose that a student calculates the water potential of a solution inside a bag is -6.25 bar and the water potential of a solution surround the bag is -3.25 bar. In which direction will the water flow?......Water will flow into the bag. This occurs because there are more solute molecules inside the bag (therefore a value further away from zero) than outside the solution.

Analysis Questions

1. If a potato core is allowed to dehydrate by sitting in open air, would the water potential of the potato cells decrease or increase? Why?

2. If a plant cell has a lower water potential than its surrounding environment and if pressure is equal to zero, is the cell hypertonic (in terms of solute concentration) or hypotonic to its environment? Will the cell gain water or lose water? Explain.

3. Consider what would happen to a red blood cell placed in distilled water:
   a. Which would have the higher concentration of water molecules? (Distilled water or Red Blood Cells)
   b. Which would have the higher water potential? (Distilled water or Red Blood Cells)
   c. What would happen to the red blood cell? Why?

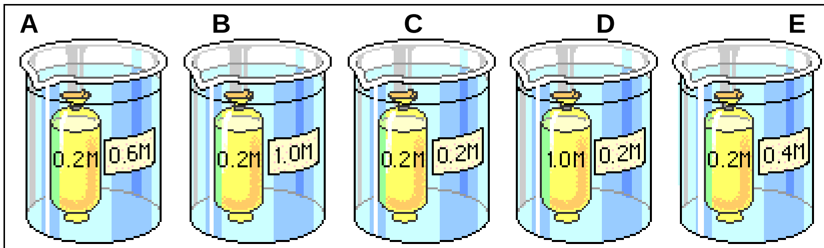


Fig 1.5

4. In Figure 1.5 the beakers are open to the atmosphere. What is the pressure potential (lvP) of the system?

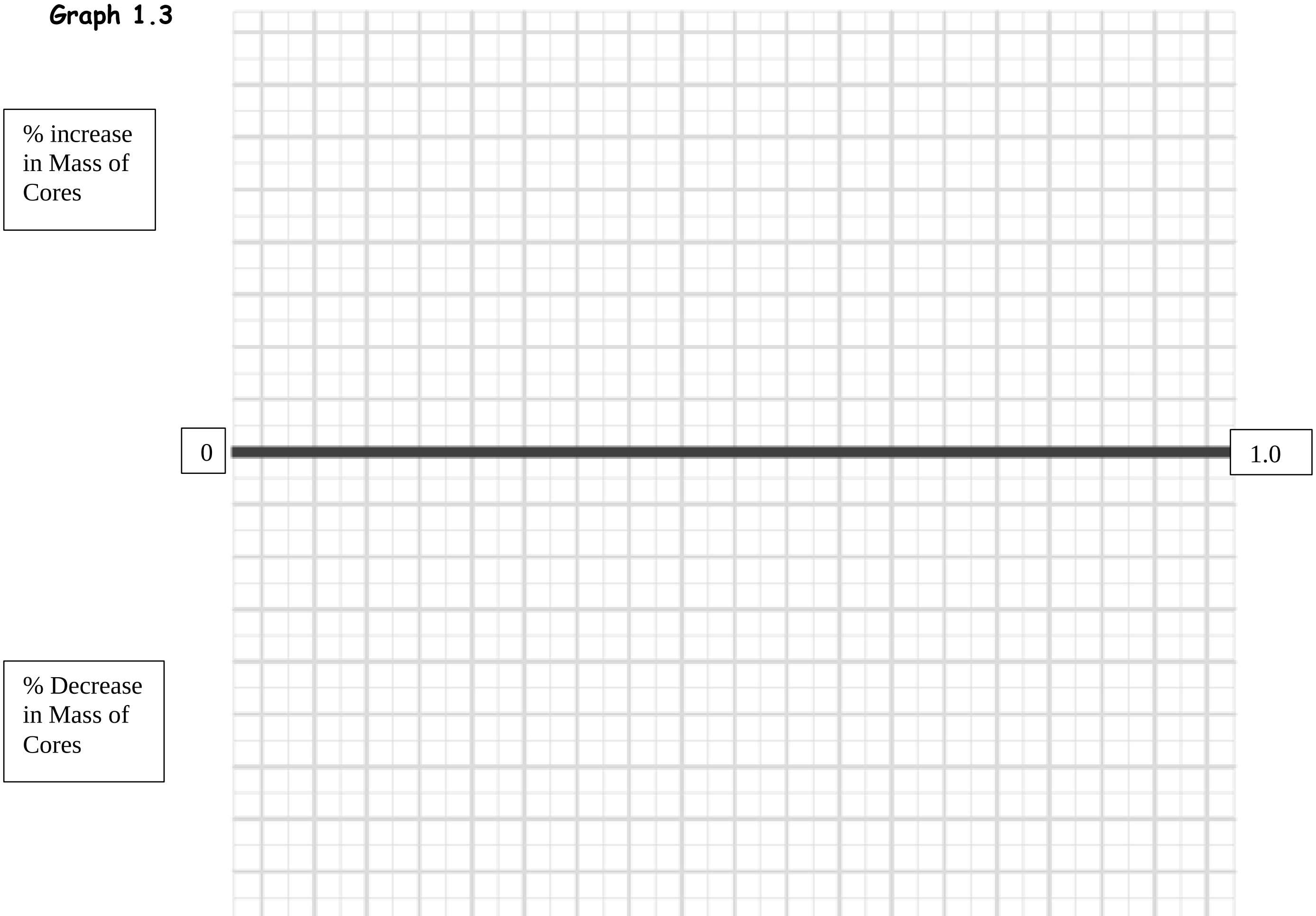
5. For each of the examples in Figure 1.5 circle where the greatest water potential is and which way water will want to move?
   A. beaker /dialysis bag   Into cell / out of cell
   B. beaker /dialysis bag   Into cell / out of cell
   C. beaker /dialysis bag   Into cell / out of cell
   D. beaker /dialysis bag   Into cell / out of cell
   E. beaker /dialysis bag   Into cell / out of cell

6. Zucchini cores placed in sucrose solutions at 27°C resulted in the following percent changes after 24 hours:

% Change in Mass	Sucrose Molarity
20%	Distilled Water
10%	0.2 **M**
–3%	*0.4M*
–17%	0.6 **M**
–25%	0.8 **M**
-30%	*1.0 M*

7. Graph the results on Graph *1.3.*

Graph 1.3



8. What is the molar concentration of solutes within the zucchini cells?

8. Refer to the procedure for calculating water potential from experimental data (page 6).

a. Calculate solute potential (ψ_s) of the sucrose solution in which the mass of the zucchini cores does not change. Show your work here:

b. Calculate the water potential (Ψ) of the solutes within the zucchini cores. Show your work here:

9. What effect does adding solute have on the solute potential component (ψ_s) of that solution? Why?

10. Consider what would happen to a red blood cell (RBC) placed in distilled water:

a. Which would have the higher concentration of water molecules? (Circle one.)

Distilled H_2O RBC

b. Which would have the higher water potential? (Circle one.)

Distilled H_2O RBC

c. What would happen to the red blood cell? Why?

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