At equilibrium, water potential is equal everywhere: $\Psi_{(cell)} = \Psi_{(solution)}$. Because the volume of the beaker is much larger than that of the cell, the tiny amount of water taken up by the cell does not significantly affect the solute concentration of the sucrose solution. Hence, Ψ_s, Ψ_p, and Ψ of the sucrose solution are not altered. Therefore, at equilibrium, $\Psi_{(cell)} = \Psi_{(solution)} = -0.244$ MPa.

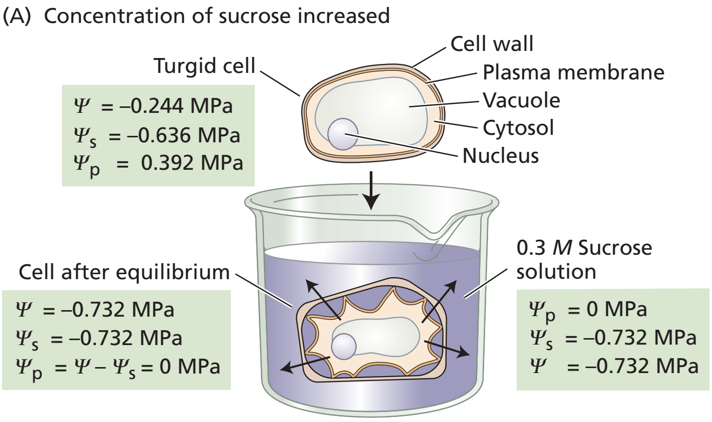
Calculation of cell Ψ_p and Ψ_s requires knowledge of the change in cell volume. In this example, let's assume that we know that the cell volume increased by 15%, such that the volume of the turgid cell is 1.15 times that of the flaccid cell. If we assume that the number of solutes within the cell remains constant as the cell hydrates, the final concentration of solutes will be diluted by 15%. The new Ψ_s can be calculated by dividing the initial Ψ_s by the relative increase in size of the hydrated cell: $\Psi_s = -0.732/1.15 = -0.636$ MPa. We can then calculate the pressure potential of the cell by rearranging Equation 3.5 as follows: $\Psi_p = \Psi - \Psi_s = (-0.244) - (-0.636) = 0.392$ MPa (see Figure 3.9C).

Water can also leave the cell in response to a water potential gradient

Water can also leave the cell by osmosis. If we now remove our plant cell from the 0.1 *M* sucrose solution and place it in a 0.3 *M* sucrose solution (**Figure 3.10A**), $\Psi_{(solution)}$ (–0.732 MPa) is more negative than $\Psi_{(cell)}$ (–0.244 MPa), and water will move from the turgid cell to the solution.

As water leaves the cell, the cell volume decreases. As the cell volume decreases, cell Ψ_p and Ψ decrease until $\Psi_{(cell)} = \Psi_{(solution)} = -0.732$ MPa. As before, we assume that the number of solutes within the cell remains constant as water flows from the cell. If we know that the cell volume decreases by 15%, the concentration of solutes will increase by 15%. Thus, we can calculate the new Ψ_s by multiplying the initial Ψ_s by the relative amount the cell volume has decreased: $\Psi_s = -0.636 \times 1.15 = -0.732$ MPa. This allows us to calculate that $\Psi_p = 0$ MPa using Equation 3.5.

If, instead of placing the turgid cell in the 0.3 *M* sucrose solution, we leave it in the 0.1 *M* solution and slowly squeeze it by pressing the cell between two plates (**Figure 3.10B**), we effectively raise the cell Ψ_p, consequently raising the cell Ψ and creating a $\Delta\Psi$ such that water now flows *out* of the cell. This is analogous to the industrial process of reverse osmosis in which externally applied pressure is used to separate water from dissolved solutes by forcing it across a semipermeable barrier. If we continue squeezing until half the cell's water is removed and then hold the cell in this condition, the cell will reach a new equilibrium. As in the previous example, at equilibrium, $\Delta\Psi = 0$ MPa, and the amount of water added to the external solution is so small that it can be ignored. The cell will thus return to the Ψ value that it had before


(A) Concentration of sucrose increased

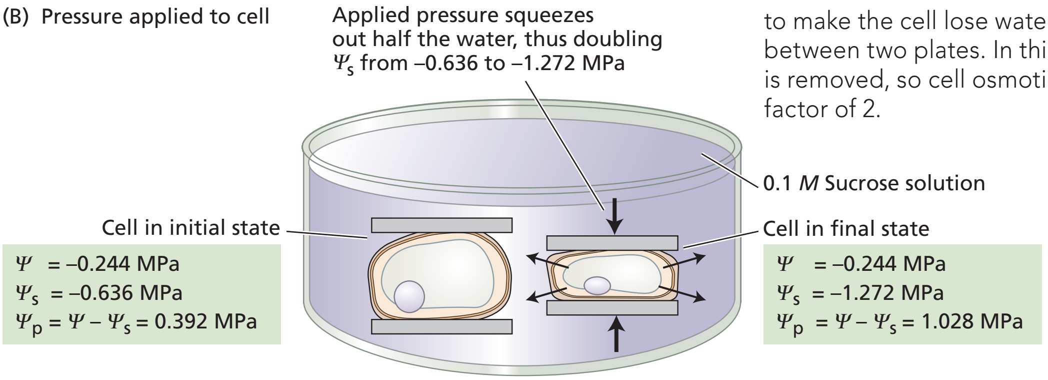

(B) Pressure applied to cell

Figure 3.10 Water potential gradients can cause water to leave a cell. (A) Increasing the concentration of sucrose in the solution makes the cell lose water. The increased sucrose concentration lowers the solution water potential, draws water out of the cell, and thereby reduces the cell's turgor pressure. In this case, the protoplast pulls away from the cell wall (i.e., the cell plasmolyzes), because sucrose molecules are able to pass through the relatively large pores of the cell walls. When this occurs, the difference in water potential between the cytoplasm and the solution is entirely across the plasma membrane, and thus the protoplast shrinks independently of the cell wall. In contrast, when a cell desiccates in air (e.g., as in the flaccid cell in Figure 3.9C), plasmolysis does not occur. Instead, the cell (cytoplasm + wall) shrinks as a unit, resulting in the cell wall being mechanically deformed as the cell loses volume. (B) Another way to make the cell lose water is to squeeze it slowly between two plates. In this case, half of the cell water is removed, so cell osmotic potential increases by a factor of 2.