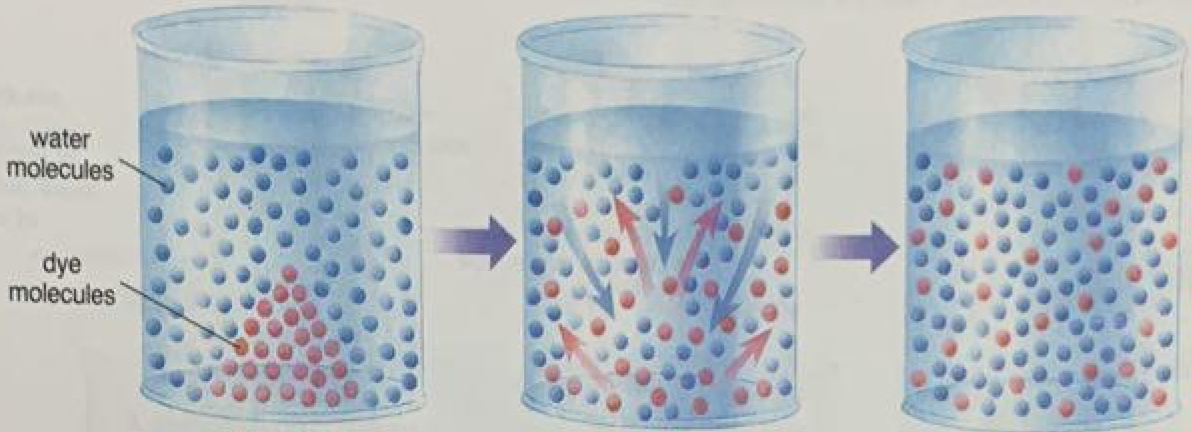
Figure 6.6

Process of diffusion is spontaneous and no energy is required to bring it about. ***a.*** When dye crystals are placed in water they are concentrated in one area. ***b.*** The dye dissolves in the water, and there is a net movement of dye molecules away from the area of concentration. There is a net movement of water molecules in the opposite direction. ***c.*** Eventually, the water and dye molecules are equally distributed throughout the container.



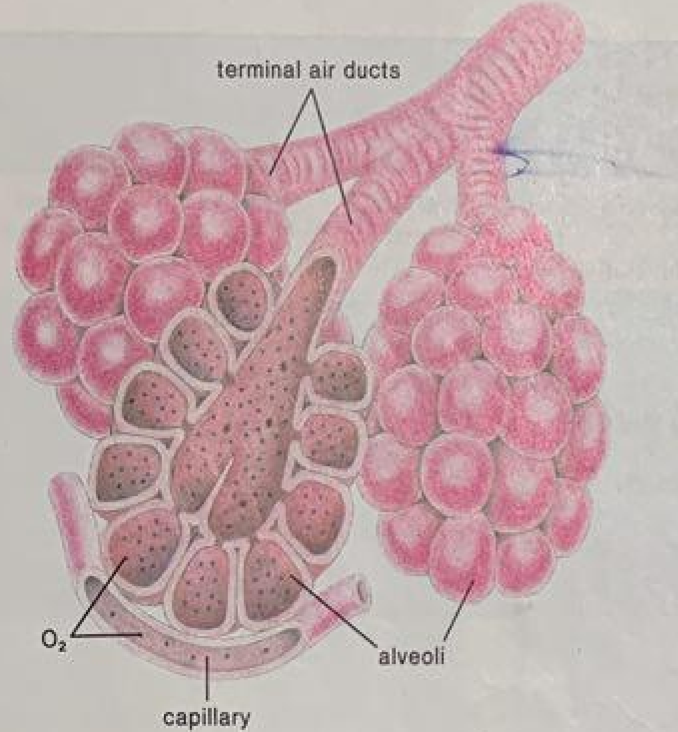
a. Crystal of dye is placed in water

b. Diffusion of water and dye molecules

c. Equal distribution of molecules results

Figure 6.7

Oxygen (dots) diffuses into the capillaries because there is a greater concentration of oxygen in the alveoli (air sacs) of the lungs than in the capillaries.



in the tube indicates the degree of **osmotic pressure** caused by the flow of water from the area of greater water concentration to the area of lesser water concentration.

Notice the following elements in this illustration of osmosis:

1. A selectively permeable membrane separates a solution from pure water.
2. A difference in solute and water concentrations exists on the 2 sides of the membrane.
3. The membrane is impermeable (does not permit passage) to the solute particles.
4. The membrane is permeable (permits passage) to the water, which moves from the area of greater water (lesser solute) concentration to the area of lesser water (greater solute) concentration.
5. An osmotic pressure is present; the amount of liquid increases on the side of the membrane with the greater solute concentration.

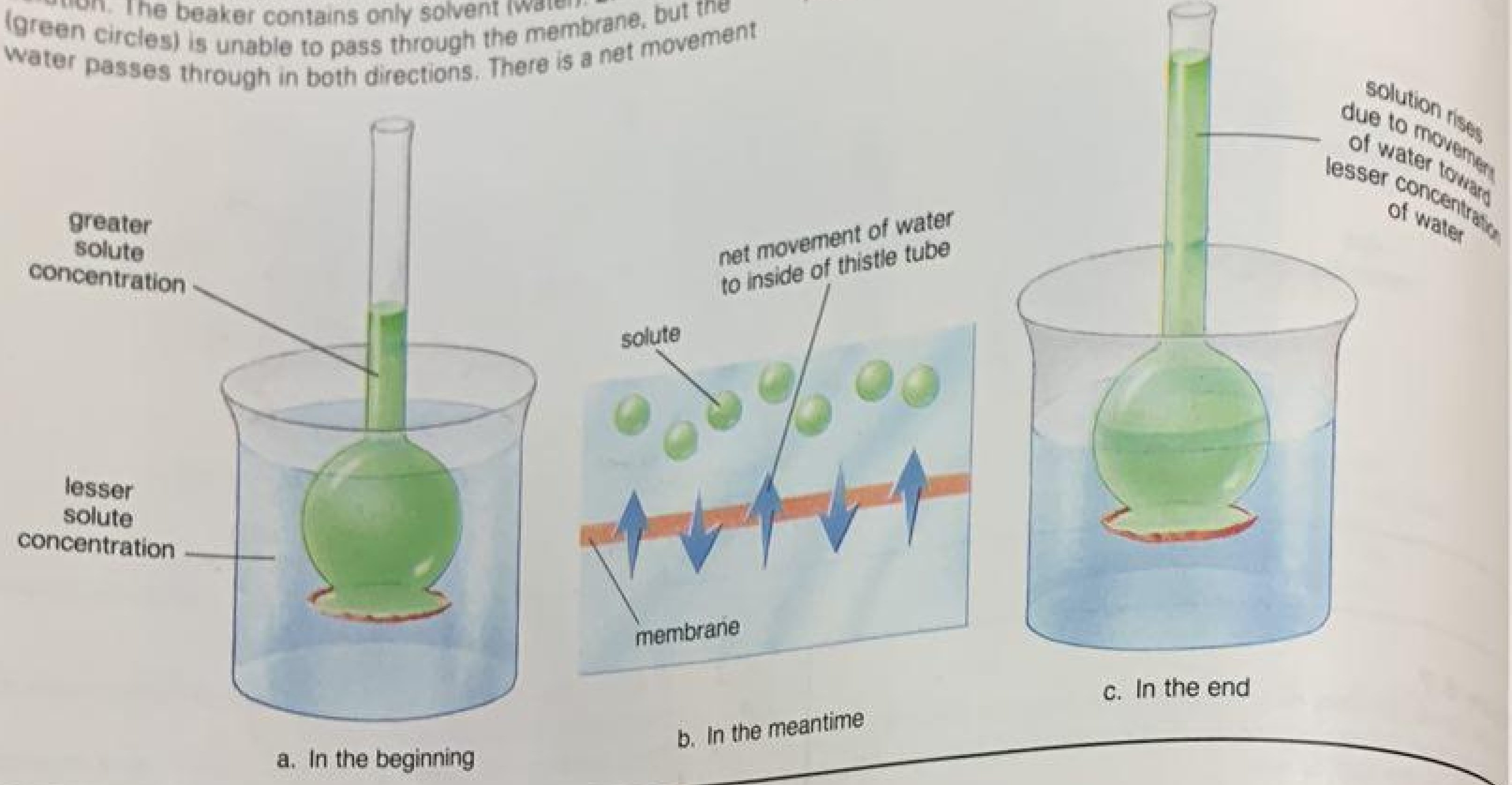
These considerations will be important as we discuss osmosis in relation to cells placed in different solutions. The plasma membrane is not completely impermeable to solutes such as sugars and salts, but the difference in permeability between water and these solutes is so great that cells do have to cope with the osmotic movement of water.

> Osmosis is the diffusion of water across a selectively permeable membrane. The presence of osmotic pressure is evident when there is an increased amount of water on the side of the membrane that has the greater solute concentration.

Tonicity

Cells can be placed in solutions that are isotonic, hypotonic, or hypertonic (table 6.1 and fig. 6.9). In an **isotonic solution,** a cell neither gains nor loses water because the concentration of solute and water is the same on both sides of the plasma membrane (*iso*—same as). Most animal cells normally live under isotonic conditions. For example, the tissue fluid that surrounds your cells is normally isotonic to them.

Figure 6.8
Osmosis demonstration. ***a.*** A thistle tube, covered at the broad end by a selectively permeable membrane, contains a sugar solution. The beaker contains only solvent (water). ***b.*** The solute (green circles) is unable to pass through the membrane, but the water passes through in both directions. There is a net movement of water toward the inside of the thistle tube, where the solute concentration is greater and the water concentration is lesser the end, the level of the solution rises in the thistle tube until a pressure equivalent to osmotic pressure builds.



a. In the beginning
b. In the meantime
c. In the end

In a **hypotonic solution,** a cell tends to gain water because the concentration of solute is lesser (*hypo*—less than) and the concentration of water is greater than that of the cell. Plants and algae that live in freshwater ponds live under hypotonic conditions. The cytoplasm and central vacuoles gain water, and the plasma membrane pushes against the rigid cell wall. The resulting pressure, called **turgor pressure,** helps give internal support to the cell. Even plants that live on land are dependent upon turgor pressure to keep them from wilting. Freshwater protozoans are not protected from osmotic swelling by a rigid cell wall, but they have a contractile vacuole that rapidly pumps out excess water (fig. 6.10).

In a **hypertonic solution,** a cell tends to lose water because the concentration of solute is greater (*hyper*—more than) and the concentration of water is less than that of the cell. When plant cells are placed in a hypertonic solution, it is possible to see that the cytoplasm has lost water and has undergone plasmolysis because the plasma membrane pulls away from the cell wall. Some organisms, such as marine fishes, live in a hypertonic environment. The gills of these fishes extrude salt from the blood, and the blood remains isotonic to the cells.

Cells can die when placed in a solution of unfavorable tonicity. For example, red blood cells will lyse (burst) when placed in a very hypotonic solution and will undergo crenation (dry up) when placed in a very hypertonic solution (fig. 6.9*e* and *f*). Organisms that live in environments with unfavorable tonicities have evolved mechanisms to keep the tonicity of cellular cytoplasm within a normal range.

Table 6.1
Effect of Osmosis on a Cell

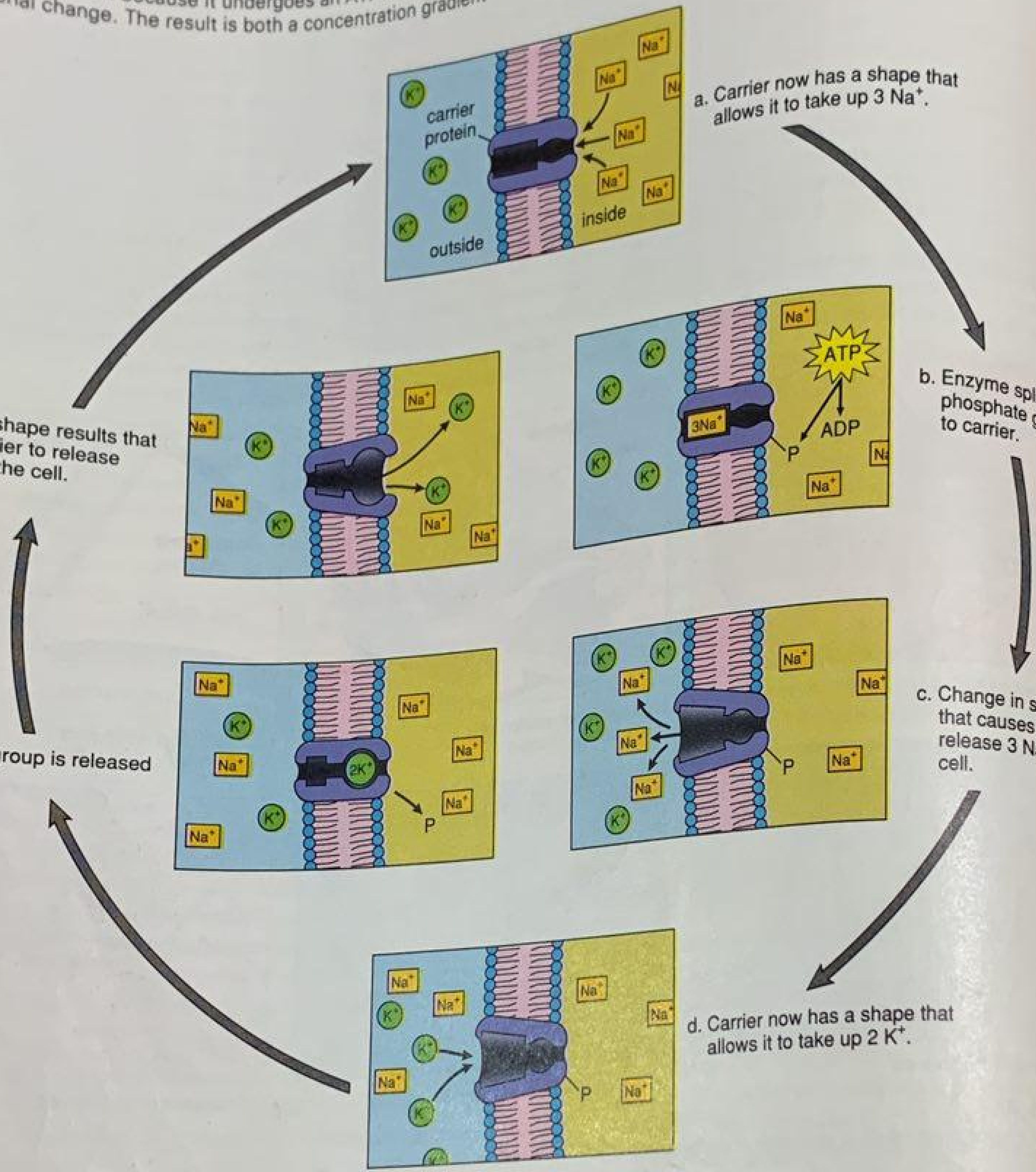
Tonicity of Solution	Concentrations		Net Movement of Water	Effect on Cell
	Solute	*Water*		
Isotonic	Same as cell	Same as cell	None	None
Hypotonic	Less than cell	More than cell	Cell gains water	Swells, turgor pressure
Hypertonic	More than cell	Less than cell	Cell loses water	Shrinks, plasmoly

When a cell is placed in an isotonic solution, it neither gains nor loses water. When a cell is placed in a hypotonic solution (lesser solute concentration than isotonic) the cell gains water. When a cell is placed in a hypertonic solution (greater solute concentration than isotonic), the cell loses water and the cytoplasm shrinks.

Transport by Carriers

The presence of the plasma membrane impedes the passage of but a few substances. Yet biologically useful molecules do and exit the cell at a rapid rate because there is a transport sys

Figure 6.12
The sodium-potassium pump. The same carrier protein transports sodium ions (Na^+) to the outside of the cell and potassium ions (K^+) to the inside of the cell because it undergoes an ATP dependent conformational change. The result is both a concentration gradient and an electrical gradient for these ions across the plasma m brane. Three sodium ions are carried outward for every 2 po ions carried inward; therefore, the inside of the cell is negativ charged compared to the outside.



a. Carrier now has a shape that allows it to take up 3 Na^+.

b. Enzyme splits ATP, a phosphate group at to carrier.

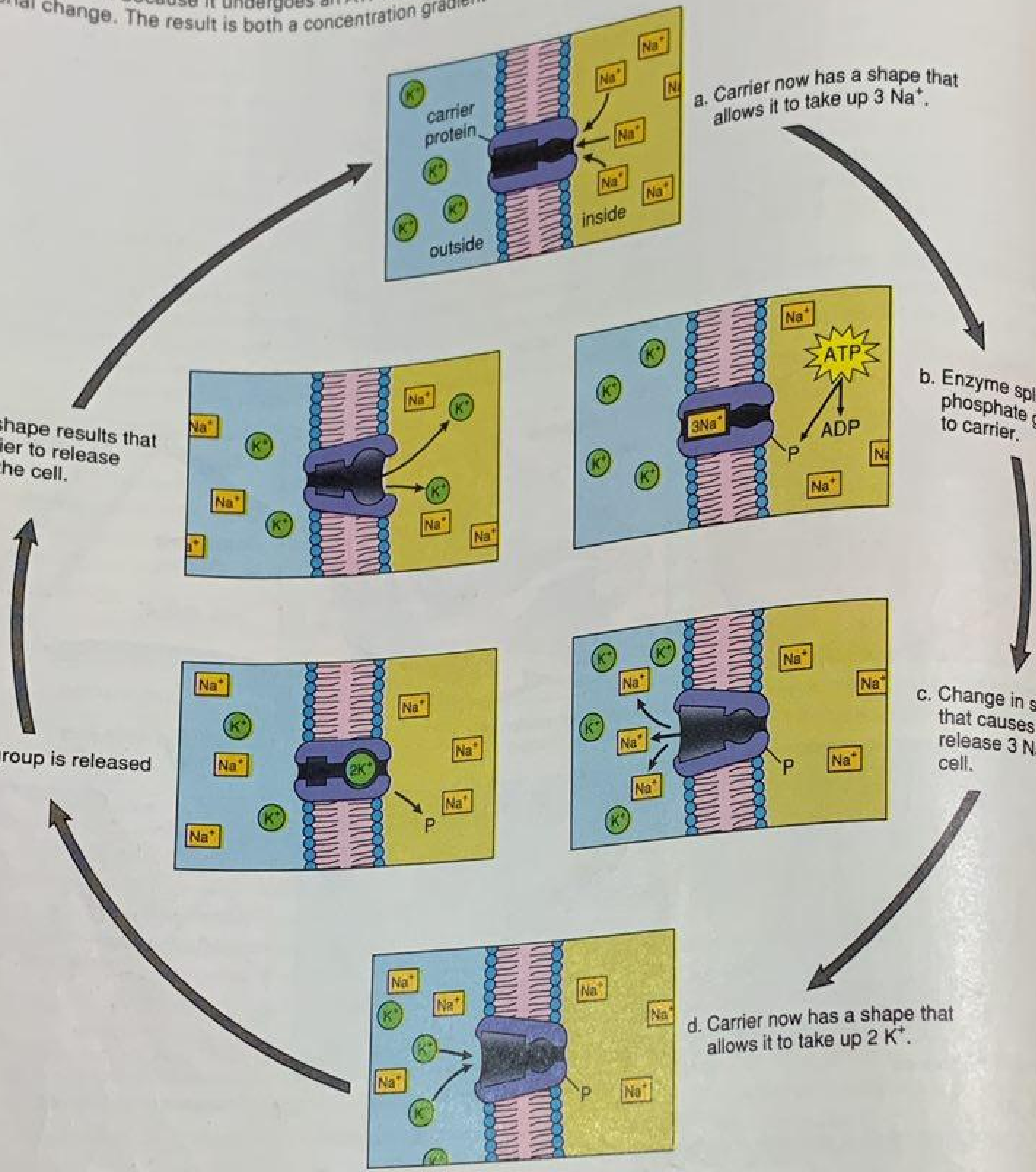
c. Change in shape resu that causes carrier to release 3 Na^+ outside cell.

d. Carrier now has a shape that allows it to take up 2 K^+.

e. Phosphate group is released from carrier.

f. Change in shape results that causes carrier to release 2 K^+ inside the cell.

Figure 6.12
The sodium-potassium pump. The same carrier protein transports sodium ions (Na^+) to the outside of the cell and potassium ions (K^+) to the inside of the cell because it undergoes an ATP dependent conformational change. The result is both a concentration gradient and an electrical gradient for these ions across the plasma m brane. Three sodium ions are carried outward for every 2 po ions carried inward; therefore, the inside of the cell is negativ charged compared to the outside.



a. Carrier now has a shape that allows it to take up 3 Na^+.

b. Enzyme splits ATP, a phosphate group attaches to carrier.

c. Change in shape results that causes carrier to release 3 Na^+ outside cell.

d. Carrier now has a shape that allows it to take up 2 K^+.

e. Phosphate group is released from carrier.

f. Change in shape results that causes carrier to release 2 K^+ inside the cell.