Figure 3.6 **Diffusion.** Molecules in solution move continuously and collide constantly with other molecules, causing them to move away from areas of their highest concentration and become evenly distributed. From left to right, molecules from a dye pellet diffuse into the surrounding water down their concentration gradient.

The Plasma Membrane: Membrane Transport

- **Relate plasma membrane structure to active and passive transport processes.**
- **Compare and contrast simple diffusion, facilitated diffusion, and osmosis relative to substances transported, direction, and mechanism.**

Our cells are bathed in an extracellular fluid called **interstitial fluid** (in″ter-stish′al) that is derived from the blood. Interstitial fluid is like a rich, nutritious "soup." It contains thousands of ingredients, including amino acids, sugars, fatty acids, vitamins, regulatory substances such as hormones and neurotransmitters, salts, and waste products. To remain healthy, each cell must extract from this mix the exact amounts of the substances it needs at specific times.

Although there is continuous traffic across the plasma membrane, it is a **selectively**, or **differentially, permeable** barrier, meaning that it allows some substances to pass while excluding others. It allows nutrients to enter the cell, but keeps many undesirable substances out. At the same time, it keeps valuable cell proteins and other substances in the cell, but allows wastes to exit.

Substances move through the plasma membrane in essentially two ways—passively or actively. In **passive processes**, substances cross the membrane without any energy input from the cell. In **active processes**, the cell provides the metabolic energy (ATP) needed to move substances across the membrane. The various transport processes that occur in cells are summarized in Table 3.1 on p. 72 and Table 3.2 on p. 80. Let's examine each of these types of membrane transport.

HOMEOSTATIC IMBALANCE

Selective permeability is a characteristic of healthy, intact cells. When a cell (or its plasma membrane) is severely damaged, the membrane becomes permeable to virtually everything, and substances flow into and out of the cell freely. This phenomenon is evident when someone has been severely burned. Precious fluids, proteins, and ions "weep" from the dead and damaged cells. ■

Passive Processes

The two main types of passive transport are *diffusion* (di-fu′zhun) and *filtration*. Diffusion is an important means of passive membrane transport for every cell of the body. Because filtration generally occurs only across capillary walls, that topic is more properly covered in conjunction with capillary transport processes later in the book.

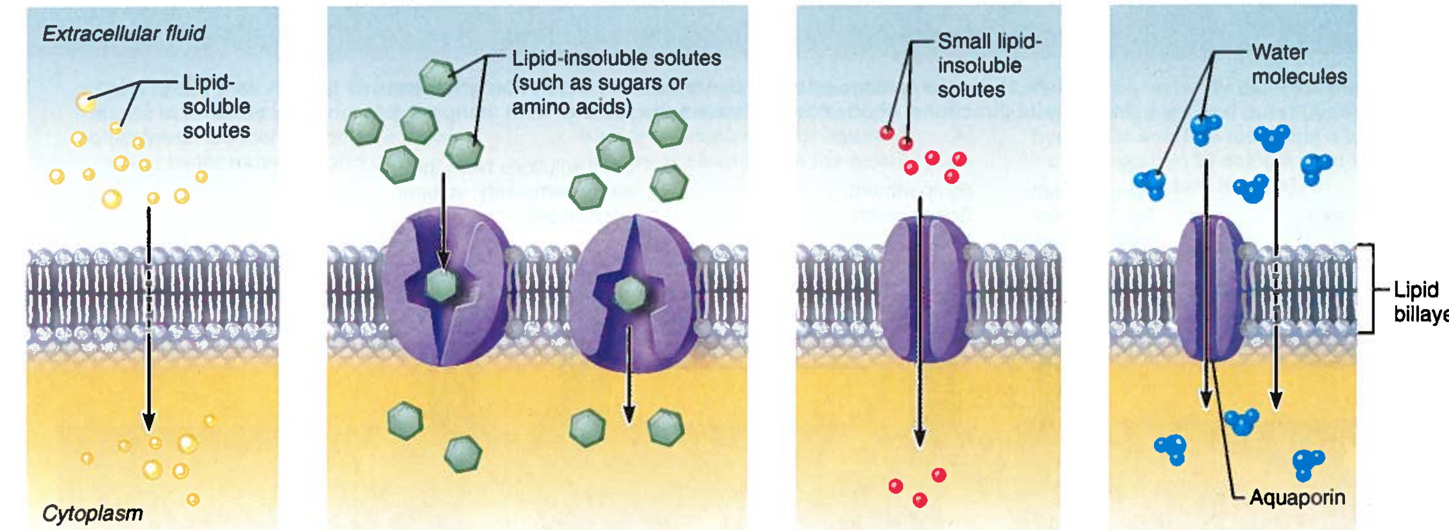
Diffusion

Diffusion is the tendency of molecules or ions to move from an area where they are in higher concentration to an area where they are in lower concentration, that is, down or along their **concentration gradient**. The constant random and high-speed motion of molecules and ions (a result of their intrinsic kinetic energy) results in collisions. With each collision, the particles ricochet off one another and change direction. The overall effect of this erratic movement is the scattering or dispersion of the particles throughout the environment (Figure 3.6). The greater the difference in concentration of the diffusing molecules and ions between the two areas, the more collisions occur and the faster the net diffusion of the particles.

Because the driving force for diffusion is the kinetic energy of the molecules themselves, the speed of diffusion is influenced by molecular *size* (the smaller, the faster) and by *temperature* (the warmer, the faster). In a closed container, diffusion eventually produces a uniform mixture of molecules. In other words, the system reaches equilibrium, with molecules moving equally in all directions (no *net* movement).

Diffusion is occurring all around us, but obvious examples of pure diffusion are almost impossible to see. The reason is that any diffusion process that occurs over an easily observable distance takes a long time, and is often accompanied by other processes (convection, for example) that affect the movement of molecules and ions. In fact, one should suspect any readily observable "example" of diffusion. Nonetheless, diffusion is immensely important in physiological systems and it occurs rapidly because the distances molecules are moving are very short, perhaps 1/1000 (or less) the thickness of this page! Examples include the movement of ions across cell membranes and the movement of neurotransmitters between two nerve cells.

The plasma membrane is a physical barrier to free diffusion because of its hydrophobic core. However, a molecule *will* diffuse



(a) Simple diffusion of fat-soluble molecules directly through the phospholipid bilayer

(b) Carrier-mediated facilitated diffusion via protein carrier specific for one chemical; binding of substrate causes shape change in transport protein

(c) Channel-mediated facilitated diffusion through a channel protein; mostly ions selected on basis of size and charge

(d) Osmosis, diffusion of a solvent such as water through a specific channel protein (aquaporin) or through the lipid bilayer

Figure 3.7 **Diffusion through the plasma membrane.**

through the membrane if the molecule is (1) lipid soluble, (2) small enough to pass through membrane channels, or (3) assisted by a carrier molecule. The unassisted diffusion of lipid-soluble or very small particles is called *simple diffusion.* A special name, *osmosis*, is given to the unassisted diffusion of a solvent (usually water) through a membrane. Assisted diffusion is known as *facilitated diffusion.*

Simple Diffusion In **simple diffusion**, nonpolar and lipid-soluble substances diffuse directly through the lipid bilayer (Figure 3.7a). Such substances include oxygen, carbon dioxide, and fat-soluble vitamins. Because oxygen concentration is always higher in the blood than in tissue cells, oxygen continuously diffuses from the blood into the cells. Carbon dioxide, on the other hand, is in higher concentration within the cells, so it diffuses from tissue cells into the blood.

Facilitated Diffusion Certain molecules, notably glucose and other sugars, some amino acids, and ions are transported passively even though they are unable to pass through the lipid bilayer. Instead they move through the membrane by a passive transport process called **facilitated diffusion** in which the transported substance either (1) binds to protein carriers in the membrane and is ferried across or (2) moves through water-filled protein channels.

- **Carriers** are transmembrane integral proteins that show specificity for molecules of a certain polar substance or class of substances that are too large to pass through membrane channels, such as sugars and amino acids. The most popular model for the action of carriers indicates that changes in the shape of the carrier allow it to first envelop and then release the transported substance, shielding it en route from the nonpolar regions of the membrane. Essentially, the binding site is moved from one face of the membrane to the other by changes in the conformation of the carrier protein (Figure 3.7b and Table 3.1).

  Note that a substance transported by carrier-mediated facilitated diffusion, such as glucose, moves down its concentration gradient, just as in simple diffusion. Glucose is normally in higher concentrations in the blood than in the cells, where it is rapidly used for ATP synthesis. So, glucose transport within the body is *typically* unidirectional—into the cells. However, carrier-mediated transport is limited by the number of protein carriers present. For example, when all the glucose carriers are "engaged," they are said to be *saturated*, and glucose transport is occurring at its maximum rate.

- **Channels** are transmembrane proteins that serve to transport substances, usually ions or water, through aqueous channels from one side of the membrane to the other (Figure 3.7c and d). Binding or association sites exist within the channels, and the channels are selective due to pore size and the charges of the amino acids lining the channel. Some channels, the so-called *leakage channels*, are always open and simply allow ion or water fluxes according to concentration gradients. Others are gated and are controlled (opened or closed) by various chemical or electrical signals.

  Like carriers, many channels can be inhibited by certain molecules, show saturation, and tend to be specific. Substances moving through them also follow the concentration gradient (always moving down the gradient). When a substance crosses the membrane by simple diffusion, the rate of diffusion is not controllable because the lipid solubility of the membrane is not immediately changeable. By contrast, the rate of facilitated diffusion *is* controllable because the