in which molecules move down the concentration gradient by means of transport proteins but without an input of energy, is called **facilitated diffusion**. Facilitated diffusion helps rid the cell of certain molecules present in high concentrations and moves molecules into the cell that are present on the outside in high concentrations. Aquaporins (see this chapter's opening story) are transport proteins that facilitate the movement of water molecules across cell membranes.

Facilitated diffusion has two essential characteristics: (1) it is *specific*, with only certain molecules being able to traverse a given channel, and (2) it is *passive*, with the direction of net movement being determined by the relative concentrations of the transported molecule inside and outside the membrane.

CONCEPT CHECKPOINT

6. A very overworked and tired first-year medical student is asked to do a red blood cell count on a patient. She extracts some blood and places a tiny drop on a slide that has several larger drops of distilled water on it. When she looks at the red blood cells under the microscope, she notices that they are swollen with water and some have burst. Explain to her why this has happened.
7. What would happen to cells from the leaf of a plant if they were placed in the distilled water on the slide?

5.14 Active transport is molecular movement that requires energy.

Cells often move substances into or out of the cell *against* the gradients of concentration, pressure, and electrical charge. A cell uses energy to move molecules against a gradient much like you might use energy to move something against gravity. For example, if you are driving downhill, you can put your car into neutral and coast (although that is not the safest way to drive downhill). The car will continue to move without a push from the engine. As soon as you come to a hill, however, you must put the car in gear and press on the accelerator or the car will soon come to a stop. Cells, too, need to use energy to move molecules uphill, or against a gradient, and cells also need to expend energy to move large molecules or particles into the cell that cannot move across the cell membrane.

A cell takes up or eliminates many molecules and ions against a concentration gradient. These molecules and ions enter and leave cells by way of a variety of selectively permeable transport channels. In all these cases, a cell must expend energy to transport these molecules against the concentration gradient and maintain the concentration difference. This type of transport is called **active transport**. Active transport is one of the most important functions of any cell. Without it, the cells of your body would be unable to maintain the proper concentrations of substances they need for survival.

An example of an important active transport mechanism in animal cells is a plasma membrane protein called the *sodium-potassium pump*. (Such active transport proteins are often called pumps.) More than one-third of all the energy expended by an animal cell that is not dividing is used to actively transport sodium ions (Na^+) out of the cell and potassium ions (K^+) into the cell. A steep gradient of these ions is necessary for various cell functions, but most importantly for nerve cells to carry impulses and muscle cells to contract. The type of channel by which *both* ions are transported across the cell membrane in opposite directions is called a coupled channel, which has binding sites for both molecules on one membrane transport protein.

The sodium-potassium pump uses energy to power its shape changes that move Na^+ and K^+ ions across the cell membrane (**Figure 5.26** ❶). The energy is supplied when a molecule of adenosine triphosphate (ATP) is broken down into adenosine diphosphate (ADP) and a phosphate group (shown as P). ATP is often used to power chemical reactions in cells; it is discussed in more detail in Chapter 6. Sodium ions are moved out of the cell to maintain a low internal concentration relative to the concentration outside the cell ❷. Conversely, potassium ions are moved into the cell to maintain a high internal concentration relative to the concentration outside the cell ❸. Three sodium ions are moved out for every two potassium ions that are moved in by the channel.

5.15 Cells move large molecules and particles into the cell by endocytosis.

Certain types of cells transport particles, small organisms, or large molecules such as proteins into their cells. In humans, for example, white blood cells police the body fluids and ingest substances as

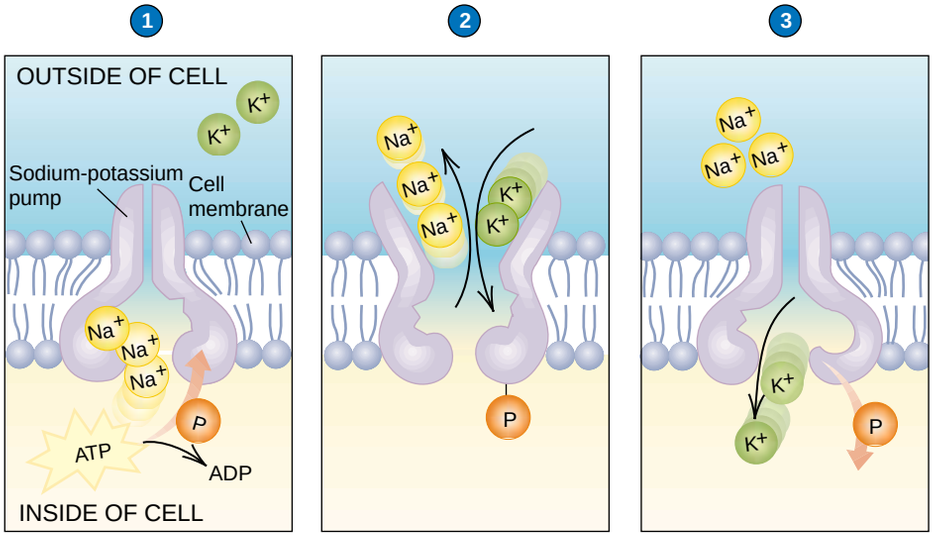

Figure 5.26 The sodium-potassium pump uses energy to move sodium ions (Na^+) out of an animal cell and potassium ions (K^+) into the cell.

Visual Thinking: How does the illustration show that energy is being used to move sodium and potassium ions?