Instructor’s Answer Key

Chapter 6: Interactions Between Cells and the Extracellular Environment

Answers to Test Your Understanding of Concepts and Principles

1. For osmosis to occur, two solutions of unequal concentrations must be separated by a membrane that is permeable to water but relatively impermeable to at least one of the solutes. Osmosis occurs under these conditions because the random movement of water molecules results in the net diffusion of water from the more dilute to the more concentrated solutions. [Note: This question is also answered in the Student Study Guide.]

2. Simple diffusion is movement from higher to lower concentration and does *not* display the properties of specificity, saturation, or competition. Because specific membrane carriers mediate facilitated diffusion all of these properties are displayed. Active transport can be distinguished from passive transport by its dependence on cellular metabolism and the continued production of ATP. If a cell is killed, so that it no longer produces ATP, active transport ceases but passive transport can continue. Active transport also involves the net movement of molecules or ions against their concentration gradient, while passive transport involves the net movement of molecules or ions down their concentration gradient.

3. The theoretical membrane equilibrium potential for K^+ is generally more negative than the true resting membrane potential. This is because in a real cell, ions other than K^+—principally Na^+—contribute to the resting potential. Some Na^+ leaks into the cell and in turn some K^+ escapes out of the cell. Because these leaks are stabilized by the action of the Na^+/K^+ pumps, the true resting membrane potential is maintained close to, but less than (at a less negative value than) the theoretical membrane K^+ equilibrium at -90 mV.

4. The Na^+/K^+ pumps are constantly active and serve to stabilize the concentration of Na^+ and K^+ across the plasma membrane, and thus to stabilize the membrane potential. The value of the membrane potential is dependent in part on the action of the Na^+/K^+ pumps, because these pumps pump out more Na^+ (3) than K^+ they pump in (2) the ratio of ions transported is 3:2. This pump-driven ratio is offset by other factors such as the attraction between ions of opposite charge and the presence of diffusion gradients that participate in the final determination of the resting membrane potential.

5. The genetic defect of cystic fibrosis involves the inadequate synthesis of a particular glycoprotein (cystic fibrosis transmembrane conductance regulator, CFTR) that forms chloride channels in the apical membrane of the epithelial cells. As a result of the defect, there is abnormal NaCl and water movement across wet epithelial membranes. Where such membranes line the pancreatic ductules and small airways, the secretions of these affected membranes become more viscous and cannot be properly cleared, leading to serious pancreatic and pulmonary disorders.

6. Osmosis is defined as the movement of water across a semipermeable membrane in the direction of highest concentration of osmotically active solutes. As Na^+ solutes move across a plasma membrane, the osmolality increases and thus draws water into the new compartment in pursuit of the solutes. Oral rehydration therapy utilizes this principle. A mixture of glucose and Na^+, as well as other ions, is provided for patients. The glucose in the mixture promotes the cotransport of Na^+, and the Na^+ transport promotes the osmotic movement of water from the intestine into the blood.

7. In *primary* active transport the hydrolysis of ATP is directly required for the function of the carrier protein, while in *secondary* active transport (coupled transport), the hydrolysis of ATP is used to establish a concentration gradient for sodium to flow down (i.e. through the actions of the Na^+/K^+ pump) and drive the flow of a molecule or ion into the cell against its concentration gradient. *Cotransport* or symport is coupled transport that occurs when two molecules are transported in the same direction across a plasma membrane. *Countertransport* or antiport is coupled transport that occurs when two molecules are transported in opposite directions across a plasma membrane. Examples of active transport are the Na^+/K^+ pump (primary active transport), the cotransport of Na^+ and glucose into the small intestine or kidney tubule cell (secondary active transport), and the countertransport of Na^+ into the cell and Ca^{2+} out of the cell (secondary active transport).

Answers to Test Your Ability to Analyze and Apply Your Knowledge

1. Mannitol is osmotically active by definition because it is a solute that *cannot* freely pass through the walls of blood capillaries in the brain (the blood-brain barrier). Intravenous administration of osmotically active molecules such as mannitol into the blood of someone with brain trauma and swelling would raise the osmotic pressure of the plasma above that in the brain tissue. Fluids would diffuse by osmosis out of the brain tissue and into the plasma in response to the higher osmotic pressure and in this way, relieve the swelling. As a sugar, mannitol is easily filtered by the glomerulus of the kidney and flows into the nephron tubules but cannot be reabsorbed. Mannitol is thus trapped in the nephron filtrate and must be excreted from the body “drawing” water with it osmotically and raising the water (and mannitol) content of the urine. In this way mannitol is an effective diuretic.

2. Carrier-mediated transport across plasma membranes is accomplished by the action of special protein carriers. If the transport is passive and the carrier operates to move molecules down their concentration gradients, then the net movement is called facilitated diffusion. If the carrier-mediated transport occurs against a concentration gradient and which therefore requires metabolic energy (ATP), then the net movement is called active transport. As previously explained in question #7, active transport exists in two forms primary and secondary. Secondary (coupled transport) active transport can be further distinguished as cotransport (or symport) and countertransport (antiport). The easiest way to distinguish between the active transport and facilitated diffusion is to introduce a metabolic poison (cyanide, for example) that would prevent ATP production. Any carrier-mediated transport that is affected by the poison would be energy requiring and would be identified as active transport.

3. Cyanide is a fast-acting lethal poison that specifically blocks the transfer of electrons from cytochrome a_3 to oxygen during the final steps of oxidative phosphorylation in the mitochondria. The net result is ATP synthesis is halted. By measuring the resting membrane potential of an experimental cell before and after cyanide treatment, the contribution of the Na^+/K^+ pumps can be determined. One way to determine the relative permeability of the plasma membrane to sodium and potassium ions would be to study the experimental variations in concentrations for these two ions across the membrane and correlating these concentrations with the measured electrical membrane potential. Essentially this is an experimental application of the Nernst equation that allows a theoretical equilibrium potential to be calculated for Na^+ and for K^+. The actual value of the resting membrane potential thus depends not only on the specific permeability of the membrane to each ion but also depends on the ratio of the concentrations of each ion on the two sides of the membrane. The normal resting membrane potential ranges from -65 mV to -85 mV. This value is closer to the equilibrium potential for K^+ because the resting membrane is more permeable to K^+ than to other ions, however many other ions are present that contribute to the resting membrane potential. The Na^+ equilibrium potential at +60 mV demonstrates that the resting membrane is relative less permeable to Na^+ ions.