Chapter 3 Notes

I. Living Systems as Compartments

A. In order to maintain a relatively stable internal environment, living systems are compartmentalized into cells.

1. The membrane surrounding a cell's cytoplasm (interior) must allow a degree of exchange with the environment.

2. Water, food, building materials, gasses and ions must be able to enter the cell.

3. Wastes and cell products must be able to leave.

B. To facilitate both its exchange and environmental separation roles, the cell membrane is selectively permeable.

1. Structurally, the plasma membrane is composed of a phospholipid and protein bilayer.

a. The lipids are composed of a polar phosphate group attached to two nonpolar fatty acid chains.

i. The polar (hydrophilic) end faces the watery interior and exterior of the cell.

ii. The nonpolar (hydrophobic) lipid tails face each other (away from water) forming two layers.

b. Proteins, glycoproteins, cholesterol, and glycolipids are sprinkled throughout both sides, sometimes bridging the two layers.

c. The membrane is referred to as a "fluid mosaic model" because individual pieces are free to flow around each other.

2. The size, polarity, and charge of substances affect their ability to pass freely through the membrane.

   a. Small, nonpolar, uncharged molecules pass though with ease (O_2, CO_2, N_2).

   b. Polar molecules can make it across if they are small and uncharged (H_2O, glycerol, ethanol).

   c. Small ions (Na^+, H^+, etc.) and larger, polar molecules (amino acids, glucose, nucleotides) must pass through special transport proteins.

II. How Cells Exchange Materials

A. The random motion of particles in solution cause substances to diffuse from high to low areas of concentration.

1. Concentration gradients are caused by a difference in concentration of molecules across a distance.

   a. Particles naturally move down the concentration gradient, but require energy to move against it.

   b. If particles (H^+, Na^+, etc.) are prevented from moving down the conc. grad. by a membrane, potential energy can be stored like a dam.

2. Osmosis is the diffusion of water across a selectively permeable membrane.

   a. If a cell is in pure water (hypotonic sol'n), water diffuses into the cell from high water conc. outside the cell.

      i. Animal cells will swell and possibly rupture.

      ii. Cell walls in plants and fungi prevent bursting, instead building turgor pressure (crisp veggies).

   b. Cells in concentrated (hypertonic) solutions lose water and shrink.

   c. Isotonic solutions have the same concentration of water as the cell and do not cause diffusion.

3. Diffusion rates depend mainly on two factors.

   a. Steep concentration gradients cause quick diffusion.

   b. Big surface area to volume ratios in cells allow faster rates of diffusion.

B. Many substances must pass through transport proteins rather than directly across plasma membranes by diffusion.

   1. Passive transport allows diffusion without input of energy.

      a. Molecules going down their concentration gradient through transport proteins use facilitated diffusion.

      b. The proteins are either open channels or attach to and carry specific molecules across the membrane.

   2. In active transport, substances are moved across a membrane against their concentration gradient.

      a. Transport proteins can accomplish this in two ways.

         i. ATP is decomposed into ADP + P_i.

         ii. Movement of one substance against its gradient is coupled to the movement of another substance with its gradient.

      b. Very large molecules (even cells) are moved by the cell membrane forming a pocket around the substance and moving it in (endocytosis) or out (exocytosis) of the cell.

III. Gas Exchange in Multicellular Organisms

A. For aerobic organisms, the basics of gas exchange are fairly universal.

1. O_2 is used by cells during respiration, resulting in low concentrations inside the cell (gradient points in).

2. CO_2 is produced by cells during respiration, resulting in high conc. inside the cell (gradient points out).

3. The gasses must be dissolved in liquid for the exchange.

4. Surface area available for gas exchange is important.

   a. "Simple" organisms with a high surface area to volume ratio can perform direct gas exchange (at the expense of a less controlled internal environment).

   b. Indirect gas exchange requires organs (lungs, gills, etc.) to increase blood-gas surface area and circulation to increase tissue-gas surface inside the body.

B. Gas exchange in water is done directly or by gills.

1. Gills are made of many thread-like filaments containing a capillary network that is exposed to the water.

2. The huge blood-water surface area uses countercurrent flow to maintain concentration gradients, maximizing gas exchange.

C. Gas exchange with air is done directly or by internal exchange.

1. Air has more O_2 than water, but tends to dehydrate organisms.

    a. Direct exchangers are slimy, leaving them prone to dehydration if they are not under cover (worms, etc.).

    b. Internal exchangers dedicate internal space to gas exchange (lots of surface area), decreasing water loss.

2. Small animals (insects, etc.) have many small, internal tubes (trachea) directly connecting the outside to internal tissues. (Spiracles prevent water loss.)

3. Many land animals use lungs for gas exchange.

    a. Air is warmed, moistened, and cleaned by cilia and mucus as it travels down the nasal passage, trachea, bronchi, and bronchioles.

    b. Fresh air is mixed with some old air in the alveoli (poor concentration gradient, better water retention) where O_2 and CO_2 diffuse in/out of capillaries.

4. Plants allow gasses into their leaves through openings called stomates.

    a. Guard cells govern the size of stomates through osmosis (swelling and opening when full of water).

    b. When closed, water loss (transpiration) is minimized.

IV. Waste Removal

A. Depending on environment and body structure, organisms can demonstrate a variety of strategies to deal with wastes.

1. Simple organisms (large s.a. to v. ratio) can excrete all wastes (H_2O, ammonia, CO_2, etc.) directly through their external surface.

2. More complex animals require special organs and metabolic techniques to deal with wastes.

a. Salt-water fish have specialized cells in their gills to excrete excess salt; sea-turtles cry a lot; seagulls have salty "snot."

b. Ammonia (produced from protein and nucleic acid metabolism) is a problem because of its toxicity.

i. It can be secreted directly if surrounded by water.

ii. Some animals convert it to urea (less toxic) which is put into solution before excretion.

iii. Birds and some desert reptiles convert ammonia to uric acid which can be excreted as crystals, requiring little water loss.

B. The human urinary system is composed of the kidneys w/ associated blood vessels (filters blood; forms urine), ureters (connect kidneys w/ bladder), urinary bladder (urine storage), and urethra (allows urine to exit the body).

1. Each kidney has ~1 million nephrons which clean ~2000 L of blood/day by filtration, reabsorption, and secretion.

    a. Pressure forces blood plasma from the glomerulus into Bowman's capsule.

    b. Glucose and small proteins are actively transported into the blood while in the proximal convoluted tubule.

    c. Water diffuses from the descending loop of Henle to surrounding, hypertonic tissues. (filtrate conc. ⇑)

    d. The ascending limb of the l. o. H. is permeable to salts rather than water – salt diffuses out or is actively transported out of the loop depending on location.

    e. In the distal convoluted tubule, water diffuses out while substances such as ammonia, drug "leftovers", and ions may enter through secretion.

    f. As urine moves through the collecting duct, water diffuses into surrounding hypertonic tissues.

2. Hormones can be used to help regulate levels of wastes.

    a. Aldosterone decreases K^+ reabsorption and increases K^+ secretion so more is excreted when appropriate.

    b. Antidiuretic hormone increases nephron permeability to H_2O, increasing reabsorption when appropriate.