BIOL 300 – Foundations of Biology
Summer 2017 – Telleen
Lecture 6

Transport Across Membranes

I. Transport Across Membranes

A. For cells to function, they need water and raw materials (i.e. food) to enter and for waste materials to be eliminated/removed
B. To do this, the molecules in question must move across the plasma membrane, which forms a physical barrier between the inside and outside of a cell.
C. There are three basic ways that molecules can cross the cell membrane:
    1. **Diffusion** directly through the membrane
    2. Being engulfed by folding of the membrane around them
    3. Proteins embedded in the membrane facilitate transport/diffusion (e.g. act as doors that allow some molecules to pass but not others)

II. Diffusion

A. Individual molecules tend to move around randomly (like shaking marbles in a cup)
B. If there are two types mixed together this eventually results in uniform mixtures (barring the action of other forces such as hydrophobic interactions)
C. Another way to state this is that **substances move 'down' a concentration gradient**
D. Molecules don't 'know' where to move, but move in all directions randomly. However, more molecules move away from where they are common than from where they are scarce.
E. We will define **diffusion** as the net movement of molecules down a concentration gradient. If left alone, mixtures will eventually reach **equilibrium** where there is:
    1. An even/homogenous distribution of the molecules
    2. No **net** movement in any direction (molecules are still in motion, but there are as many molecules moving away from any particular place as there are moving to it)

III. Osmosis

A. Diffusion allows some molecules to cross the plasma membrane, but they must have the correct properties (e.g. small and gaseous (O_2, CO_2) or hydrophobic (i.e. lipids))
B. H_2O can't cross a pure lipid bilayer, but biological membranes have small channels called **aquaporins** that allow free movement of water
C. Water diffuses across a cell membrane, but it is dependent on the concentrations of other substances in solution, which may or may not also be able to cross the membrane.
D. Biological membranes are called **semi-permeable** because some molecules can move across, but others cannot.
E. Movement of H_2O across a semi-permeable membrane is called **osmosis**
F. How does osmosis work?
    1. The concentration of all molecules dissolved in a solution (the solutes) is called the **osmotic concentration** of the solution
    2. Three terms are used to compare the osmotic concentrations of two solutions:
        a. **Hypertonic** solutions have a greater osmotic conc.
        b. **Hypotonic** solutions have a lower osmotic conc.
        c. **Isotonic** solutions have equal osmotic conc.
    3. Water moving into a cell by osmosis creates pressure, which is called **osmotic pressure**.

4. Most cells cannot withstand the osmotic pressure without a mechanism of support (e.g. the cell wall). Animal cells don't have cell walls, so they regulate the osmotic concentration in the extracellular matrix so that it is isotonic with the inside of the cell (so there is no osmotic pressure)
5. Cells can be **lysed** (or burst) due to osmotic pressure (usually animal cells).
6. Cells can also be **turgid**, or full of water but not lysed due to their cell wall
7. When placed in a hypertonic solution animal cells can become **crenated** (shrunken/shriveled) as water moves out of the cells
8. Cell with cell walls placed in a hypertonic solution instead become **plasmolyzed** (shrunken/shriveled away from the cell walls due to lack of osmotic pressure)

IV. Bulk Passage to and from Cells

A. Some molecules enter cells by being engulfed in a process known as **endocytosis**, which results in 'food' molecules entering the cell in a vesicle (which can then fuse with a lysosome/peroxisome, etc.)
B. There are two types of endocytosis depending on the nature of the particles engulfed:
    1. **Phagocytosis** (from the Greek, literally 'eat cell') is the endocytosis of large particles (sometimes even entire other cells!)
    2. **Pinocytosis** (Greek, 'drink cell') is the endocytosis of small particles and molecules in solution
C. The reverse process is called **exocytosis**, the discharge of materials (such as neurotransmitters, enzymes, cell wall materials, etc.)
D. **Receptor mediated endocytosis** is a common form
    1. Endocytosis is triggered by recognition of specific molecules by binding to receptors
    2. These receptors are in a pit in the membrane which also contains a protein called **clatharin**
    3. When molecules bind to the receptors, the pit gets larger and forms a vesicle engulfing whatever was in or near the pit. This process is highly specific and very fast.
    4. Endocytosis of low density lipoprotein (LOL) is a good example. In this case, cholesterol is brought into cells for incorporation into membranes
E. **Selective Permeability** refers to the fact that cells can control what enters and leaves (sort of, remember that some kinds of molecules can still diffuse across the membrane without any help). This is usually accomplished by proteins in the membrane:
    1. **Channel proteins** are present that allow the diffusion of specific types of molecules (e.g. aquaporins). This process is called **selective diffusion** because it basically opens the door for specific molecules, which can then diffuse normally down their concentration gradient. Some ion channels (such as those in our nervous systems) are an example of this.
    2. **Facilitated diffusion** is a slightly different process in which a specific type of molecule moves across the membrane, but rather than being like an open door, a **carrier protein** facilitates the movement. This does not require energy because the movement is still down the concentration gradient. However, unlike selective diffusion, the rate of facilitated diffusion can be saturated (e.g. the carrier protein can only move a certain number of molecules in a certain time period). We visualize this a more like a turnstile or revolving door (which limits movement somewhat) rather than just an open door.

V. Active Transport

A. Transport that requires energy is called **active transport**, which refers to the movement of molecules *against* their concentration gradient

B. This allows cells to maintain higher/lower concentrations of specific molecules inside by moving them *up* their conc. gradient!
C. Most active transport in cells is performed by two main types of channels:
    1. **Proton (H^+) Pumps**
    2. **Na^+-K^+ Pumps**
D. Proton Pumps expend metabolic energy to move H^+ ions across the membrane to build a gradient. They are usually coupled with another channel, allowing H^+ ions to move back across the membrane, that harvests the energy to drive production of ATP from ADP and P_i (inorganic phosphate) in a process called **chemiosmosis**
E. Sodium-Potassium Pumps use energy to move Na^+ ions out of the cell and K^+ ions into the cell. More than 1/3 of all energy in the human body is used for these pumps; this energy is derived from ATP (generated by chemiosmosis!). This results in decreased [Na^+], which can be exploited by cells in many ways such as:
    1. Nerve impulses
    2. Pulling sugars/amino acids/etc. into cells against their concentration gradients. This is accomplished by the coupling of the Na-K pump with facilitated diffusion channels that allow Na^+ back in but only with a partner molecule (e.g. sugar, amino acid, etc.). The Na^+ gradient is steeper than for sugar so sugar is moved into the cell against its gradient using energy derived form the sodium gradient

VI. Information and Cells

A. Cells' only contact with the outside is through the plasma membrane, but cells must be able to respond to changes in the environment to survive
B. This is accomplished through two different types of signals that are recognized by different proteins in the membrane: **Chemical signals** and **electrical signals**
C. Chemical signals are recognized by protein receptors that stick out of the plasma membrane and bind to a particular type of molecule. Binding of the target molecule causes the receptor to change conformation and leads to various downstream effects depending on the specific type of receptor. This type of signaling is used to identify the presence of other cells, determine the identity of other cells, sense chemicals/food/toxins in the environment, and communicate between cells (this is how hormones work!).
D. Electrical signals are sensed using **voltage sensitive channels**, which have charged amino acids that change conformation in response to changes in voltage. These are often channels for ions (such as the Na^+ and K^+ channels in neurons)
E. Both of these types of signals and information transmission can occur in both prokaryotic and eukaryotic cells.