6: MEMBRANES (part 2)

ALL cells are surrounded by a membrane. Even plants cells, with their thick cell wall made of cellulose, still have a membrane under that wall. And what is that membrane made of? Phospholipid bilayer, of course. The membrane separates the inside from the outside; kind of obvious, perhaps, but a concept often emphasized in high school texts. Once "inside" and "outside" have been established, the cell now needs a way to bring things in and send things out. The cell will need to bring in nutrients and other helpful molecules, and will need to send manufactured products to other cells and to get rid of wastes. There are a number of different methods of getting things across the membrane, depending on the size and chemical properties of the materials being transported. The first thing to consider is whether these methods use energy or not.

We use the word "transport" to describe the process of crossing the membrane. We add the word "passive" to describe transport that does not require any energy. So ***passive transport*** is crossing the membrane without using energy.

PASSIVE TRANSPORT: There are two types of passive transport. They both use the principle of ***diffusion***, so we need to discuss that first. Diffusion comes from a Greek word meaning "to spread out." Diffusion is what happens when you open a bottle of something very smelly in a closed room. At first, people standing at the far end of the room can't smell anything. Then, as time goes on, the smell spreads and fills the room. Soon all areas of the room are equally smelly. Diffusion is the movement of molecules from where there are more of them to where there are less of them. The "goal" of the molecules is to end up equally distributed everywhere. The molecules will keep moving after this, but they will remain equally distributed. In our example, the smelly molecules did not have anything blocking them from moving around so we were not too surprised that they could fill the room.

If we had put a paper wall across the middle of the room and sealed all the edges, this would have made it more difficult for the smelly molecules to fill the room, but not impossible if the molecules were small enough to go through the microscopic holes in the paper. A paper wall isn't going to stop a smell like gasoline, for instance. This shows us that diffusion can still happen across a barrier if the chemistry is right. Water would also be able to get across our paper wall but not quite as quickly. Barriers that allow things to pass right through are called ***permeable***. (So why have them in the first place, right?) Barriers that allow only some things to pass through are ***semi-permeable***. Cell membranes fall into the category of semi-permeable, but an even better word would be ***selectively permeable*** because cells can select some things to come in and other things to stay outside. Again, these words mean exactly what they say, so it should not be hard to remember them.

Now that we know what diffusion is, we can learn the two types of passive transport. They are **1) *simple diffusion*** and **2) *facilitated diffusion***. Simple diffusion is often just called diffusion without the word simple in front of it. However, it might be easier to remember these terms if their format is the same. The brain likes pairs and groups and always looks for similarities, so we can help out brains remember if we cooperate and try to group things logically. The visual layout of the drawing will help you, also. Passive on the left, active on the right, with the types listed below.

Simple diffusion: Some things can diffuse right through the phospholipid membrane. If the concentration of that type of molecule is greater outside the cell than inside, the molecule will diffuse in. What kind of molecule will be able to do this? As you might guess, it would have to be small. Size is important. What about chemical properties? Look at the phospholipid bilayer. Which area is thicker—the head area or the tail area? The tails are very long, so the lipid layer in the middle is much thicker. This means that any molecule passing through will have most of its journey be through the fatty, non-polar area. Overall, this means that **fat-friendly, non-polar molecules** stand a better chance of getting through the bilayer than water-friendly, polar ones. Examples of small, fat-friendly molecules that can diffuse through the membrane are **vitamins A, D, E and K, and steroids**. These vitamins are often called the "fat-soluble" vitamins. Their molecular structure includes rings of carbons, like we saw in cholesterol, so they get along very well with the cholesterol molecules that sit in and among the fatty tails. They have no trouble slipping through. Steroids are also based on rings of carbon. In fact, your body turns cholesterol into steroid molecules (and also into vitamin D). Cholesterol isn't a poison; it is an essential molecule you can't live without. The steroids made from cholesterol include estrogen, testosterone, and anti-inflammatory steroids.

Oxygen and carbon dioxide are small and are non-polar so they can use simple diffusion, too. They are very numerous and must get across quickly, so it is good that they can just cross on their own. If they had to wait for a molecular gate to open, this would cause a chemical traffic jam for sure!

Water used to be on the list of molecules that use simple diffusion, but now that has been called into question. It is true that even though **water** is polar, the molecules are very small and they do indeed often slip through the membrane to the other side. The "pull" of diffusion (wanting to be where there are less of them) will sometimes be enough to get them through. However, we now know that even though water does sometimes diffuse through, the molecules prefer to go through a channel that we will discuss on the next page.

Facilitated diffusion: The word "facilitate" means "to make easier." In faciliated diffusion we find some molecules that can diffuse if they have just a little bit of help. Molecules that are not-so-small, or are polar, can't slip through that fatty middle layer of tails. There's just no way they are getting through that "We hate water and polarity" zone. They need some kind of tunnel that they can go through. The tunnels are often called "channel proteins." (There isn't one officially correct name for these channels. Some authors call them more complicated names, like "transmembrane integral proteins." We're going to stick with "channel proteins.") You don't know exactly what a protein is yet, but we'll go ahead and use that word since you are familiar with it. The key word is "channel." These channels provide a way for small polar or electrically charged molecules to diffuse in and out of the cell. Now we can go back to discussing water.

A) ***Aquaporins*:** Until 1992, it was thought that water simply diffused into cells. This is true to some degree. It's not impossible for a water molecule to get through the membrane. However, the journey is not easy. Scientists began to suspect that water was getting through another way but they did not know how. Then an American scientist named Peter Agre discovered a protein channel that he named ***aquaporin***. It's a pore that lets "aqua" (water) through. This discovery was so important that he received the nobel prize in 2003. (Just think of all the textbooks that had to be rewritten!) Aquaporins are channels that let water, and only water, diffuse in and out of the membrane. As Agre's team studied aquaporins they found out that there are many different kinds, depending on the cell type. Some aquaporins are found only in brain cells, other in eye or skin cells. You'll learn a little more about aquaporin in one of the activities that goes with this lesson.

At this point, we need throw another vocabulary word at you. You may already know this word; it shows up in botany and physics books, too. When water diffuses through a membrane, we don't call it diffusion — we call it ***osmosis***. We might guess that "osmos" means "water" in another language, but it doesn't. "Osmos" is Greek for "push." Water looks like it is pushing through the membrane? The person who named it apparently seemed to think so. Even though it doesn't mean "water," thinking of water when you see "osmo" is still a good idea. Most science words that start with "osmo" have something to do with water.

As long as we are throwing vocabulary words at you, we might as well go ahead and cover the last major diffusion term that you need to know. The action of going from where there are more of them (a higher concentration) to where there are less of them (a lesser concentration) is often called "following the ***concentration gradient***." Sometimes biologists will say that the molecules go "***down the concentration gradient***." You know what concentration means. Let's look at the word "gradient." The word "grade" is used by landscapers to describe the steepness of a hill. The grade of a hill is given in degrees (of geometry, not temperature). A gentle slope might be 3 degrees; a steep one would be 30 degrees. The word "grade" can also be used as a verb. Landscapers will "grade" the dirt around a house so that it goes downhill, away from the house. (This helps to keep rain water out of the basement.) So when you see the term "concentration gradient," don't panic. Just think of grading dirt so that water flows DOWN the slope and away from the house. The key word is DOWN. Molecules go DOWN their concentration gradient, from places of high concentration to places of lower concentration. When you see the word "gradient," think of a slope where things role from high places to low places. Think of rolling DOWN a hill. High to low, high to low.

It's actually not a hard a concept, despite the fact that the term "concentration gradient" sounds like it might be difficult. You will see this term used all the time in biology books, so it is best not to be scared of it!

B) ***Ion channels***: Another example of facilitated diffusion is the ***ion channel***. An ion channel is designed to let only one type of ion get through. The most common types of ion channels are for sodium (Na^+), potassium (K^+), chlorine (Cl^-) and calcium (Ca^{2+}). Ion channels tend to look like two funnels stuck together at their narrow ends. The wide top and bottom are described as "water-filled." The narrow part in the middle is very small indeed, perhaps only one or two atoms wide. The channels can be constantly open or they can be "gated," meaning that they only allow ions through when certain conditions exist. Gates can act as a triggering mechanisms, allowing a sudden influx of ions that will cause a whole series cellular events.

Gated channels come in many kinds. Some respond to light (cells in the eye), temperature (skin cells), or pressure (skin cells). Some are triggered by messenger molecules coming from outside. The gated channels in your nerve cells are triggered by differences in electrical voltage. There are about 300 different types of ion channels present in most cell membranes. (That's 300 types, not 300 total.) The most important thing to know about ion channels is that they do not require energy to operate. They are passive, not using energy.

One particular type of channel needs special mention—the channel that transports **glucose** sugar molecules into cells. This channel relies on shape. Glucose molecules look like a hexagonal ring. When a glucose molecule goes into the channel, it is like a key fitting into a lock. The shape clicks in place. When it clicks in, this automatically causes the channel to change shape so that the glucose drops out the bottom and into the cell. With glucose gone, the shape returns to normal.

ACTIVE TRANSPORT: Active transport requires energy. Your body is full of tiny molecular re-chargeable batteries. The most well-known is called **ATP**. We'll take a closer look at ATP in a future lesson. Chances are good that you've heard of ATP already, so you won't be in too much suspense till then. Right now all you need to know is that ATP stands for "adenosine triphosphate" and that it is like a rechargeable battery for your cell. The molecule has three phosphates, and the third one can be popped on and off. When it is popped off, energy is released. Phosphates have all kinds of uses in the cell, but this is the most famous one. ATP provides energy of cellular work.

Two other (slightly less famous) rechargeable molecules are ***NADH*** and ***FADH***. You don't need to know what those letters stand for. (But for those of you who are curious, NADH stands for Nicotinamide Adenine Dinucleotide.) These molecules carry electrons to ion pumps. There are some very important ion pumps in your cells that depend on these molecules to deliver high-energy electrons. We will see them again during the lesson on what goes on inside a mitochondria.

We are going to look at three kinds of active transport: ***ion pumps, endocytosis and exocytosis***.

Ion pumps: These look similar in structure to ion channels. They cross the entire bilayer, and have an entry or exit at each end. Recently, researchers have found even more similarities and in future years you might be reading about their discoveries. The most important difference between them is that the pumps are going "***against the concentration gradient***." Water goes downhill, with gravity. Pumps can pump it back up, against gravity. But pumps need the energy of your arm or a motor to make them go. Ion pumps use ATP energy. There are places at the bottom of the pumps where ATP molecules attach and release their third phosphate. Details about this energy and how it is used by the pump are beyond the scope of this course. (Very quickly you get into quantum physics!) Ion pumps are found in plant cells, too, not just animal cells. The process of photosynthesis relies heavily on ion pumps. We'll also see ion pumps as a major feature of cellular respiration in a future lesson.

The most famous ion pump is the sodium-potassium pump located in the membrane of nerve cells. It pumps sodium out of the cell and potassium into the cell. The ions would not naturally go in this direction, because this is against their concentration gradient. Huge numbers of the ions build up on one side of the membrane, then they are let back in very suddenly when the gates of their ion channels open. (There are separate channels for sodium and potassium.) A pump and two channels work together, so to speak.

Endocytosis: "Endo" means "in," and "cyto" means "cell." So endocytosis just means going inside the cell. Endocytosis is used to take in very large things. In a future lesson, we'll meet immune system cells that take in all kinds of things, including bacteria. There is a special name for when a cell takes in just a tiny amount of something. This is called ***pinocytosis***. It is often described as cells "drinking or sipping." We will see cells doing this when we study the cells that line the insides of blood vessels and capillaries.

The best way to learn about endocytosis is to watch an animation of it. (Watch those supplemental videos on the YouTube channel.) An indent starts to form in the membrane, and it becomes deeper and deeper. The particle gets trapped inside this pocket. The pocket goes so deep that it starts to close off and pull away from the membrane. The pocket breaks away from the membrane and becomes a vesicle with the particle inside. This vesicle can be transported to where it is needed in the cell.

Exocytosis: "Ex" means "out" so exocytosis means things moving to outside the cell. Exocytosis is the opposite of endocytosis. When the cell wants to send something out, it puts it into a vesicle then send the vesicle to merge with the membrane. When the vesicle touches the membrane, it become part of it. The vesicle turns into a deep pocket which becomes more and more shallow until there is nothing left. The particle that was inside the vesicle now finds itself outside the membrane. Some cells of your body produce molecules that are needed by cells all over the body. These molecules exit the cell by exocytosis, and go into the blood so that they can circulate throughout the body.