

Name:

1.2 Cell Physiology

In cells, the barrier between the cell and outside world is called the **cell membrane** or **plasma membrane**. It separates the extracellular (outside) environment from the cytosol, which is the intracellular (inside) fluid. It is semi-permeable, meaning that some things are allowed through while others are not. Anions and cations are among the things that cannot pass a pure plasma membrane. However, in a cell, the membrane is filled with molecules called proteins. There are many, many, many types of proteins, and they all perform different functions. In this course, we will focus on **channels** and **pumps** formed by proteins.

Channels are essentially small holes in the cell membrane. Different types of channels open and close during different environmental conditions. This could include changes in the charge of the cell, changes in acidity, the presence of certain chemicals, and many other scenarios. Some channels only allow cations through, while some only allow anions. This diversity is important for the cell to regulate what is in the intracellular environment.

Pumps are more active than channels. Rather than simply opening a hole to the extracellular environment, pumps use energy in the cell to move specific ions into and out of the cell. The picture above shows a sodium-potassium pump. 3 Na⁺ ions are transported out of the cell for every 2 K⁺ ions brought in. This is not an even trade of charges, and requires

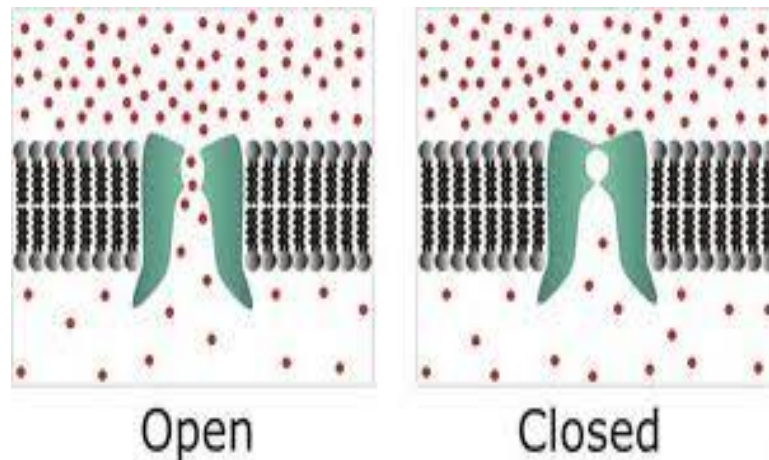


Figure 4: A channel (shown in teal) embedded in the cell membrane, bridging the two sides of the cell. Channels open and close based on environmental conditions and signals from the cell.

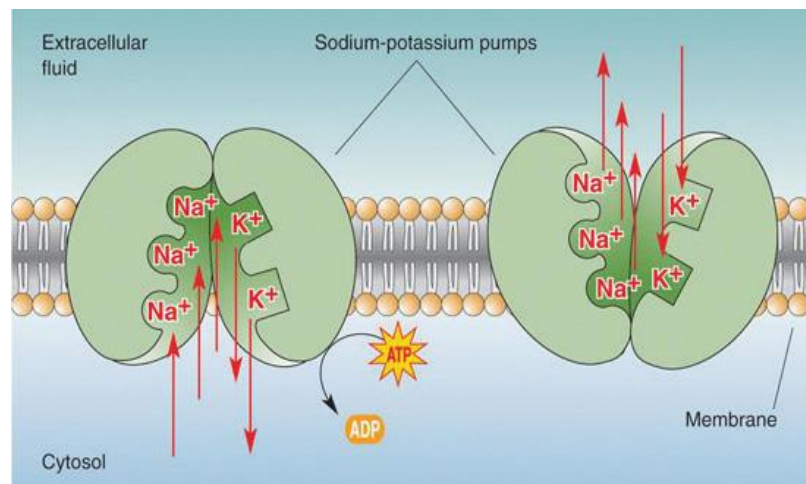


Figure 5: An example of a sodium-potassium pump embedded in the cell membrane. It requires energy in the form of the molecule ATP to work, creating the ionic gradient

energy to accomplish. To power this reaction, the pump uses a molecule of ATP, which is a cell's main fuel source.

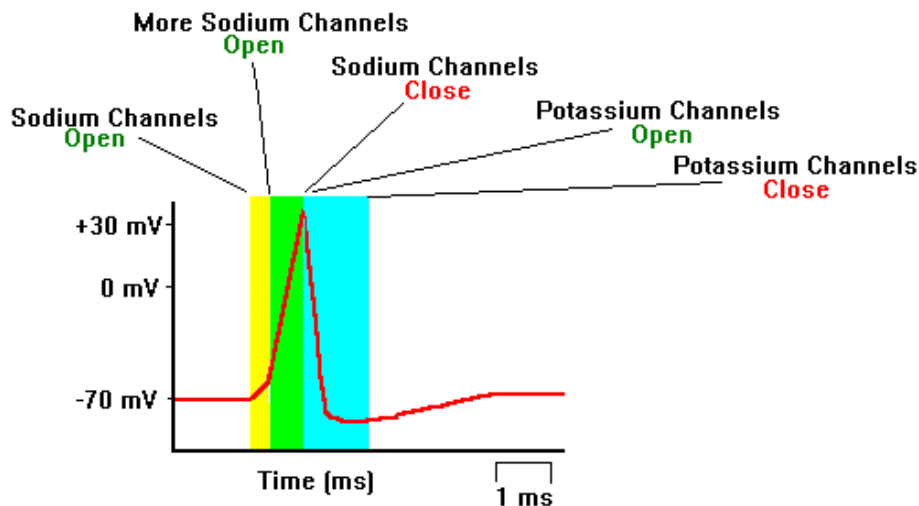
Pumps are very important because they increase the electrical potential energy across the cell. This is equivalent to pushing a rollercoaster back up the tracks, giving it more potential energy for later. This exchange of potassium and sodium leads to the cytosol having fewer cations than the extracellular fluid. The excess cations on the outside of the cell want to flow back inside, but the membrane stops them. This is how the cell generates the electric potential across the membrane, which is simply called the *membrane potential*.

Resting potential

The resting potential of a cell is created through a combination of sodium-potassium pumps and ion channels. The sodium-potassium pump increases the potential of the cell by actively pushing out cations. While this is happening, some of the ion channels are open. As the cell's potential increases, the cell exerts more 'pull' on cations, meaning more come through the open channels. Eventually this pull negates the efforts of the sodium-potassium pumps, and the system reaches equilibrium – cations are entering the cell as fast as they are leaving. This equilibrium is the *resting potential*. While it changes for every type of cell, the resting potential for most neurons is roughly -70mV.

Action Potential

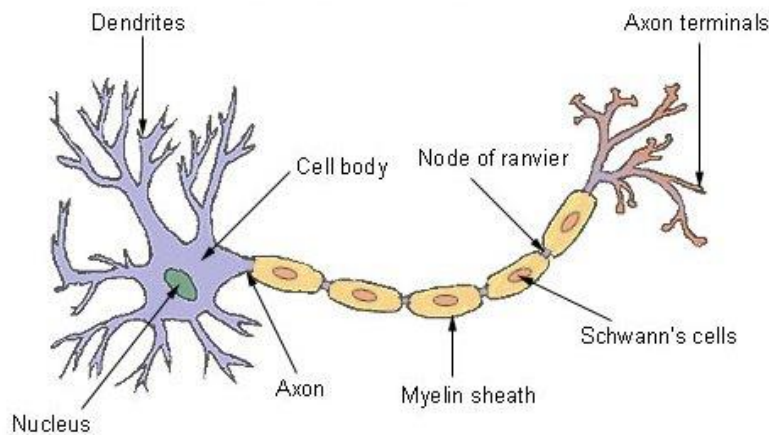
Action potentials are how neurons in the brain communicate, which forms the foundation for all thought and behavior. Below is a graph that shows how the membrane potential changes over the course of an action potential,



Various factors can affect the cell membrane potential, but the biggest effects come from *neurotransmitters*. Neurotransmitters work with *neuroreceptors*, which are proteins that are stuck in the cell membrane like the sodium-potassium pumps mentioned above. Neurotransmitters fit into their respective neuroreceptors like a

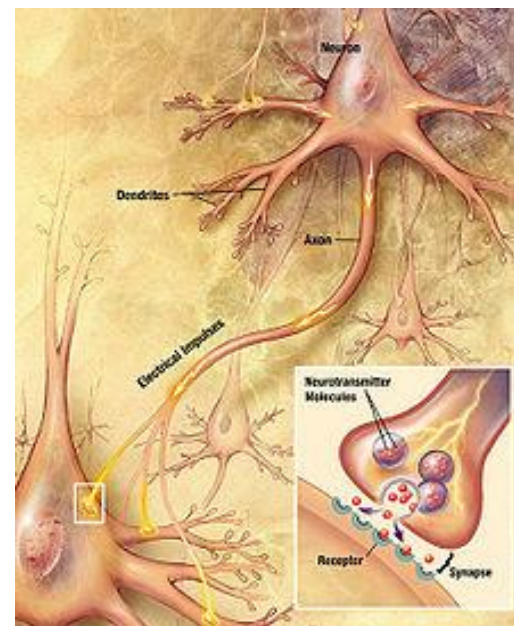
lock and key – once the key is in the lock, it can open or close the receptor, those allowing or barring certain chemicals from entering the cell. This allows fluctuations in the potential of the cell. If the cell's potential changes enough to get it to the *threshold potential* (somewhere between -40 mV and -55 mV), then a major shift in the cell chemistry happens and action potential begins.

To start, a first wave of channels open and allow positive sodium ions to rush into the negatively charged cell. This greatly increases the potential of the cell, and causes another set of sodium channels to open, allowing even more positively charged ions into the cell. This positive feedback loop continues until the neuron is roughly 30 mV (notice that it is a positive voltage), and then the sodium channels begin to close. At this point, the potassium channels open, allowing the excess potassium to flow out of the cell, bringing the membrane potential back to its resting state. The sodium-potassium pumps then work to bring potassium back into the cell while getting rid of sodium, allowing the cell to have another action potential.



During the action potential, the axon is signaled to release neurotransmitters from its terminal. This has an effect on the neurons around it, and starts the process over again. This is how signals are transmitted in the brain – one neuron firing causes another neuron to fire, which causes another neuron to fire.

The picture to the right gives us an idea of what happens when a one terminal (or synapse) of a neuron is communicating with another neuron. Every neuron has thousands of synapses. If there are 10^{10} billion neurons in the brain, imagine how many synapse connections there are!



Questions

1. When learning about the charged particles of a neuron at resting potential, a simple analogy is to think of the neuron as being a salted banana. Can you explain why? What elements make up salt? And what element is rich in bananas?
2. First, _____ channels open and _____ ions enter the cell, causing the membrane potential to increase/decrease (circle one). Then, _____ channels open and _____ ions exit the cell, causing the membrane potential to return to its _____. When the cell is at _____, a _____ pump maintains a resting potential of approximately _____ mV.
3. Say our neuron begins at resting potential. If a sodium ion entering the cell will increase the membrane potential by 0.5 and none of our potassium ions are flowing into or out of the cell, approximately how many sodium ions need to enter the cell to cause an action potential?