Membrane Potential and Action Potential

by Sophia

WHAT'S COVERED

In this lesson, you will learn about how the differences in concentration of ions across the plasma membrane can set the stage for a nerve impulse. Specifically, this lesson will cover:

1. Membrane Potential

Sodium and potassium are the two ions that are very important for setting the stage for a nerve impulse. Recall from the Unit I lesson on Facilitated Diffusion that **sodium-potassium pumps** are proteins embedded in the plasma membrane. With the help of ATP, these pumps move sodium (Na+) from an area of low concentration within the cell to an area of high concentration outside the cell. At the same time, these pumps move potassium (K+) from an area of low concentration outside the cell to an area of high concentration inside the cell. This creates a chemical gradient, but it also creates an electrical gradient (a "voltage potential"). Cells have a **resting membrane potential** that is slightly negatively charged compared to the environment outside the cell.

If both sodium (Na+) and potassium (K+) have the same positive charge, how does forcing them to swap places across the cell membrane make a cell negatively charged? For every three sodium ions pumped out of the cell, two potassium ions are pumped in:

3 Na+ out of the cell (-3) plus 2 K+ (+2)

-3 + 2 = -1 charge inside the cell

The slight negative charge of a cell's **resting potential** is what allows a signal to travel so fast down the length of a neuron or even the entire body. (Think about how quickly you go from deciding to wiggle your toes to actually performing the action—the signal moves from your brain to your toes nearly instantly.) When a signal reaches a neuron while it's in it's resting membrane potential, all the neuron has to do is open the channels in the plasma membrane, let the excess sodium flow down its electrochemical gradient (from positively-charged, high concentration outside the cell to negatively-charged, low concentration inside the cell) in what is called an action potential.

TERMS TO KNOW

Sodium/Potassium Pump

A protein embedded in the plasma membrane that actively transports sodium and potassium against their concentration gradients.

Resting Membrane Potential

The difference in the charge across a cell membrane which has the potential for an action potential to occur.

Resting Potential

The steady voltage difference that occurs across a neuron's membrane when it is not being stimulated.

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2. Action Potential

An **action potential** is basically just another way of saying a nerve impulse. An action potential occurs when a stimulus causes the voltage difference across a cell membrane to shift. Sometimes the voltage difference will shift at random, but this will not cause neurons to fire randomly (as is the case with epilepsy). To relay only true signals, a neuron's stimulation has to be so strong that the voltage changes about a **threshold**—a minimum shift needed for that action potential to occur. Once it occurs, the signal travels very fast along the neuron.

For this action potential to occur, the voltage difference across a cell membrane has to shift by a certain amount (above the threshold). Once it's shifted by that amount, an action potential can happen.

Here are the steps that occur in an action potential.

STEP BY STEP

Step 1: Stimulation

First, stimulation has to occur. Signals will reach the **input zone** of a neuron and will change what occurs in the cell membrane of that neuron.

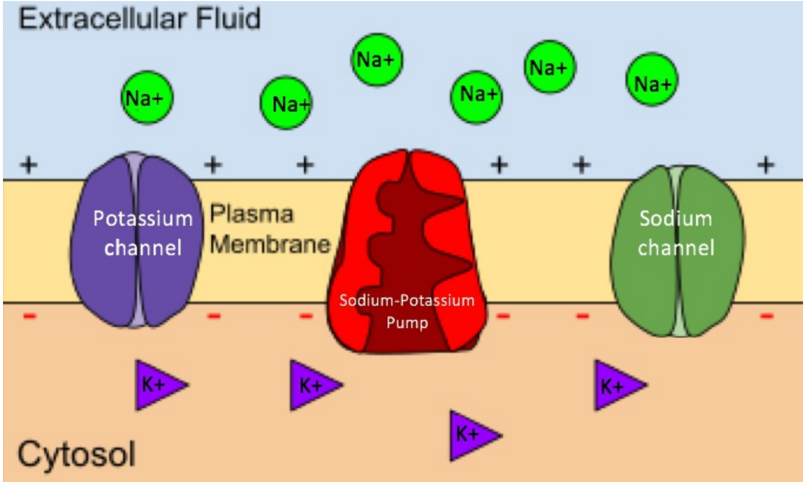
Step 2: Open Sodium Gates

This stimulus will cause sodium gates in the membrane of the cell to open, which allows sodium to rush into the cell. Normally in a resting membrane, the outside of the cell is positive relative to the inside of the cell. As these sodium gates open, sodium will rush in, causing more gates to open until that threshold we discussed is reached, causing the voltage difference across the cell membrane to reverse.

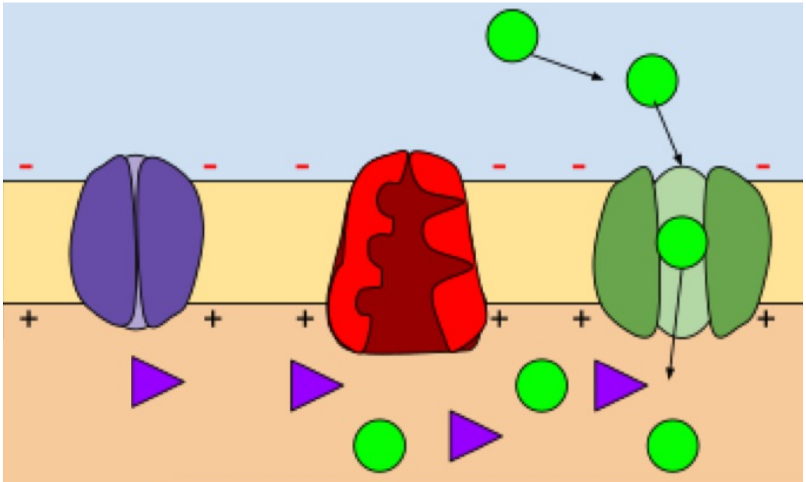
Step 3: Restore Resting Membrane Potential

Now in order for another action potential to occur, you have to restore the resting membrane potential, which is done so by sodium-potassium pumps. To understand this, it is important to review the structure of a neuron here. A neuron is a nerve cell and made up of dendrites, which are part of the input zone. Information will move through the input zone, through the dendrites, to the cell body. From there, the action potential will travel along this long narrow part of the neuron called the axon, and then down to the axon endings. So information goes through the input zone, through the cell body, along the axon, to the axon endings. Then from there, that signal will be sent either to another neuron or to a muscle or a gland cell.

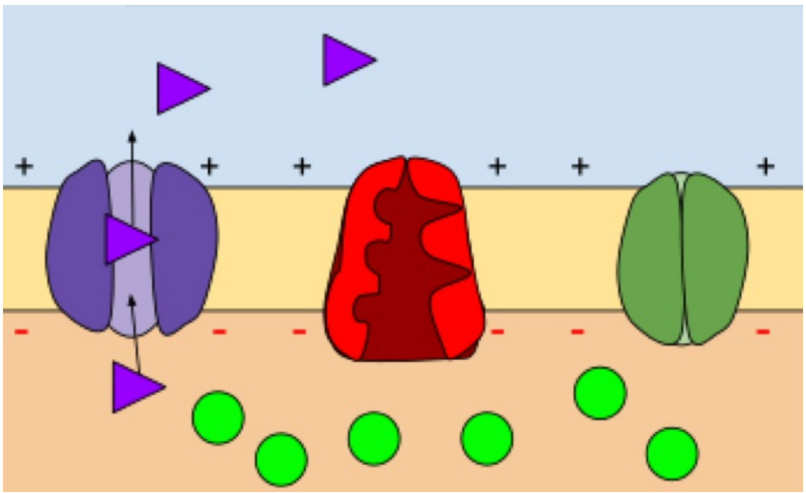
To better understand what happens in action potential, take a look at the diagrams below.



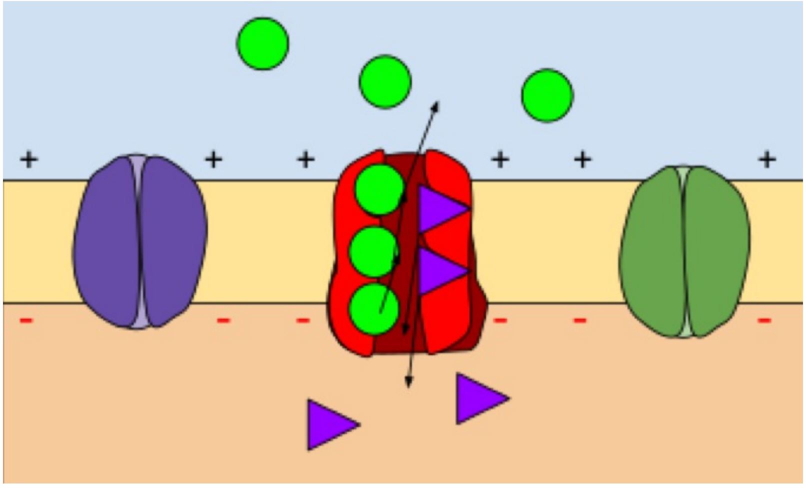
As mentioned, the outside of the neuron is generally positive relative to the inside. You have your cell membrane and then embedded within that, you have something called a sodium-potassium pump. Then you have your gated sodium channels. Typically, these gated sodium channels are closed, making the cell membrane more or less impermeable to sodium. Sodium is not allowed to flow through freely.



When stimulation causes an action potential, sodium gates will open, allowing sodium to flow into the cell. As that happens, more and more of these gates will open, allowing more and more sodium to flow in. This will continue to happen until the threshold is reached and the voltage difference is reversed.



Now, this isn't all happening throughout the whole membrane at the same time; it occurs in patches of the membrane. As sodium moves into the cell in one patch, the previous patch of that membrane will allow potassium to leak out. This reverses the voltage difference across the cell membrane and will cause the impulse to propagate along that cell membrane in patches. You can think of an action potential moving down the axon the way a ring might slide down your finger.



Eventually, the resting membrane potential has to be restored. That's where the sodium-potassium pumps (in red) come into play. The sodium-potassium pumps will restore that resting membrane potential. In order to perform this, it has to use the cell's ATP, which is a form of active transport because it's using ATP to restore this membrane potential. What the sodium-potassium pump will do is put sodium back out and potassium back in. As that action potential was happening, you had your sodium diffusing in and potassium diffusing out, which was reversing our voltage difference across the membrane. However, in order to restore that resting membrane potential, you have to get the sodium back out and the potassium back in. Only then our resting membrane potential can be restored.

Once the action potential has reached the **output zone**, the signal will be sent across the synapse (the tiny gap between the axon endings and another cell), usually via a neurotransmitter to the next cell that needs to receive the signal (another neuron, a muscle fiber or a gland cell).

TERMS TO KNOW

Action Potential
A nerve impulse.

Threshold
The minimum voltage shift across a membrane required for an action.

Input Zone
The region of a neuron where signals enter (usually the dendrites around the cell body).

Output Zone
The part of the neuron that consists of the axon endings where signals are sent on to another neuron or to a gland or muscle cell.

Trigger Zone
The part of the neuron located at the base of the cell body that initiates action potentials.

SUMMARY

This lesson has been an overview of **membrane potential** and how sodium and potassium ions and **action potentials**. You also got to learn about the specific steps involved in action potential.

Keep up the learning and have a great day!

Source: THIS WORK IS ADAPTED FROM SOPHIA AUTHOR AMANDA SODERLIND

ATTRIBUTIONS

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