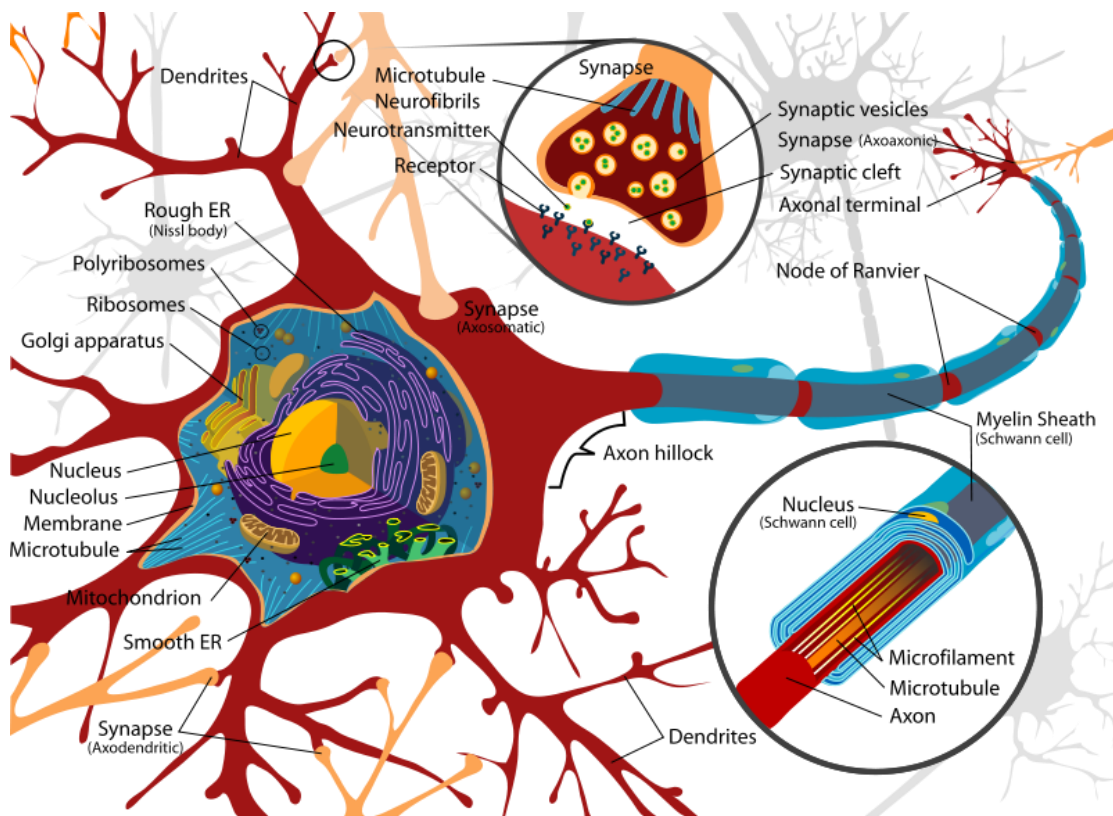


Physiology

The Nervous System

The human nervous system consists of billions of nerve cells (or neurons) plus supporting (neuroglial) cells. Neurons are able to respond to stimuli (such as touch, sound, light, and so on), conduct impulses, and communicate with each other (and with other types of cells like muscle cells).

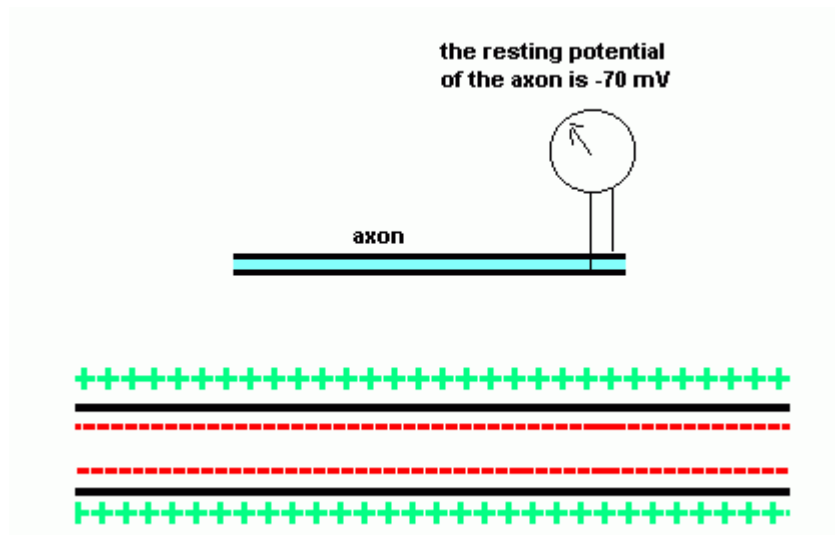
The nucleus of a neuron is located in the cell body. Extending out from the cell body are processes called dendrites and axons. These processes vary in number & relative length but always serve to conduct impulses (with dendrites conducting impulses toward the cell body and axons conducting impulses away from the cell body).



Neurons can respond to stimuli and conduct impulses because a membrane potential is established across the cell membrane. In other words, there is an unequal distribution of ions (charged atoms) on the two sides of a nerve cell membrane. This can be illustrated with a voltmeter :

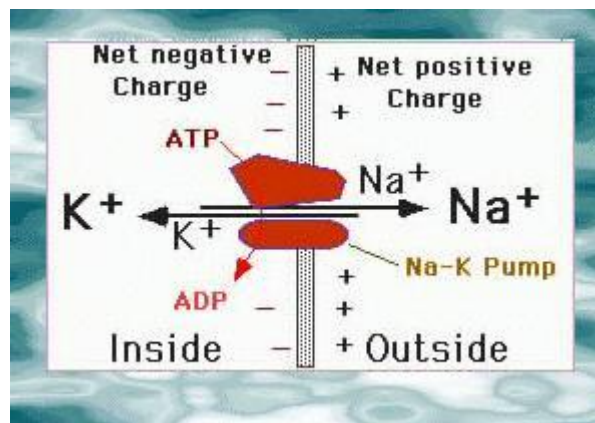
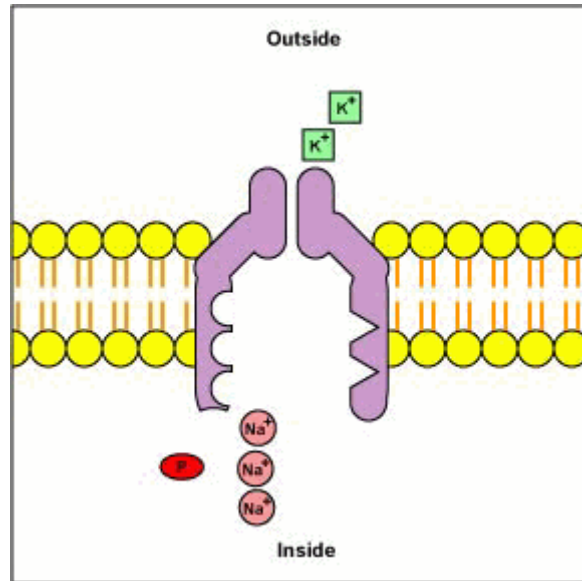
Establishment of the Resting Membrane Potential

Membranes are polarized or, in other words, exhibit a **RESTING MEMBRANE POTENTIAL**. This means that there is an unequal distribution of ions (atoms with a positive or negative charge) on the two sides of the nerve cell membrane. This **POTENTIAL** generally measures about 70 millivolts (with the **INSIDE** of the membrane negative with respect to the outside). So, the **RESTING MEMBRANE POTENTIAL** is expressed as -70 mV , and the minus means that the inside is negative relative to (or compared to) the outside. It is called a **RESTING** potential because it occurs when a membrane is not being stimulated or conducting impulses (in other words, it's resting



What factors contribute to this membrane potential?

Two ions are responsible: sodium (Na^+) and potassium (K^+). An unequal distribution of these two ions occurs on the two sides of a nerve cell membrane because carriers actively transport these two ions: sodium from the inside to the outside and potassium from the outside to the inside. AS A **RESULT** of this active transport mechanism (commonly referred to as the [SODIUM - POTASSIUM PUMP](#)), there is a higher concentration of sodium on the outside than the inside and a higher concentration of potassium on the inside than the outside.



The nerve cell membrane also contains special passageways for these two ions that are commonly referred to as GATES or CHANNELS. Thus, there are SODIUM GATES and POTASSIUM GATES. These gates represent the only way that these ions can diffuse through a nerve cell membrane. IN A RESTING NERVE CELL MEMBRANE, all the sodium gates are closed and some of the potassium gates are open. AS A RESULT, sodium cannot diffuse through the membrane & largely remains outside the membrane. HOWEVER, some potassium ions are able to diffuse out.

OVERALL, therefore, there are lots of positively charged potassium ions just inside the membrane and lots of positively charged sodium ions PLUS some potassium ions on the outside. THIS MEANS THAT

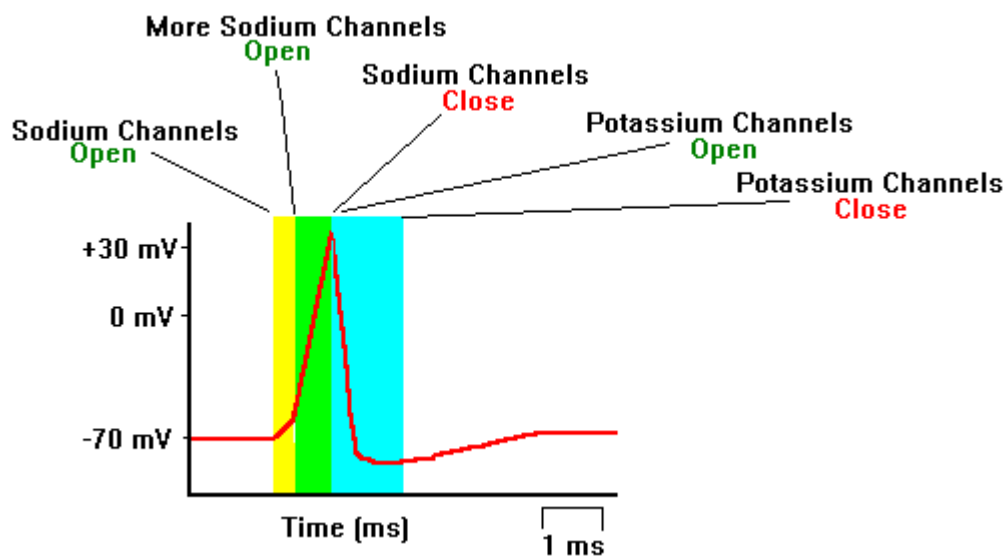
THERE ARE MORE POSITIVE CHARGES ON THE OUTSIDE THAN ON THE INSIDE. In other words, there is an unequal distribution of ions or a resting membrane potential. This potential will be maintained until the membrane is disturbed or stimulated. Then, if it's a sufficiently strong stimulus, an action potential will occur

ACTION POTENTIAL

An action potential is a very rapid change in membrane potential that occurs when a nerve cell membrane is stimulated. Specifically, the membrane potential goes from the resting potential (typically -70 mV) to some positive value (typically about $+30$ mV) in a very short period of time (just a few milliseconds).

What causes this change in potential to occur? The [stimulus causes the sodium gates \(or channels\) to open](#) and, because there's more sodium on the outside than the inside of the membrane, sodium then diffuses rapidly into the nerve cell. All these positively-charged sodiums rushing in causes the membrane potential to become positive (the inside of the membrane is now positive relative to the outside). The sodium channels open only briefly, then close again.

The potassium channels then open, and, because there is more potassium inside the membrane than outside, positively-charged potassium ions diffuse out. As these positive ions go out, the inside of the membrane once again becomes negative with respect to the outside (Animation: [Voltage-gated channels](#)).



Threshold stimulus & potential

Action potentials occur only when the membrane is stimulated (depolarized) enough so that sodium channels open completely. The minimum stimulus needed to achieve an action potential is called the .threshold stimulus

The threshold stimulus causes the membrane potential to become less negative (because a stimulus, no matter how small, causes a few sodium channels to open and allows some positively-charged sodium ions to .(diffuse in

If the membrane potential reaches the threshold potential (generally 5 - 15 mV less negative than the resting potential), the voltage-regulated sodium channels all open. Sodium ions rapidly diffuse inward, & .depolarization occurs

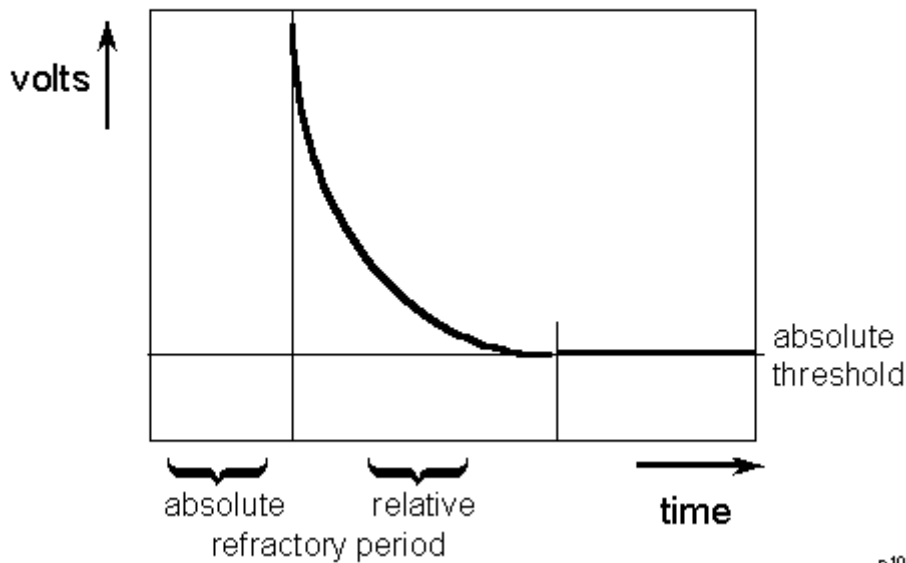
All-or-None Law - action potentials occur maximally or not at all. In other words, there's no such thing as a partial or weak action potential. Either the threshold potential is reached and an action potential occurs, or .it isn't reached and no action potential occurs

Refractory periods:

ABSOLUTE -

- During an action potential, a second stimulus will not produce a second action potential (no matter how strong that stimulus is)
- corresponds to the period when the sodium channels are open (typically just a millisecond or less)

Refractoriness: threshold at different times after an action potential



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RELATIVE -

- Another action potential can be produced, but only if the stimulus is greater than the threshold stimulus
- corresponds to the period when the potassium channels are open (several milliseconds)
- the nerve cell membrane becomes progressively more 'sensitive' (easier to stimulate) as the relative refractory period proceeds. So, it takes a very strong stimulus to cause an action potential at the beginning of the relative refractory period, but only a slightly above threshold stimulus to cause an action potential near the end of the relative refractory period

The absolute refractory period places a limit on the rate at which a neuron can conduct impulses, and the relative refractory period permits variation in the rate at which a neuron conducts impulses. Such variation is important because it is one of the ways by which our nervous system recognizes differences in stimulus strength, e.g., dim light = retinal cells conduct fewer impulses per second vs. brighter light = retinal cells conduct more impulses per second.