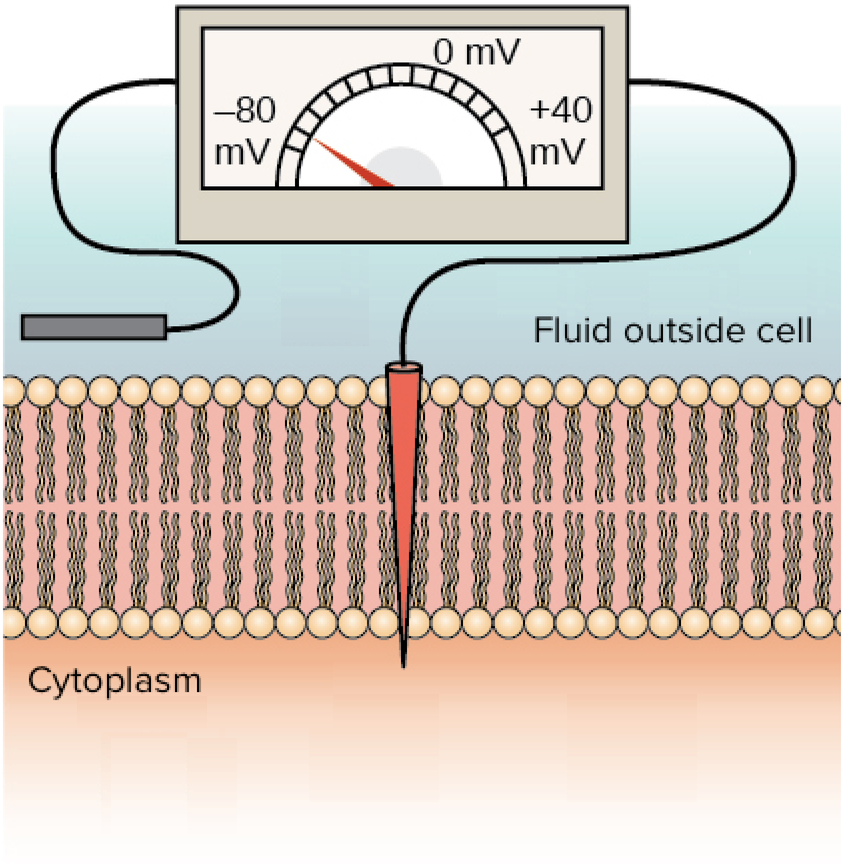
The resting membrane potential

Imagine taking two electrodes and placing one on the outside and the other on the inside of the plasma membrane of a living cell. If you did this, you would measure an electrical potential difference, or voltage, between the electrodes. This electrical potential difference is called the **membrane potential**. The voltmeter shows a -70 mV voltage across the membrane.



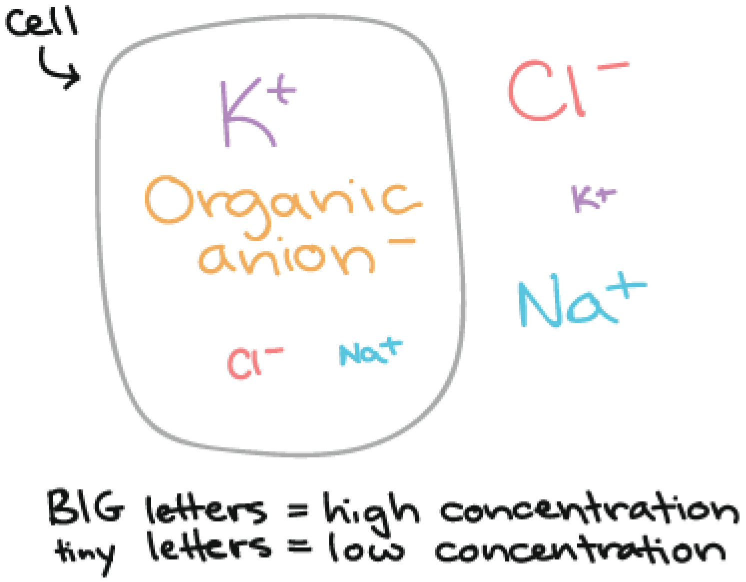
Where does the resting membrane potential come from?

The resting membrane potential is determined by the uneven distribution of **ions** (charged particles) between the inside and the outside of the cell, and by the different permeability of the membrane to different types of ions.

Types of ions found in neurons and their surrounding fluid

- Positively charged (cations): Sodium Na^+ and potassium K^+
- Negatively charged (anions): Chloride Cl^- and organic anions

In most neurons K^+ and organic anions (such as those found in proteins and amino acids) are present at higher concentrations inside the cell than outside. In contrast Na^+ and Cl^- are usually present at higher concentrations outside the cell. This means there are stable concentration gradients across the membrane for all of the most abundant ion types.



This diagram represents the relative concentrations of various ion types inside and outside of a neuron.

- K+ is more concentrated inside than outside the cell.
- Organic anions are more concentrated inside than outside the cell.
- Cl- is more concentrated outside than inside the cell.

Na+ is more concentrated outside than inside the cell

with the inside of the cell more negative than the outside. That is, neurons have a **resting membrane potential** of about -70

Because there is a potential difference across the cell membrane, the membrane is said to be **polarized**.

Transmission of Nerve Impulses

The transmission of a nerve impulse along a neuron from one end to the other occurs as a result of electrical changes across the membrane of the neuron. The membrane of an unstimulated neuron is polarized—that is, there is a difference in electrical charge between the outside and inside of the membrane. The inside is negative with respect to the outside.

Polarization is established by maintaining an excess of sodium ions (Na^+) on the outside and an excess of potassium ions (K^+) on the inside. A certain amount of Na^+ and K^+ is always leaking across the membrane through leakage channels, but Na^+/K^+ pumps in the membrane actively restore the ions to the appropriate side.

The main contribution to the resting membrane potential (a polarized nerve) is the difference in permeability of the resting membrane to potassium ions versus sodium ions. The resting membrane is much more permeable to potassium ions than to sodium ions resulting in slightly more net potassium ion diffusion (from the inside of the neuron to the outside) than sodium ion diffusion (from the outside of the neuron to the inside) causing the slight difference in polarity right along the membrane of the axon.

Other ions, such as large, negatively charged proteins and nucleic acids, reside within the cell. It is these large, negatively charged ions that contribute to the overall negative charge on the inside of the cell membrane as compared to the outside.

In addition to crossing the membrane through leakage channels, ions may cross through **gated channels.** Gated channels open in response to neurotransmitters, changes in membrane potential, or other stimuli.

ACTION POTENTIAL

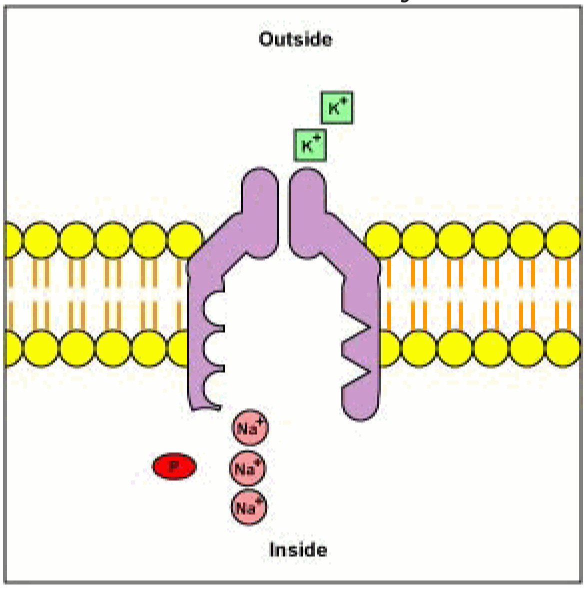
An action potential is a very rapid change in membrane potential that occurs when a nerve cell membrane is stimulated. Specifically, the membrane potential goes from the resting potential (typically -70 mV) to some positive value (typically about +30 mV) in a very short period of time (just a few milliseconds).

Depolarization refers to the loss of polarization which is caused by the change in the permeability of sodium ions. This leads to the migration of sodium ions to the interior of a nerve cell. The resting membrane potential is -70 mV. when a signal transmits through a neuron, an action potential is created by a depolarizing current. The depolarizing current is generated by the opening of sodium ion channels. Sodium ions migrate inside the cell from the outside. When the membrane potential reaches -55 mV, the action potential is generated. The -55 mV is called the threshold. The membrane potential at the action potential is +30 mV. The

Repolarization. In response to the inflow of Na^+, K^+ channels open, this time allowing K^+ on the inside to rush out of the cell. The movement of K^+ out of the cell causes repolarization by restoring the original membrane polarization. Unlike the resting potential, however, in repolarization the K^+ are on the outside and the Na^+ are on the inside. Soon after the K^+ gates open, the Na^+ gates close.

Hyperpolarization. By the time the K^+ channels close, more K^+ have moved out of the cell than is actually necessary to establish the original polarized potential. Thus, the membrane becomes hyperpolarized (about –80 millivolts). The membrane is polarized, but the Na^+ and K^+ are on the wrong sides of the membrane

To reestablish the original distribution of these ions, the Na^+ and K^+ are returned to their resting potential location by Na^+/K^+ pumps in the cell membrane. Once these ions are completely returned to their resting potential location, the neuron is ready for another stimulus



Sodium-Potassium Pump

Refractory period

ABSOLUTE Refractory period. With the passage of the action potential, the cell membrane is in an unusual state of affairs. During this refractory period, the axon will not respond to a new stimulus

During an action potential, a second stimulus will not produce a second action potential.

RELATIVE Refractory period

- Another action potential can be produced, but only if the stimulus is greater than the threshold stimulus

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.