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Howard Hughes Medical Institute 2008 Holiday Lectures on Science

Making Your Mind
Molecules, Motion, and Memory

Two leading neuroscientists discuss our current understanding of memory and brain development.

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How Neurons Work

A neuron is a specialized cell that transmits information by electrical and chemical signals. A typical neuron has dendrites, a cell body, an axon, and axon terminals. Axon terminals transmit signals and dendrites receive signals.

Dendrite

Cell Body

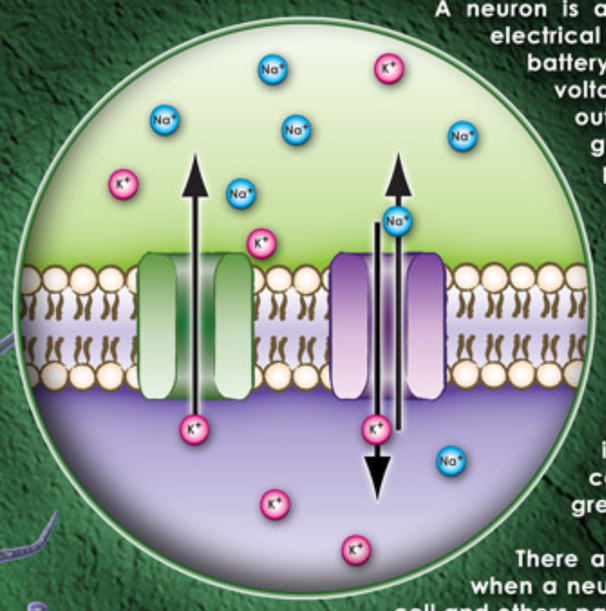
Axon

Myelin Sheath

Axon Terminal

Neurons Are Batteries!

A neuron is a cellular battery, with a voltage—or an electrical potential—of 70 mV (1/20th of one AA battery). This is the neuron's resting potential. The voltage inside the cell is –70 mV and the outside is 0 V. Neurons use their voltage to generate electrical signals called action potentials. Action potentials allow neurons to carry information from all our senses, and to transmit important orders to our muscles and other organs.



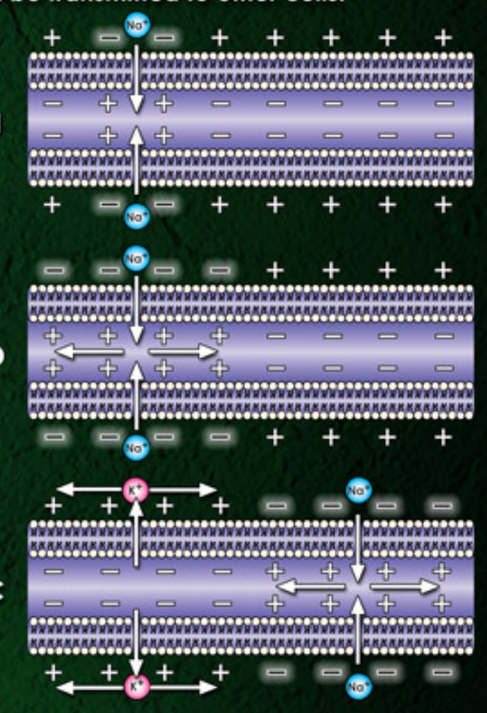
Keeping the Battery Charged

Neurons expend energy to maintain their resting potential. They run a pump (right, purple) that pushes sodium ions (Na^+) out of the cell and brings potassium ions (K^+) into the cell. K^+ can leak back out of the cell through passive protein channels (left, green) that are always open.

There are other protein channels that only open when a neuron is stimulated. Some pass Na^+ into the cell and others pass K^+ out of the cell. Both types are closed when the neuron is at rest.

Using the Battery

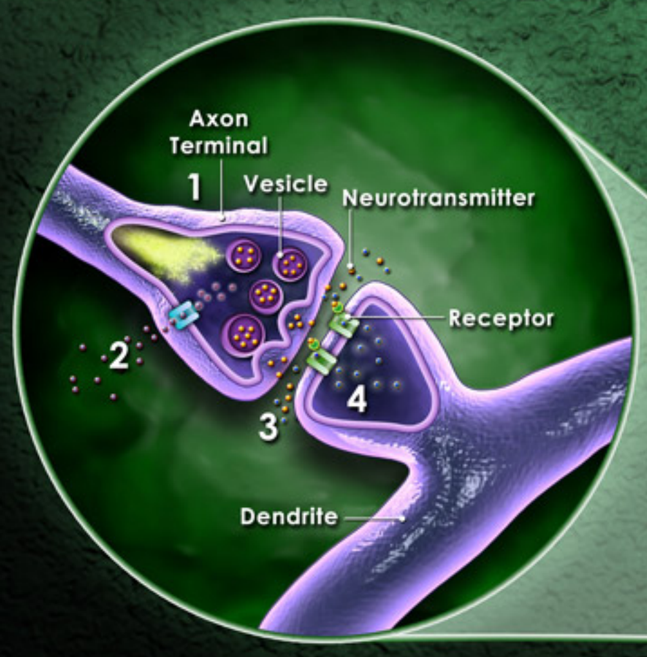
An action potential is triggered when one neuron is stimulated by another (see "Synapse"). Once an action potential is triggered, it rushes along the axon to the axon terminals, where the signal can be transmitted to other cells.



The stimulus causes sodium channels to open and Na^+ to flow into the cell locally (a). As a result the cell loses negative charge, which in turn opens more Na^+ channels. As more channels open, and more Na^+ rushes in, the loss of negative charge rapidly spreads up and down the axon (b). Very soon after opening, the Na+ channels close, and K^+ moves out of the cell to end the action potential and restore the negative resting potential (c).

Synapse

Neurons use structures called synapses to talk to one another. At a synapse, two neurons nearly touch each other. They are so close that chemical messages can be sent rapidly across the small gap. The chemical signals, called neurotransmitters, are packaged into small vesicles. When an action potential (see "Using the Battery") arrives at the axon terminal, a sequence of events occurs to transmit the signal to the next cell.



1. Action potential arrives at the axon terminal.
2. Calcium ions (Ca^{++}) flow in.
3. Small vesicles fuse with the membrane and release their neurotransmitter content into the gap between the two cells.
4. The neurotransmitters bind to receptors on the next cell. These receptors open, allowing positive ions to rush in and stimulate the cell.

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