

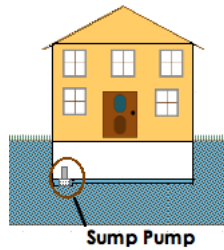
Nerve Cells & Impulses

Class 05: The Neural Impulse

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Some Background Metaphors

- If your home cellar is built in very wet ground, what do you need to keep the cellar from flooding?
- What happens when you flush a toilet? How frequently can you flush?



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Some basics about electricity

What's in an atom?



Atoms consist of a nucleus with **protons** & **neutrons** and an outside shell of one or more electron(s)



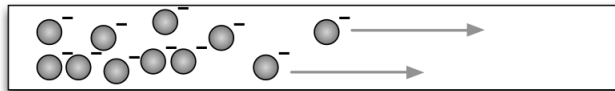
An electron is a subatomic particle which has a single negative charge



A proton is a subatomic particle which has a single positive charge

What's an electrical current?

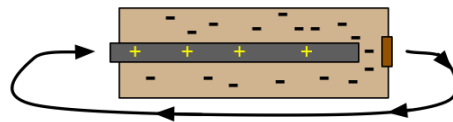
An electrical current is the flow of negatively-charged electrons toward a region that is less negatively charged through some type of conducting material (e.g., a wire or, even, liquid)



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What's a battery?


A battery is a device with one or more electrochemical cells in which there is an uneven distribution of electrical charges because of chemical reactions within the cells



As we will see, a neuron is a kind of organic battery

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Ions



Salt = Sodium Chloride = NaCl

Na^+ + Cl^-

Molecule has 2 atoms Na^+ Cl^- and no electric charge

But, if the atoms are separated, each of them has an electric charge.

Na^+ Sodium is positive (+) since it is missing 1 electron

Cl^- Chlorine is negative (-) since it has 1 extra electron

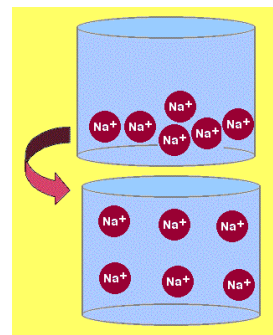
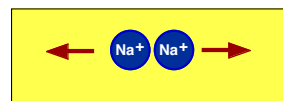
An atom which is positively charged is a + ion
and
an atom which is negatively charged is a - ion

K^+ Potassium is positive (+) and its symbol is K^+

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2 Types of “Pressure” among Ions

- Like electrons, ions can flow or move in liquids
- Ions of the same charge repel each other (called **an electrostatic or electrical gradient**)
- Ions tend to diffuse to equalize their concentration in a liquid, i.e., high concentration spreads out to areas of low concentration (**concentration gradient**)

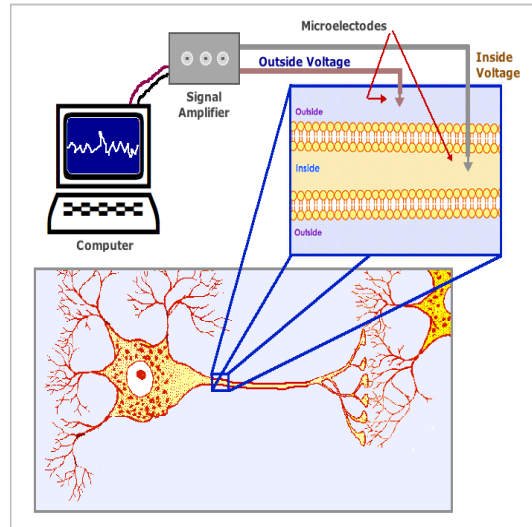


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Measuring Voltage across Neural Membrane

How can we measure the voltage on either side of the neuron's membrane?

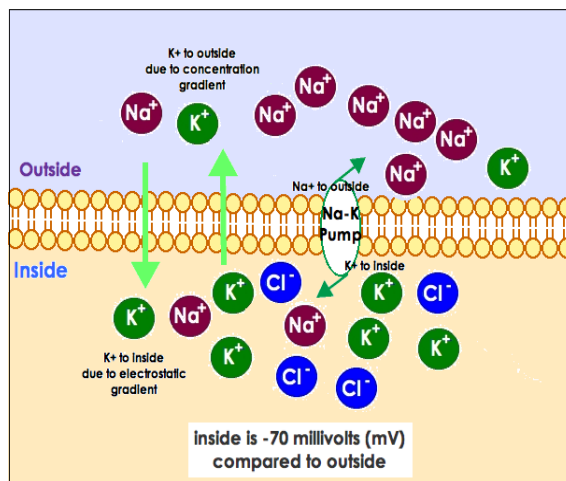
Scientists use very tiny **microelectrodes** which are connected to a signal amplifier and, then, a computer



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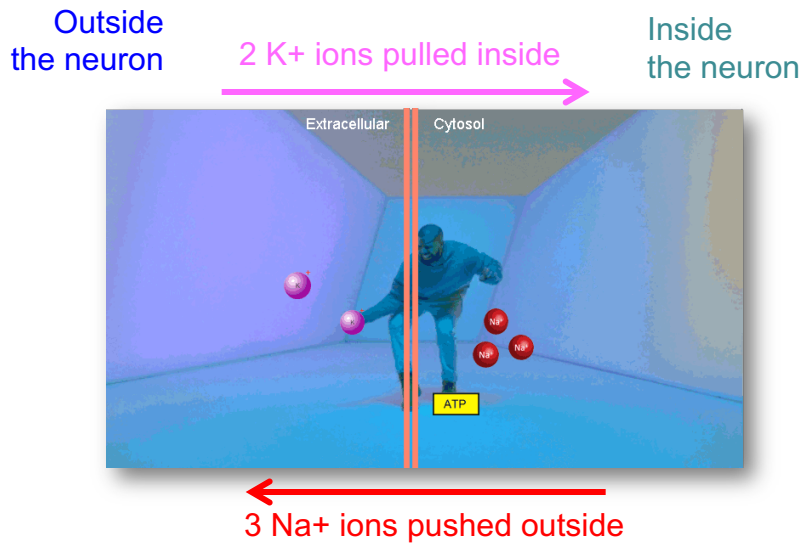
The Neuron at Rest

- The areas inside & outside the membrane are liquid but with different concentrations of ions
- **More Na⁺ outside & more K⁺ inside**
- Membrane is **selectively permeable**
- Neurons “leak” K⁺
- K⁺ both enters and exits membrane
- **Sodium-Potassium (Na-K) Pump** (a protein complex) maintains the resting state
- Other channels (gates) in the membrane remain closed



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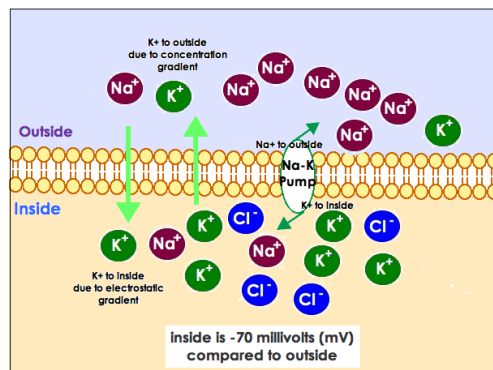
Illustration of the Sodium-Potassium Pump



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The Neuron at Rest 2

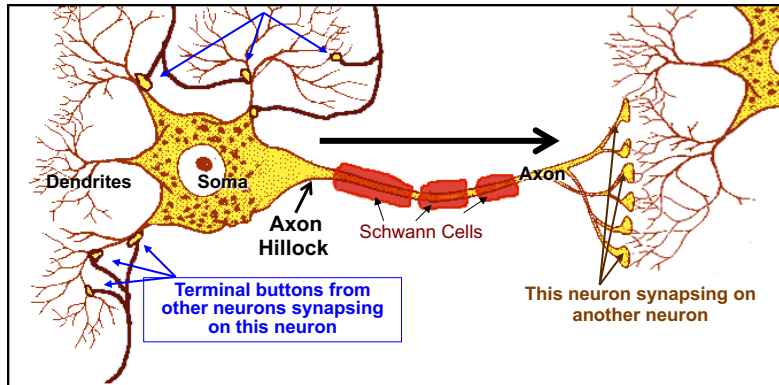
- Because of the unequal concentrations of ions, there is a **strong electrical gradient AND concentration gradient** upon the Na⁺ ions to move inside the membrane.
- The inside is -70 mV relative to the outside. This is its **“resting potential”**
- Hence, a neuron at rest is **like a battery with a charge of -70 mV**



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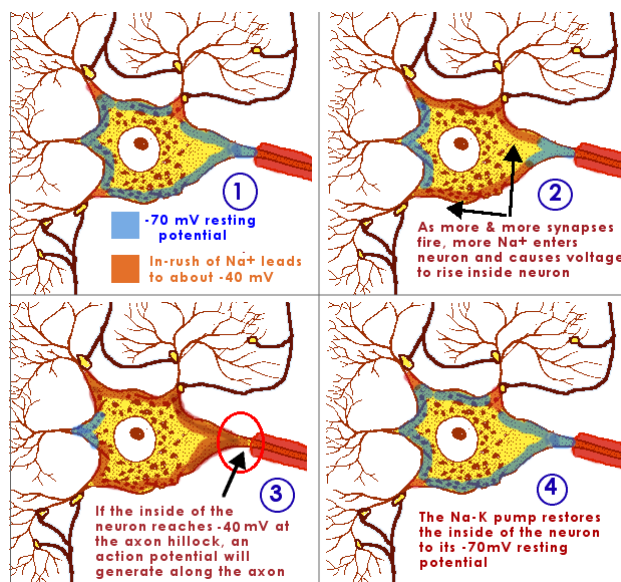
Neuron in Context

How does the neuron go from its resting potential to an action potential?



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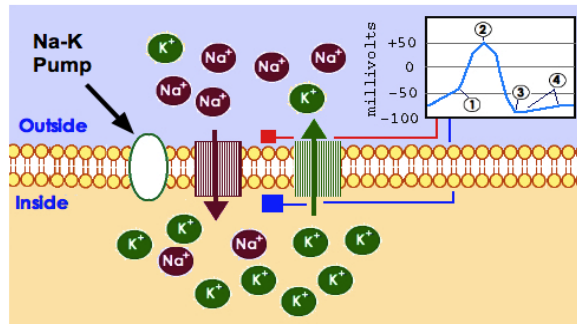
Causing an Action Potential



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Action Potential

- The axon is lined with Na^+ and K^+ channels which open and close depending upon the voltage inside the neuron. Thus, **they are voltage-activated.**
- The action potential is the movement of ions inside and outside the neuron in a **patterned sequence**



- ① At -40 mV, Na^+ channels open & Na^+ ions flood in. After a short delay, K^+ channels open as well & K^+ ions flood outside
- ② At +50 mV, Na^+ channels close but K^+ channels remain open & K^+ ions continue to pour inside
- ③ When inside voltage decreases to -90mV, K^+ channels close.
- ④ Na-K pump restores potential to -70mV in 1 msec.