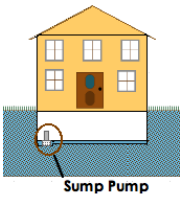
Nerve Cells & Impulses

Class 05: The Neural Impulse (I)

1

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?
- The neuron's equivalent is the sodium-potassium pump which restore the right balance inside the neuron



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Some basics about electricity

What's in an atom?

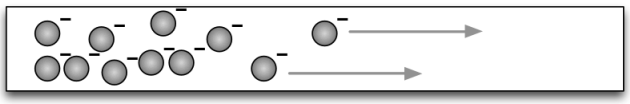
Atoms consist of a nucleus with protons & neutrons and an outside shell of one or more electron(s)

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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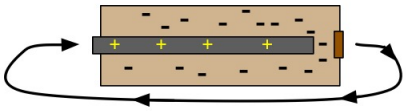
What's a battery?

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 then 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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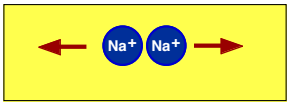
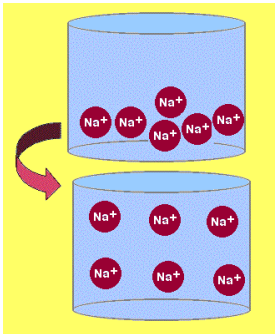
2 Types of "Pressure" among Ions

- 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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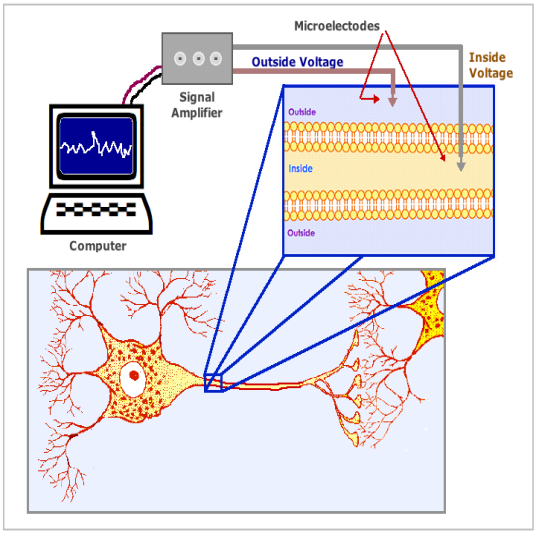
Measuring Voltage across Neural Membrane

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
- Neuron "leaks" 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

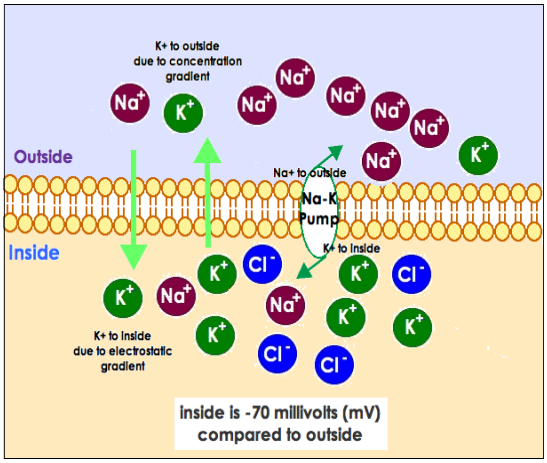

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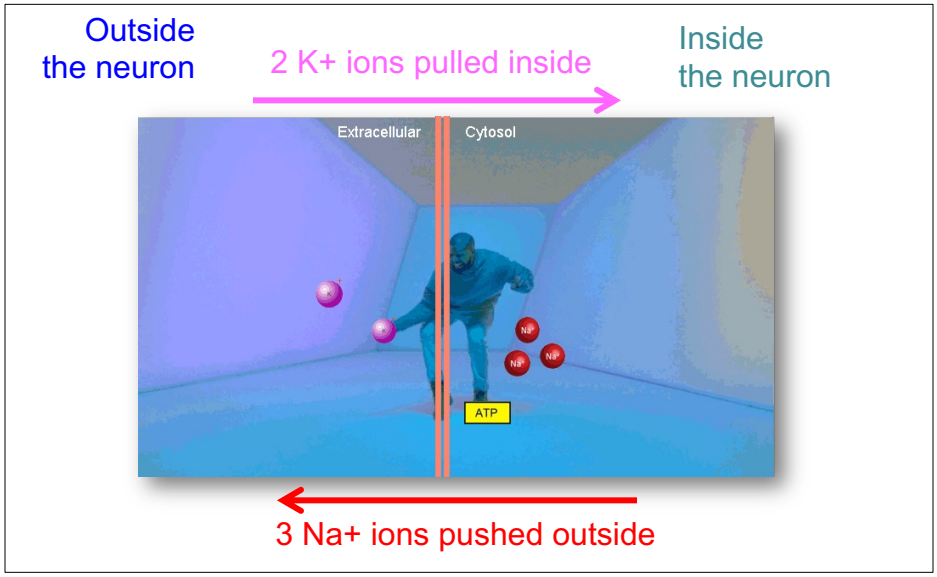
Illustration of the Sodium-Potassium Pump



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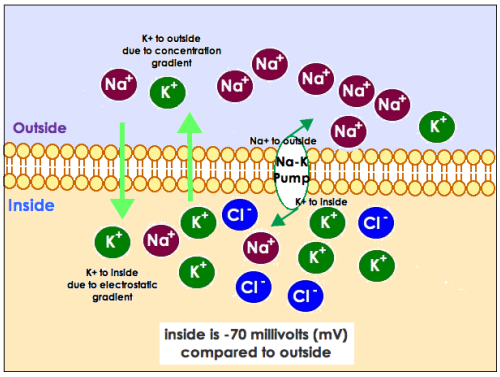
The Neuron at Rest 2

- 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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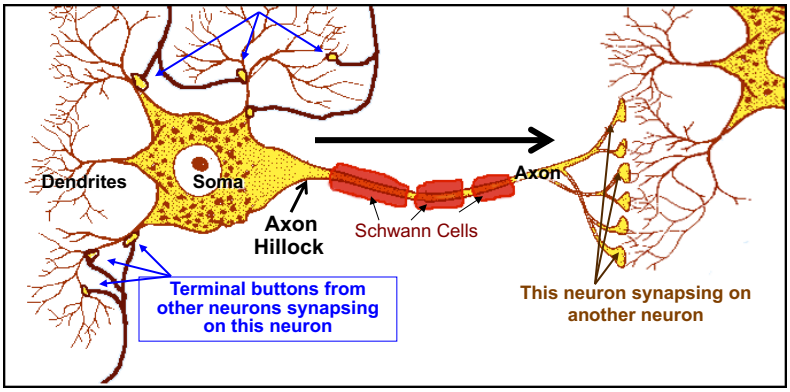
Neuron in Context

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



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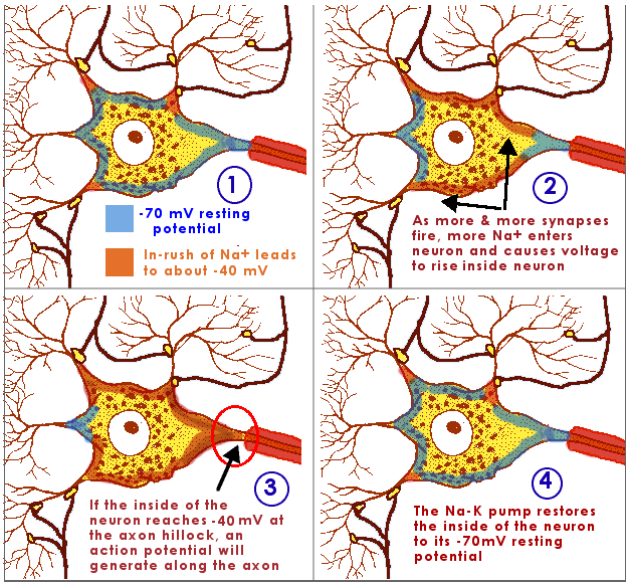
Causing an Action Potential



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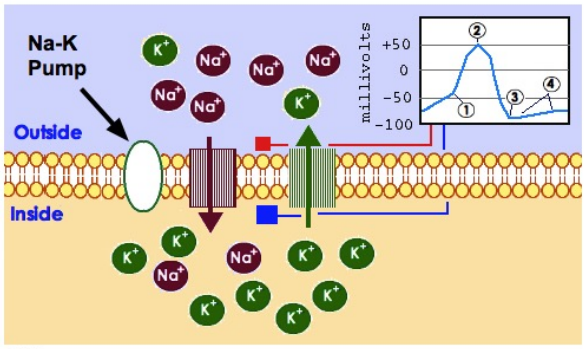
Action Potential

- 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 ump restores potential to -70mV in 1 msec.**

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Go to Part II at the PSY 340 web page

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