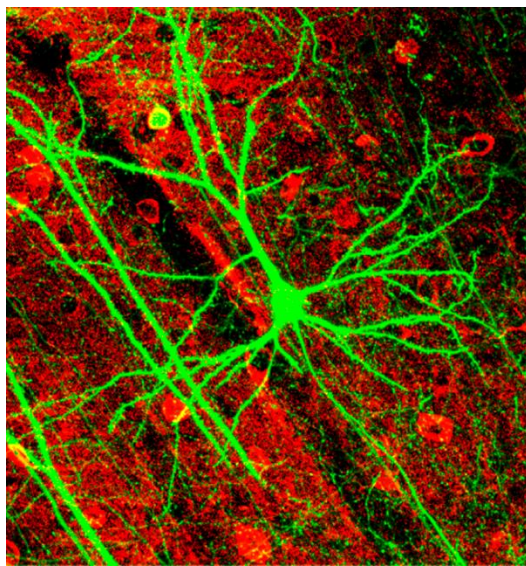


Computational Neuroscience: Neurobiology 101



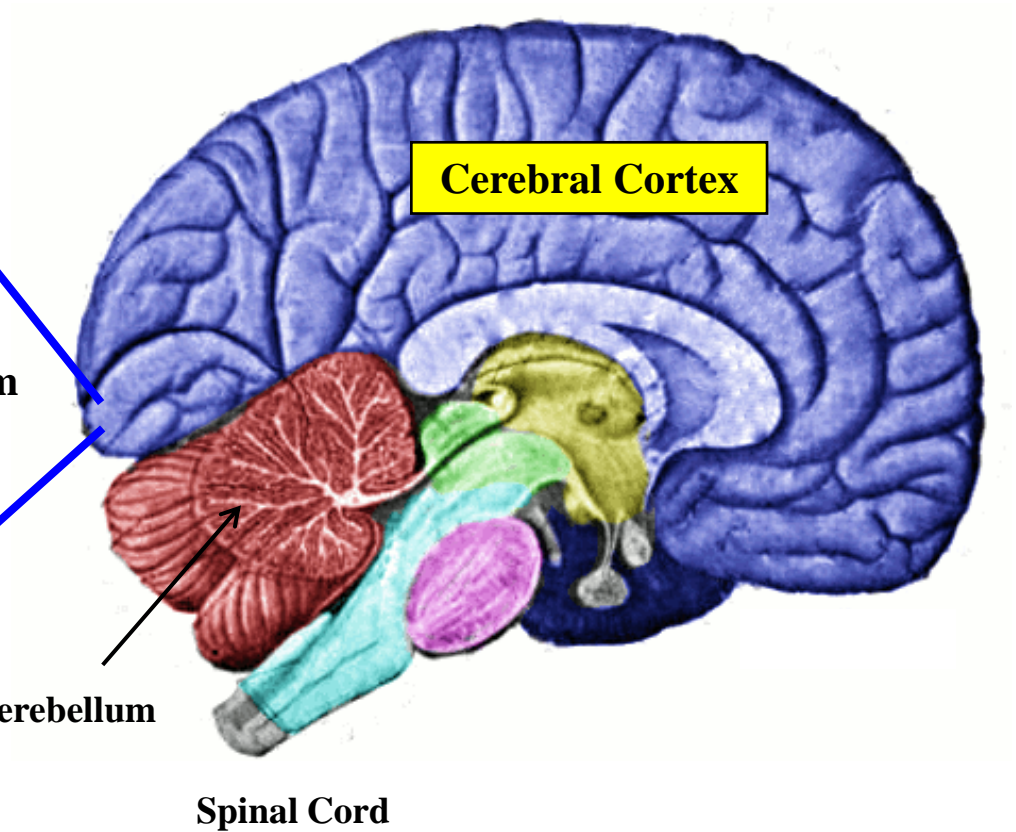
**Neurons, Synapses, and
Brain Regions**

Enter...the Neuron (Brain Cell)

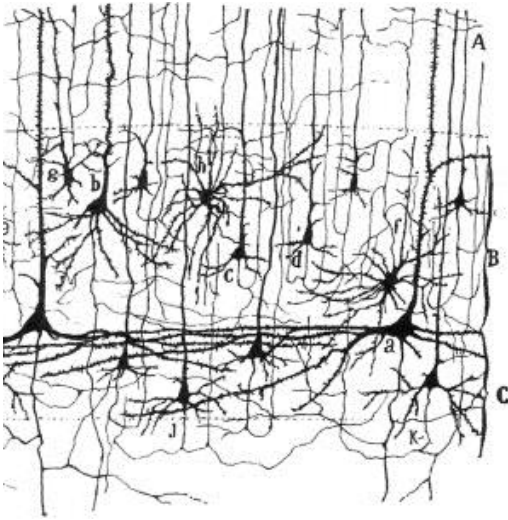


A Cortical Neuron

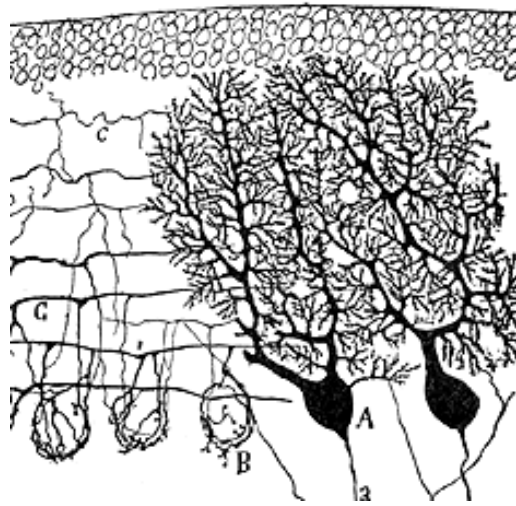
| ~25 μm



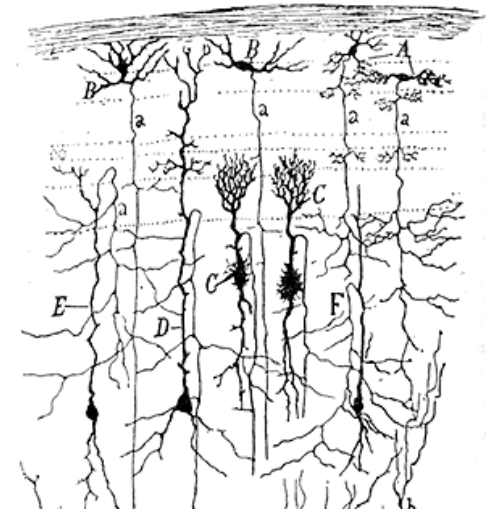
The Neuronal Zoo



Visual Cortex



Cerebellum



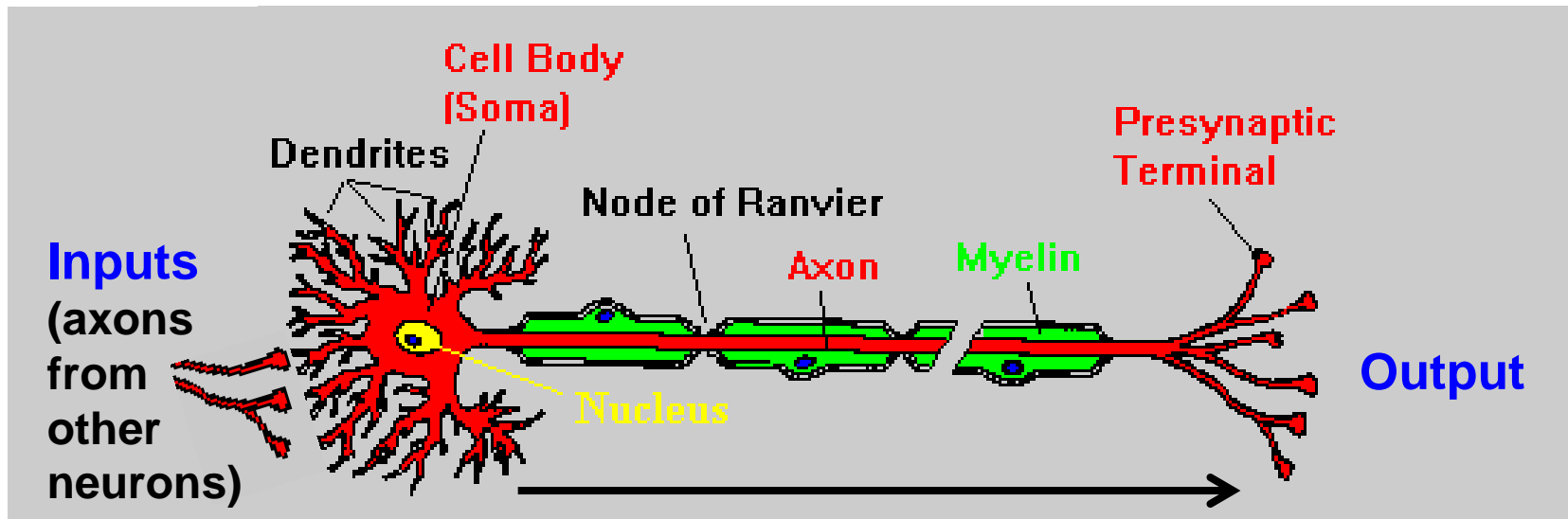
Optic Tectum

(Drawings by Ramón y Cajal, c. 1900)

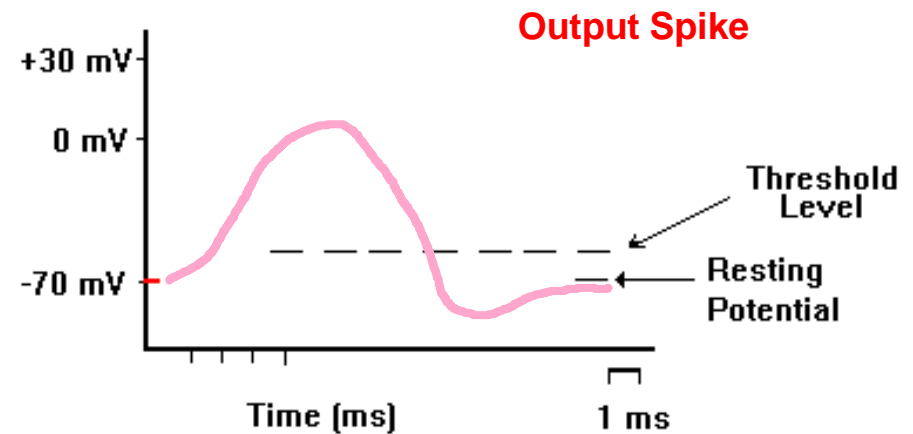
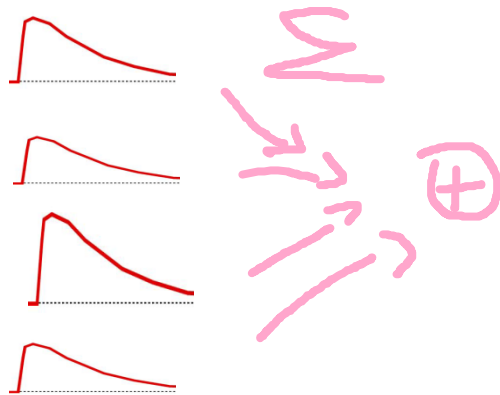
Neuron Doctrine:

- The neuron is the fundamental structural & functional unit of the brain
- Neurons are discrete cells and not continuous with other cells
- Information flows from the dendrites to the axon via the cell body

The Idealized Neuron



**EPSP =
Excitatory
Post-Synaptic
Potential**



What is a Neuron?

- ◆ A “leaky bag of charged liquid”

漏了包，里面有带电液体

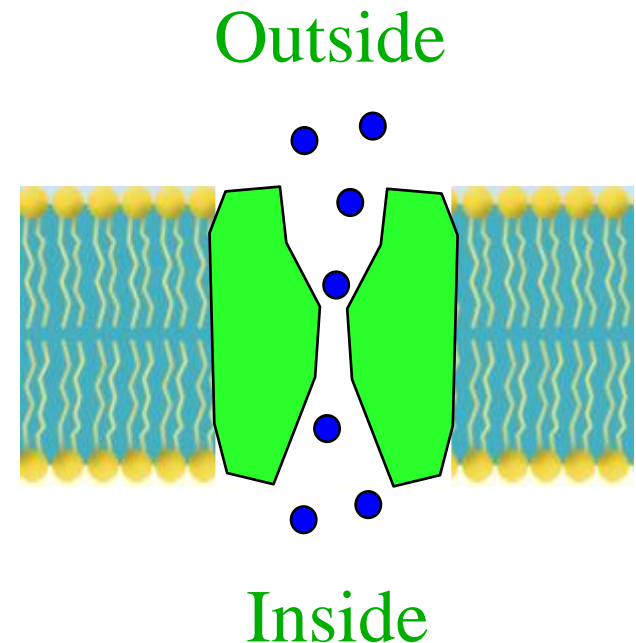
- ◆ Contents of the neuron enclosed within a *cell membrane*

- ◆ Cell membrane is a *lipid* bilayer

脂肪

- ⇒ Bilayer is impermeable to charged ion species such as Na^+ , Cl^- , and K^+

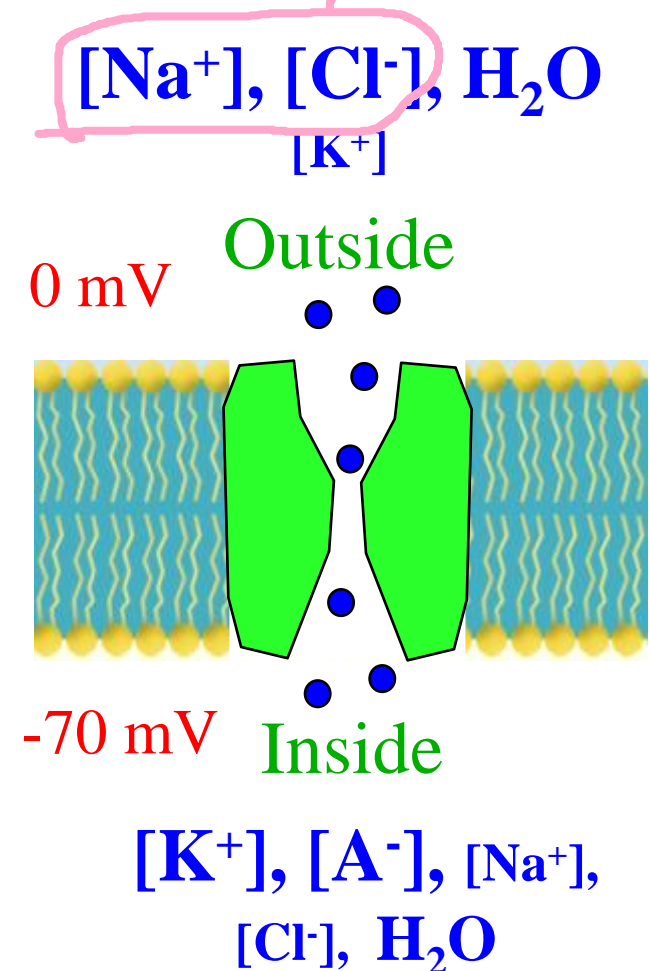
- ⇒ Ionic channels embedded in membrane allow ions to flow in or out



The Electrical Personality of a Neuron

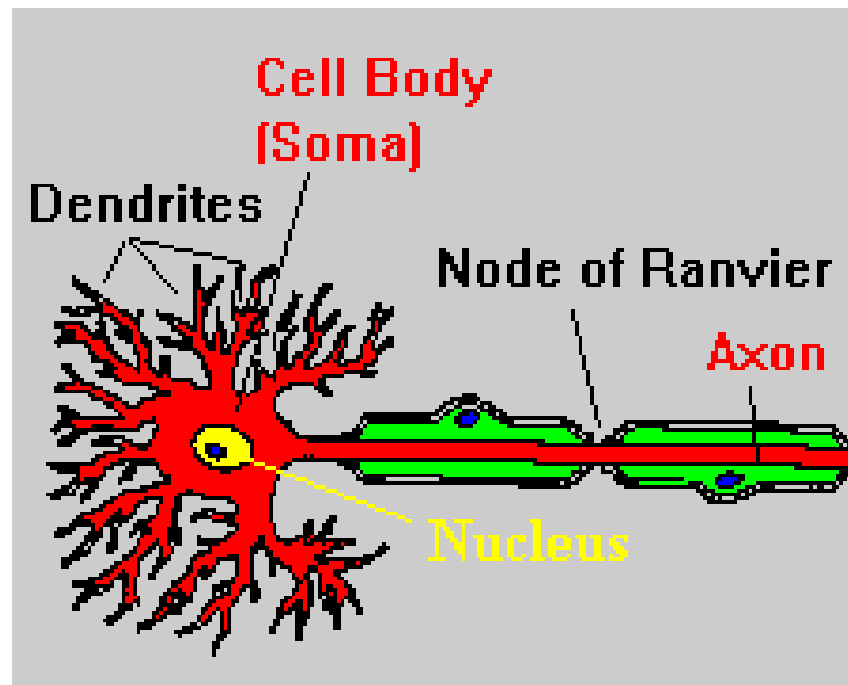
海水，曾经单细胞生命的环境。

- ◆ Each neuron maintains a *potential difference* across its membrane
 - ⇒ Inside is about **-70 mV** relative to outside
 - ⇒ $[\text{Na}^+]$ and $[\text{Cl}^-]$ higher outside; $[\text{K}^+]$ and organic anions $[\text{A}^-]$ higher inside
 - ⇒ *Ionic pump* maintains -70 mV difference by expelling Na^+ out and allowing K^+ ions in



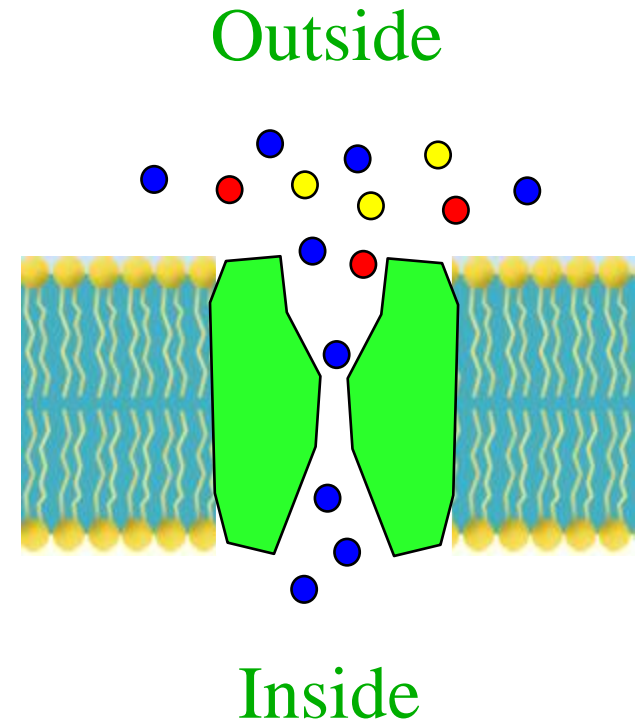
Influencing a Neuron's Electrical Personality

How can the electrical potential be changed in local regions of a neuron?



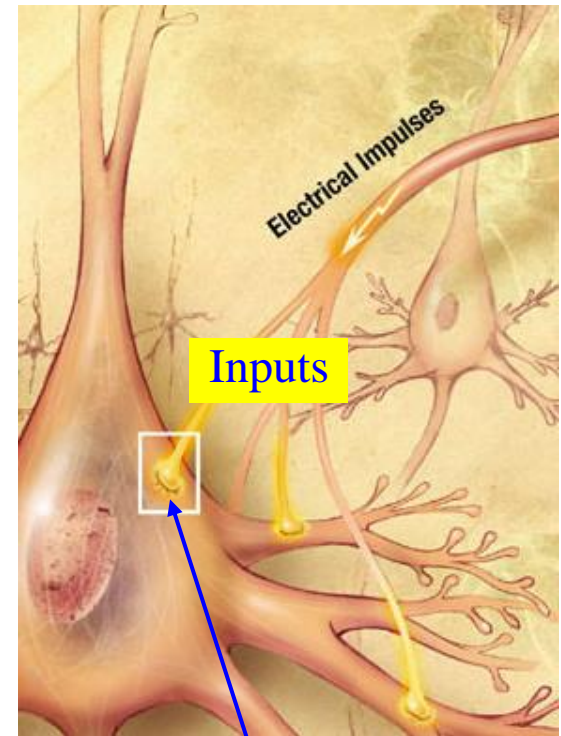
Ionic Channels: The Gatekeepers

- ♦ Ionic channels in membranes are proteins that are *selective* and allow *only specific ions* to pass through
 - ⇒ E.g. Pass Na^+ but not K^+ or Cl^-
- ♦ Ionic channels are *gated*
 - ⇒ **Voltage-gated**: Probability of opening depends on membrane voltage
 - ⇒ **Chemically-gated**: Binding to a chemical causes channel to open
 - ⇒ **Mechanically-gated**: Sensitive to pressure or stretch



Gated Channels allow Neuronal Signaling

- ◆ Inputs from other neurons → **chemically-gated channels** (at “**synapses**”) open → Changes in local membrane potential
- ◆ This in turn causes opening/closing of **voltage-gated channels** in dendrites, body, and axon, resulting in **depolarization** (**positive change in voltage**) or **hyperpolarization** (**negative change in voltage**)
- ◆ Strong enough depolarization causes a spike or “action potential”

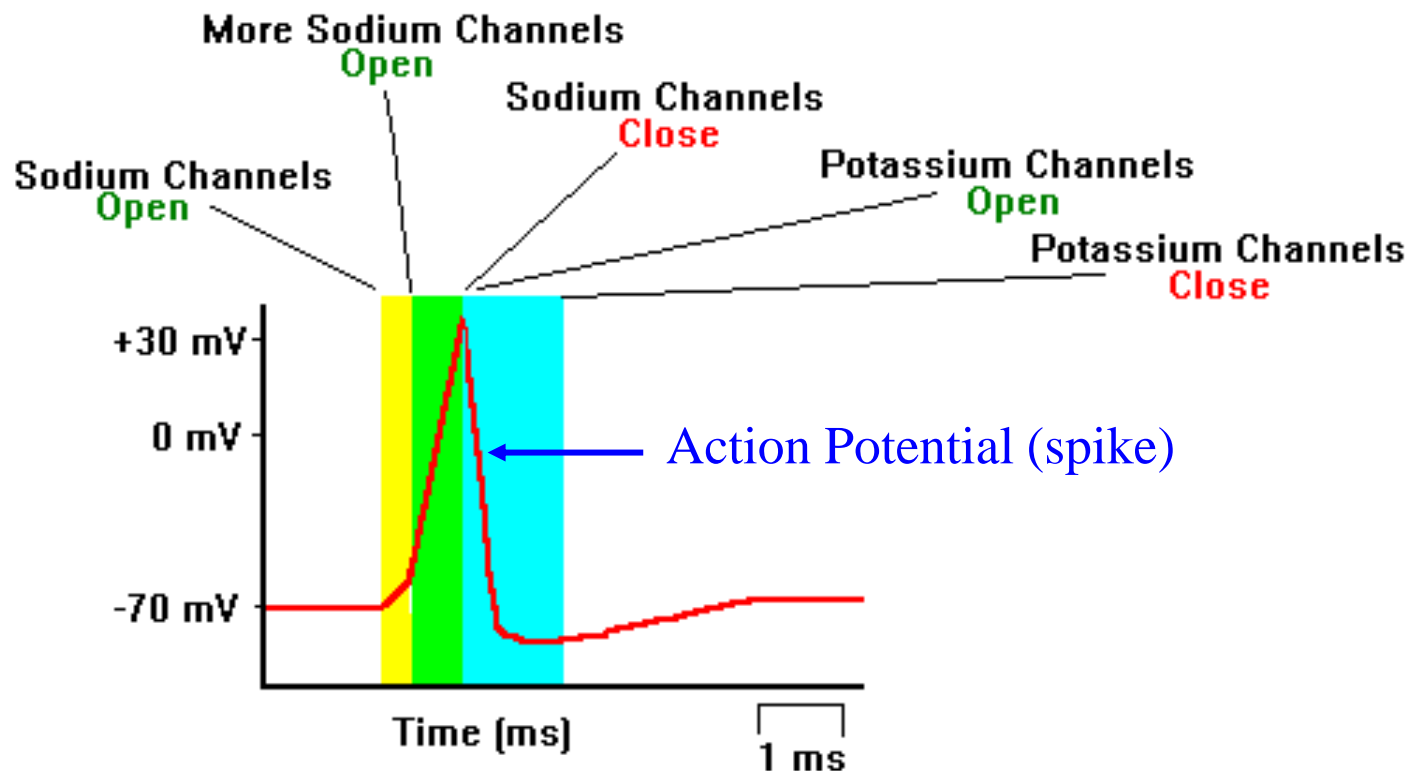


Synapse
(Junction between
neurons)

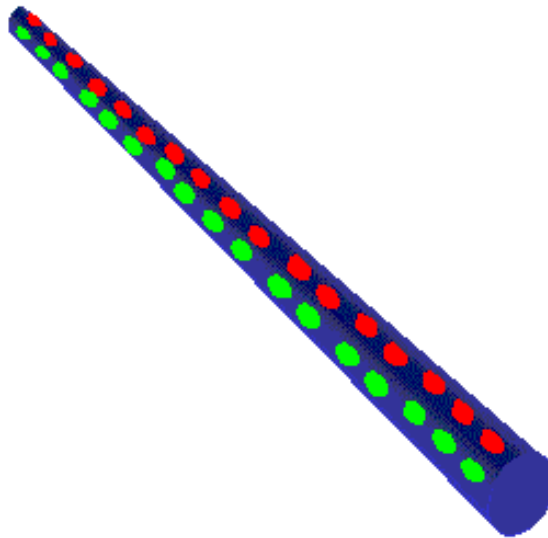
The Output of a Neuron: Action Potential (Spike)

Voltage-gated channels cause action potentials (spikes)

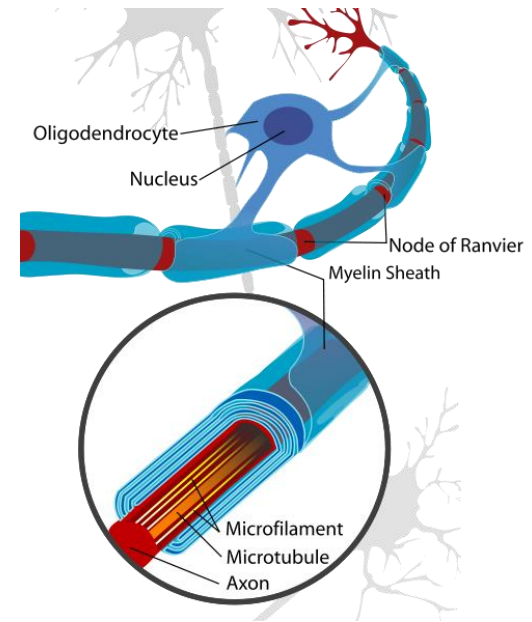
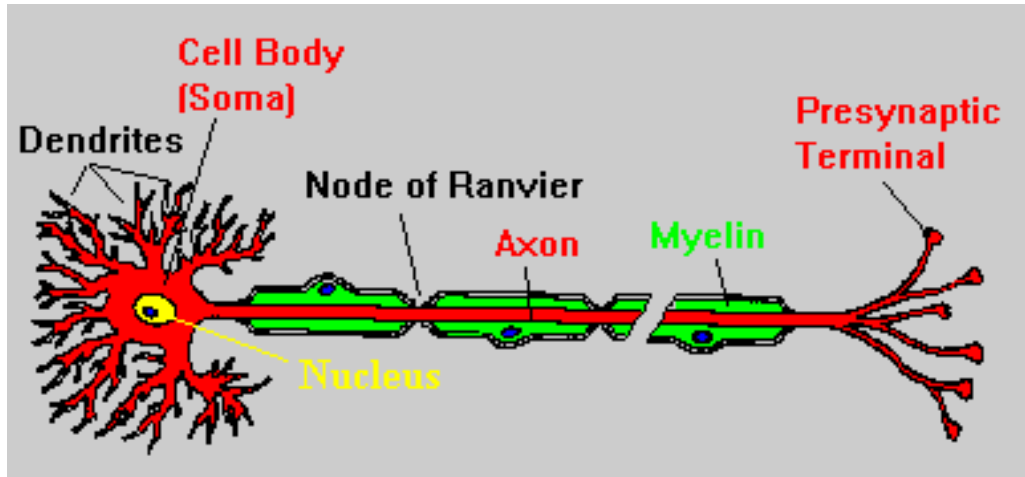
1. Strong depolarization opens Na^+ channels, causing rapid *Na^+ influx* and more channels to open, until they inactivate
2. *K^+ outflux* restores membrane potential



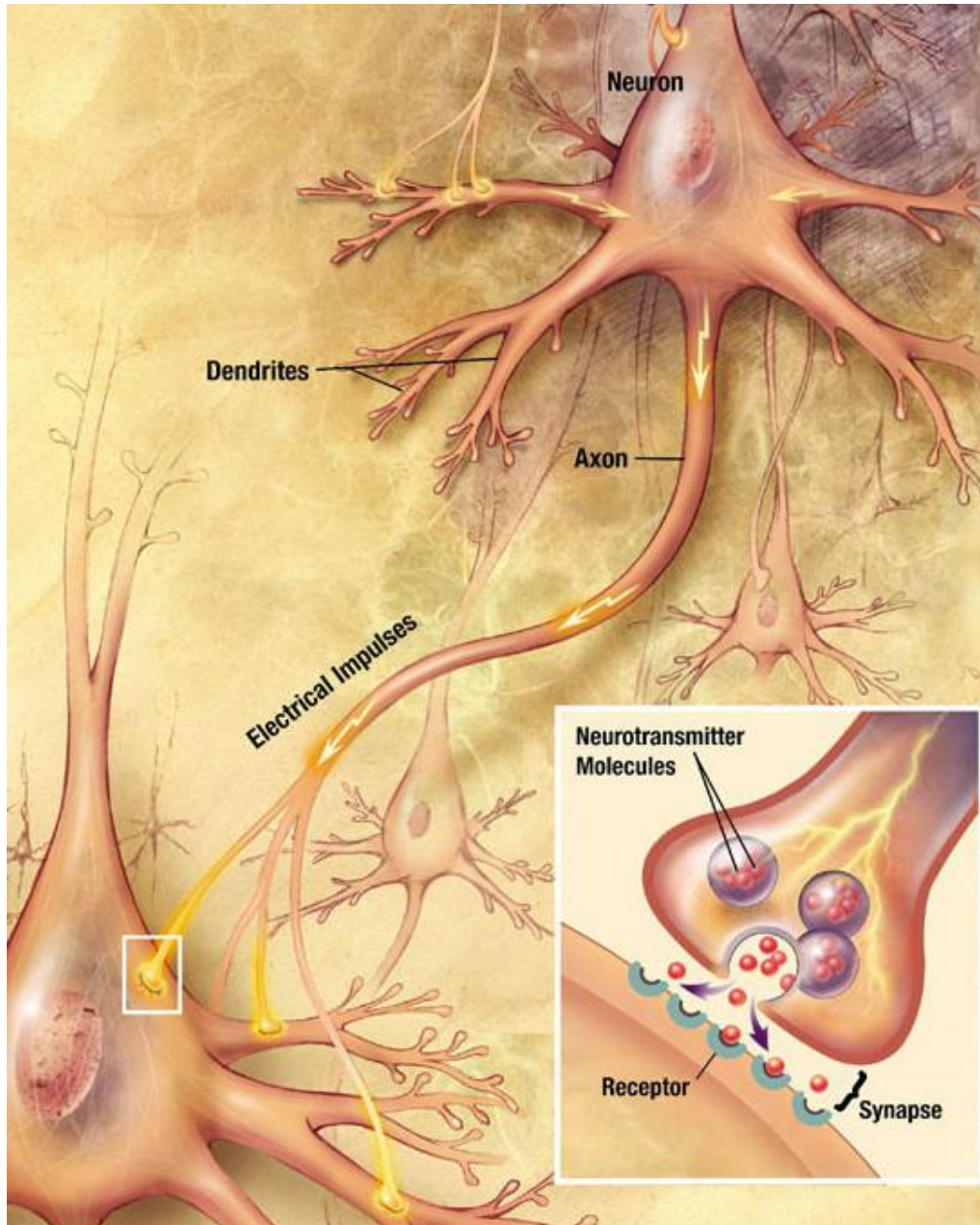
Propagation of a Spike along an Axon



Active Wiring: Myelination of Axons



- ◆ Myelin due to oligodendrocytes (glial cells) wrap axons and enable *fast long-range spike communication*
 - ⇒ Action potential “hops” from one non-myelinated region (node of Ranvier) to the next (*saltatory conduction*)
 - ⇒ “Active wire” allows *lossless signal propagation*



What happens
to the spike
(action
potential) when
it reaches the
end of an axon?

Enter...
the Synapse

[Next Lecture]