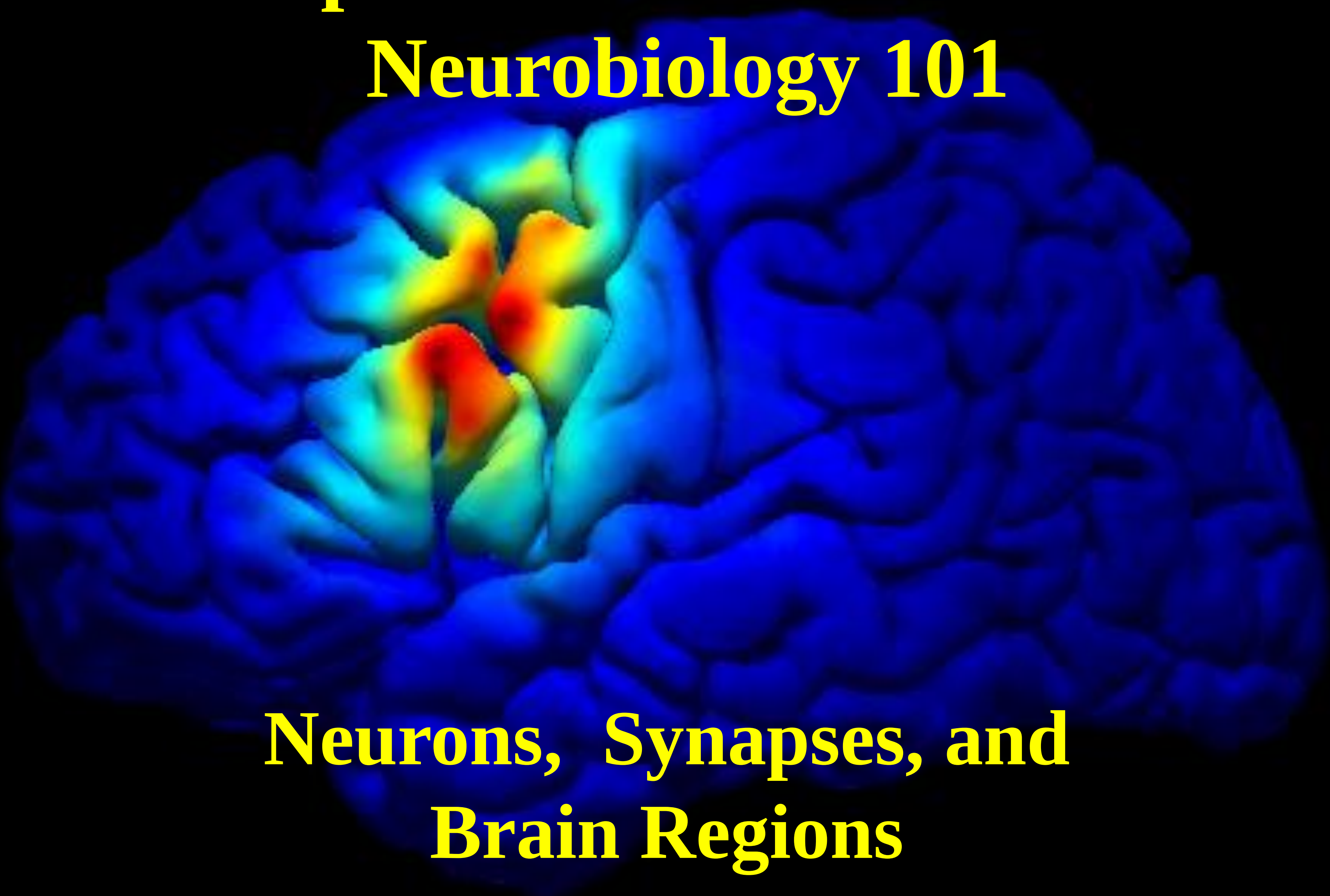
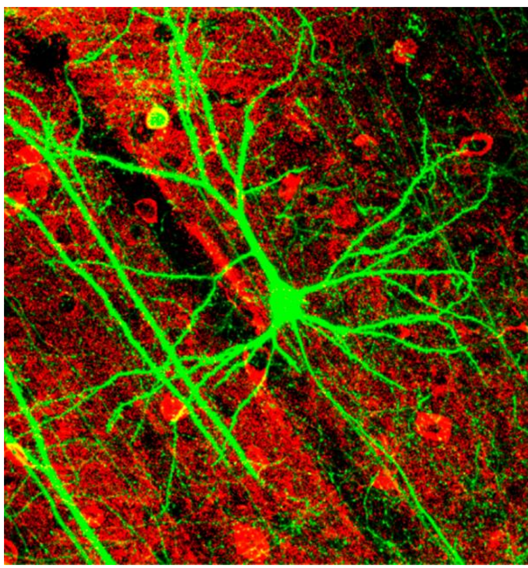
Computational Neuroscience: Neurobiology 101

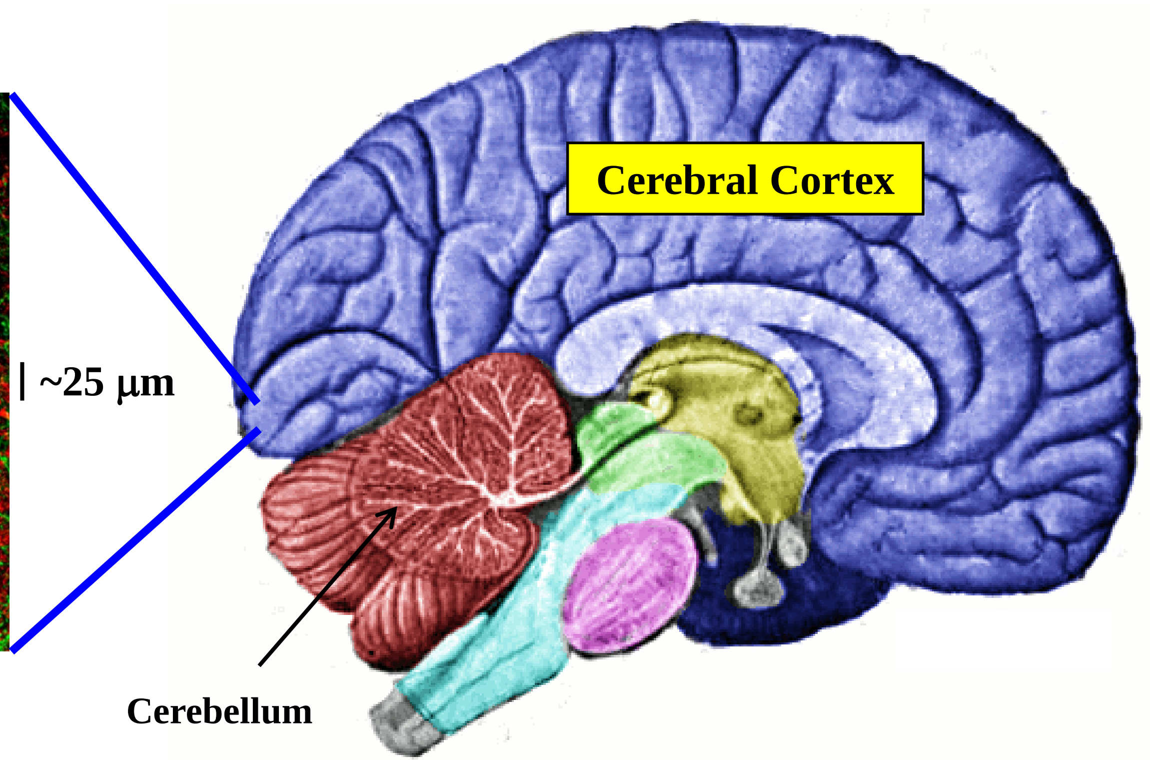


Neurons, Synapses, and Brain Regions

Enter…the Neuron (Brain Cell)



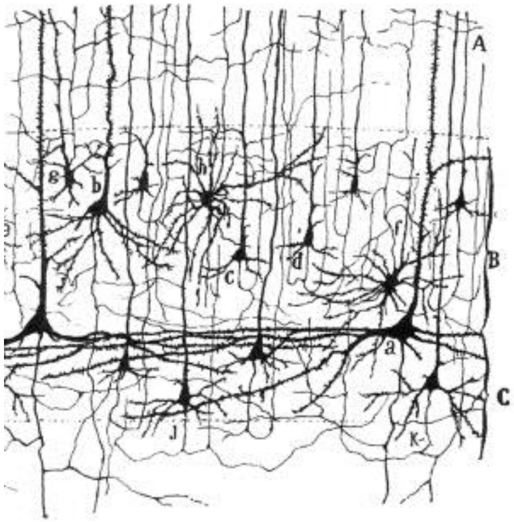
A Cortical Neuron



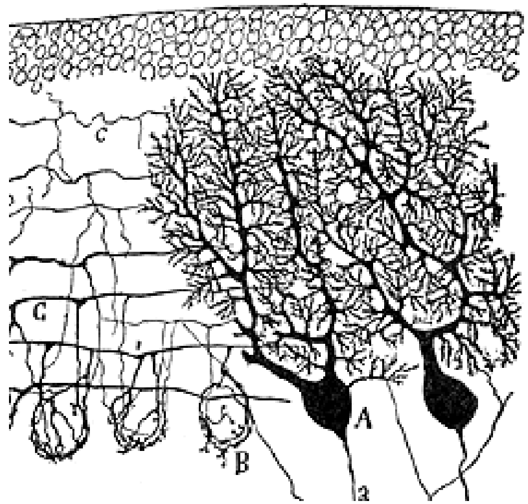
Spinal Cord

Image Source: Wikimedia Commons

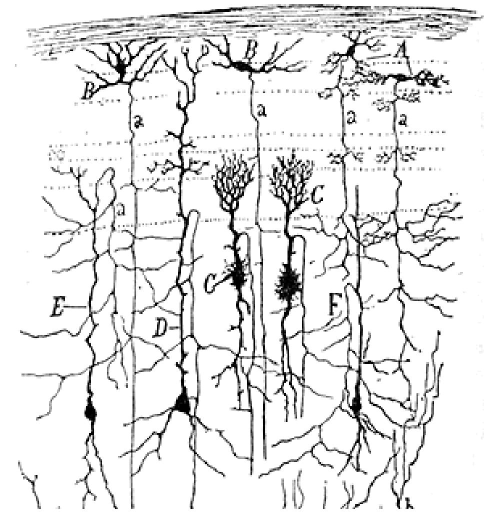
The Neuronal Zoo



Visual Cortex



Cerebellum



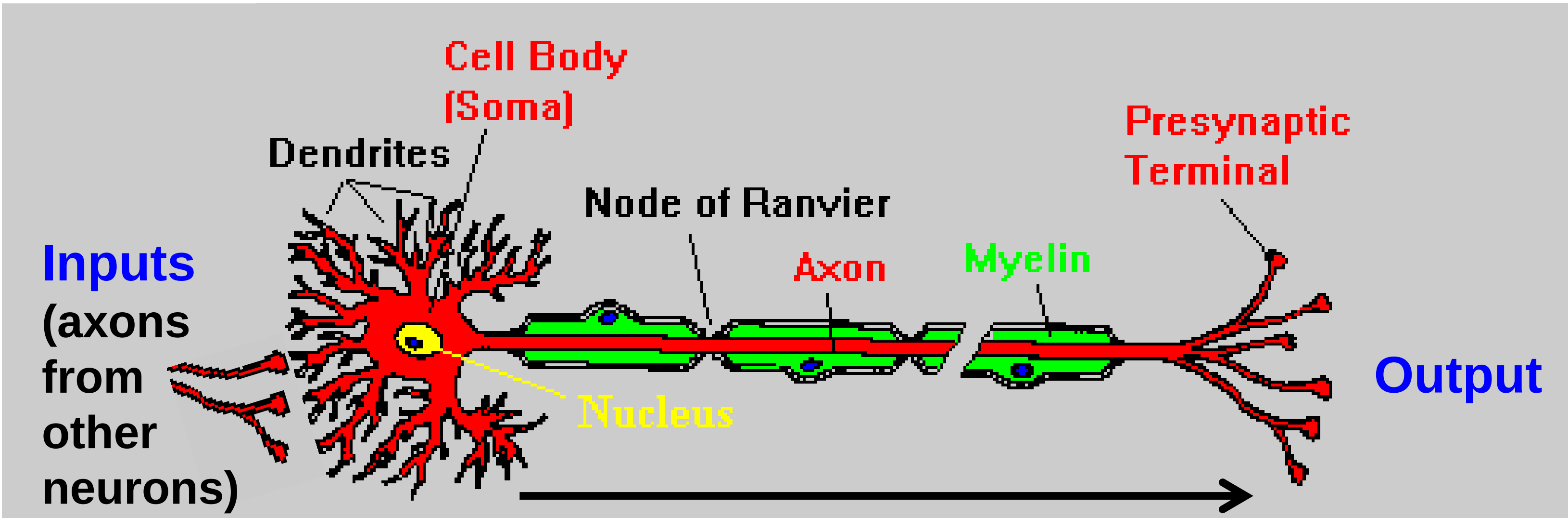
Optic Tectum

(Drawings by Ramón y Cajal, c. 1900)

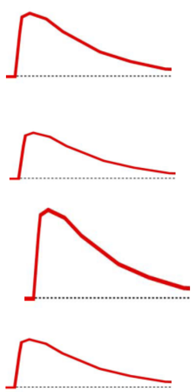
Neuron Doctrine:

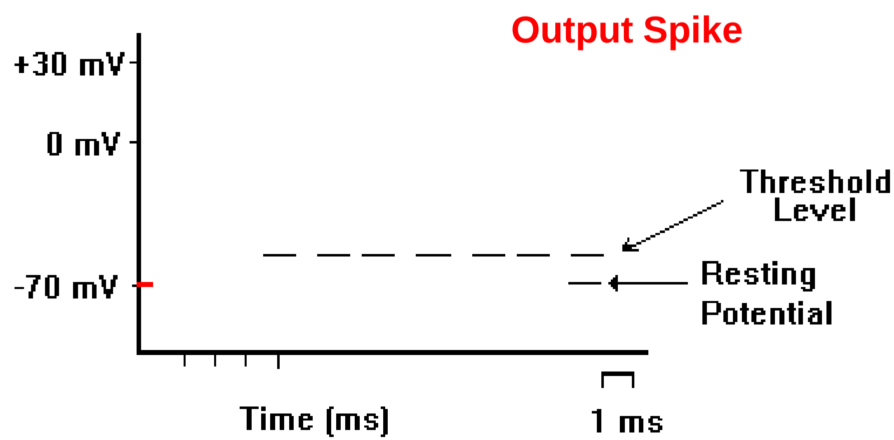
- The neuron is the fundamental structural & functional unit of the brain
- Neurons are discrete cells and not continuous with other cells
- Information flows from the dendrites to the axon via the cell body

The Idealized Neuron



EPSP =
Excitatory
Post-Synaptic
Potential

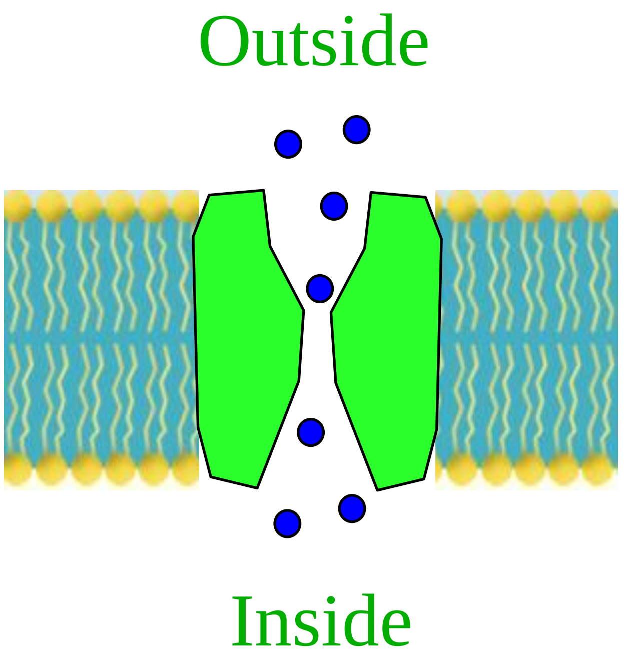




Images by Eric Chudler, UW

What is a Neuron?

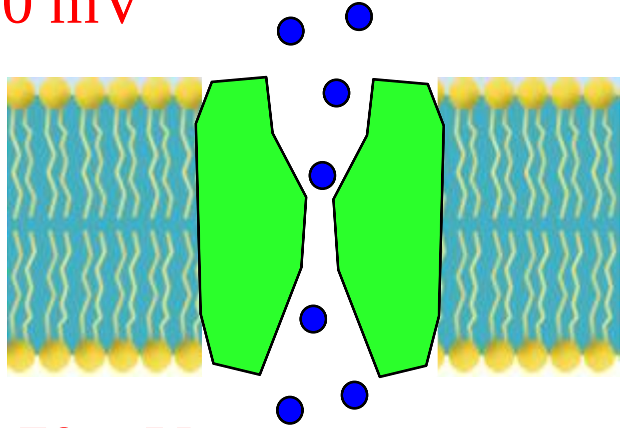
- A “leaky bag of charged liquid”
- Contents of the neuron enclosed within a *cell membrane*
- Cell membrane is a *lipid* bilayer
  - Bilayer is impermeable to charged ion species such as Na^+, Cl^-, and K^+
  - Ionic channels embedded in membrane allow ions to flow in or out



Adapted from Wikipedia

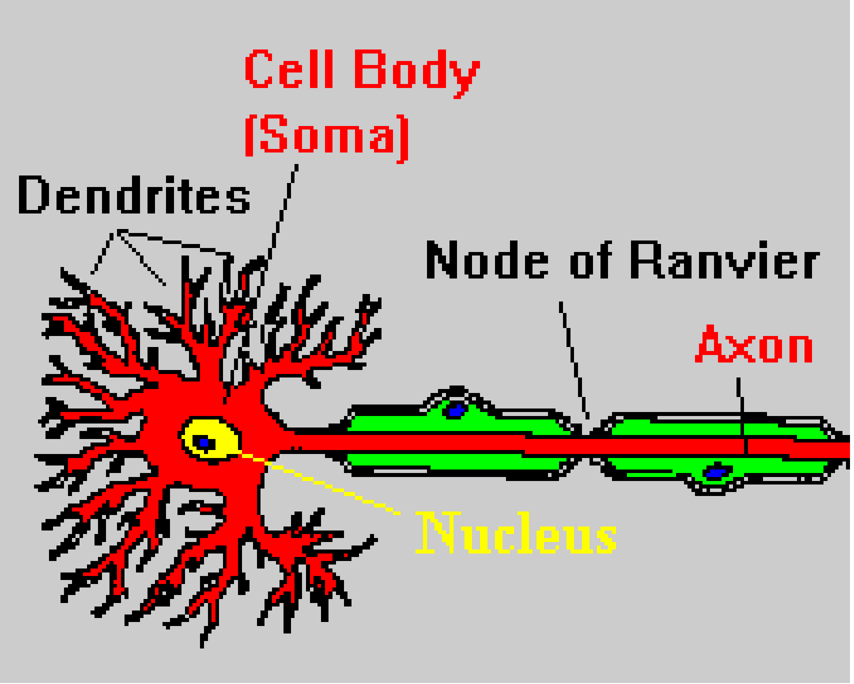
The Electrical Personality of a Neuron

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



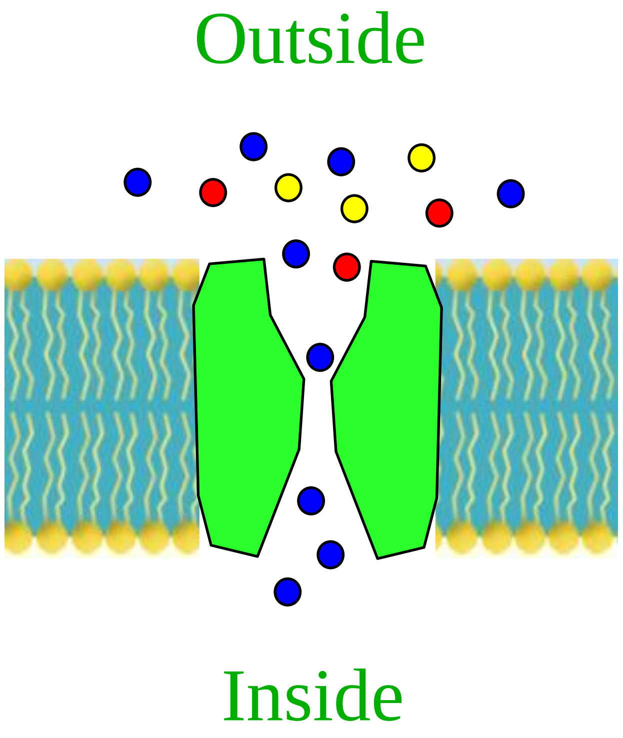
Influencing a Neuron's Electrical Personality

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



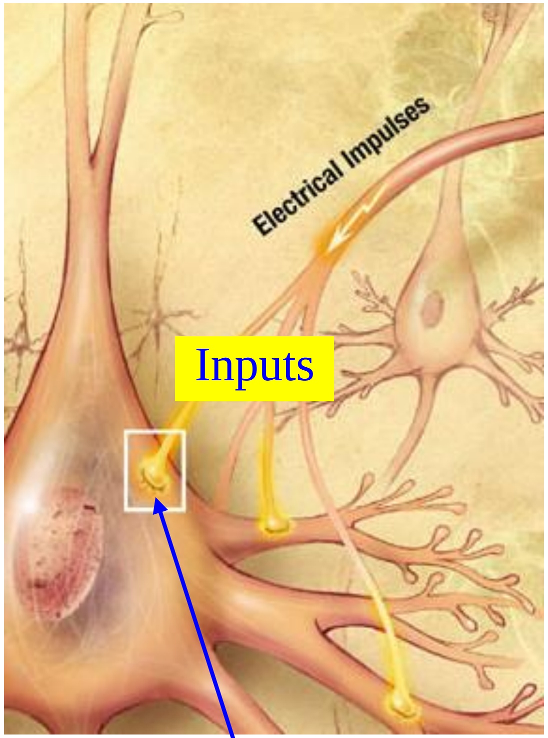
Ionic Channels: The Gatekeepers

- 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)

Image Source: Wikimedia Commons

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

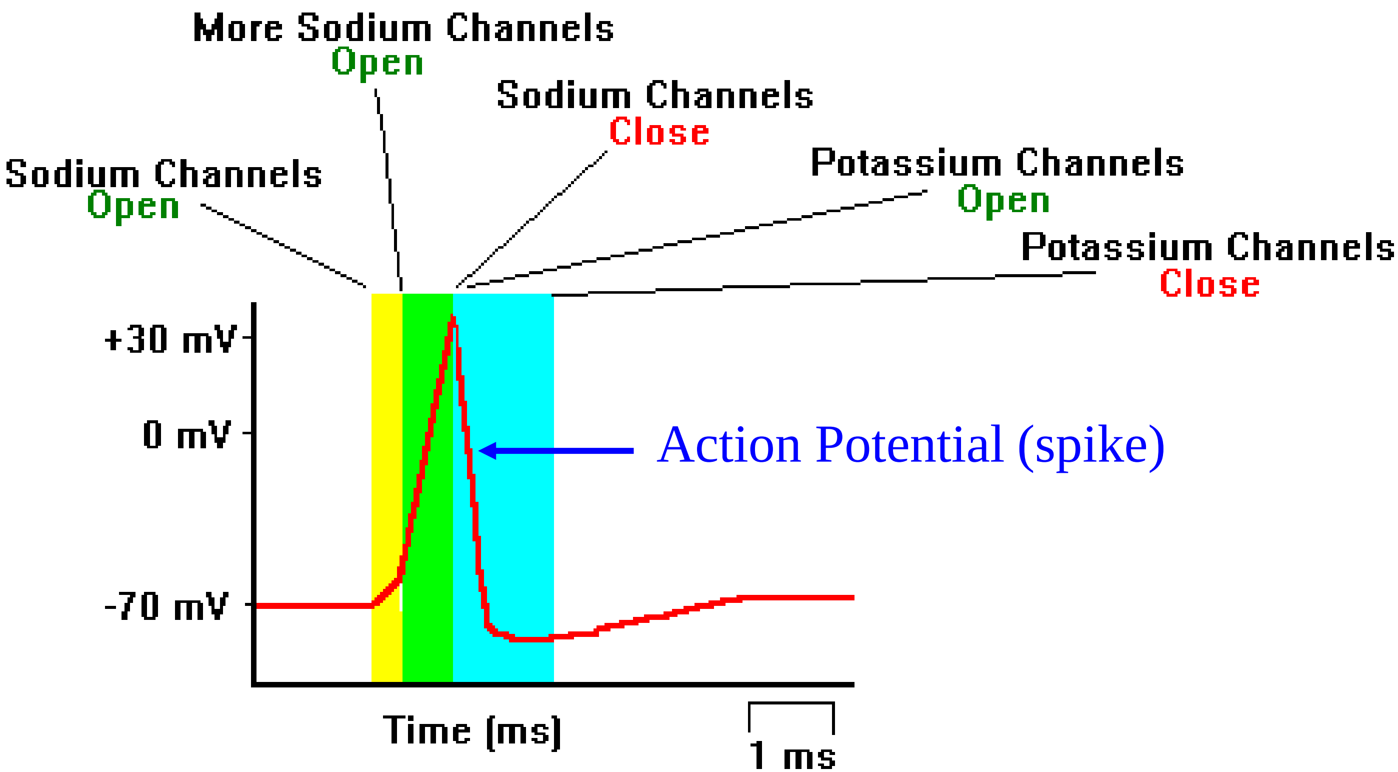
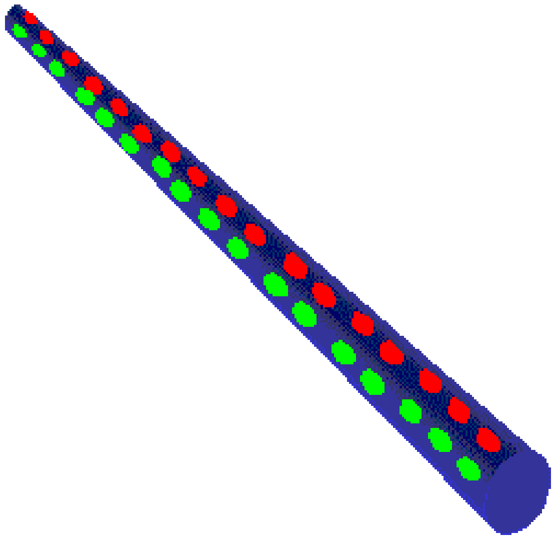


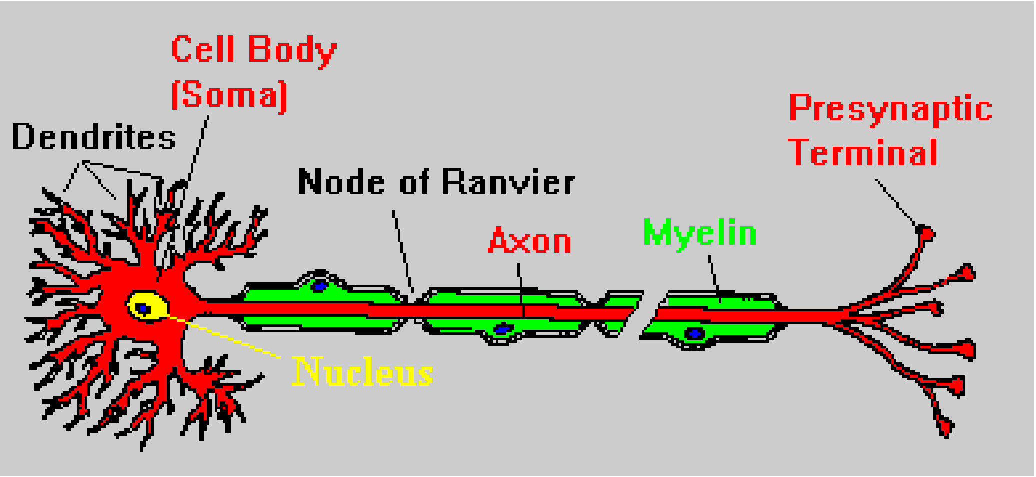
Image by Eric Chudler, UW

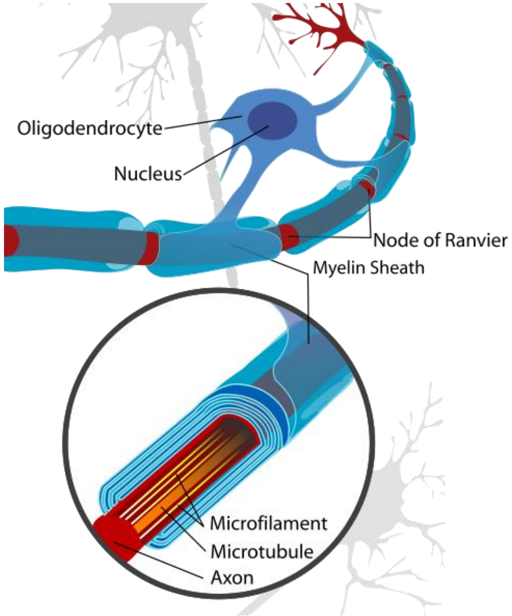
Propagation of a Spike along an Axon



From: http://psych.hanover.edu/Krantz/neural/actpotanim.html

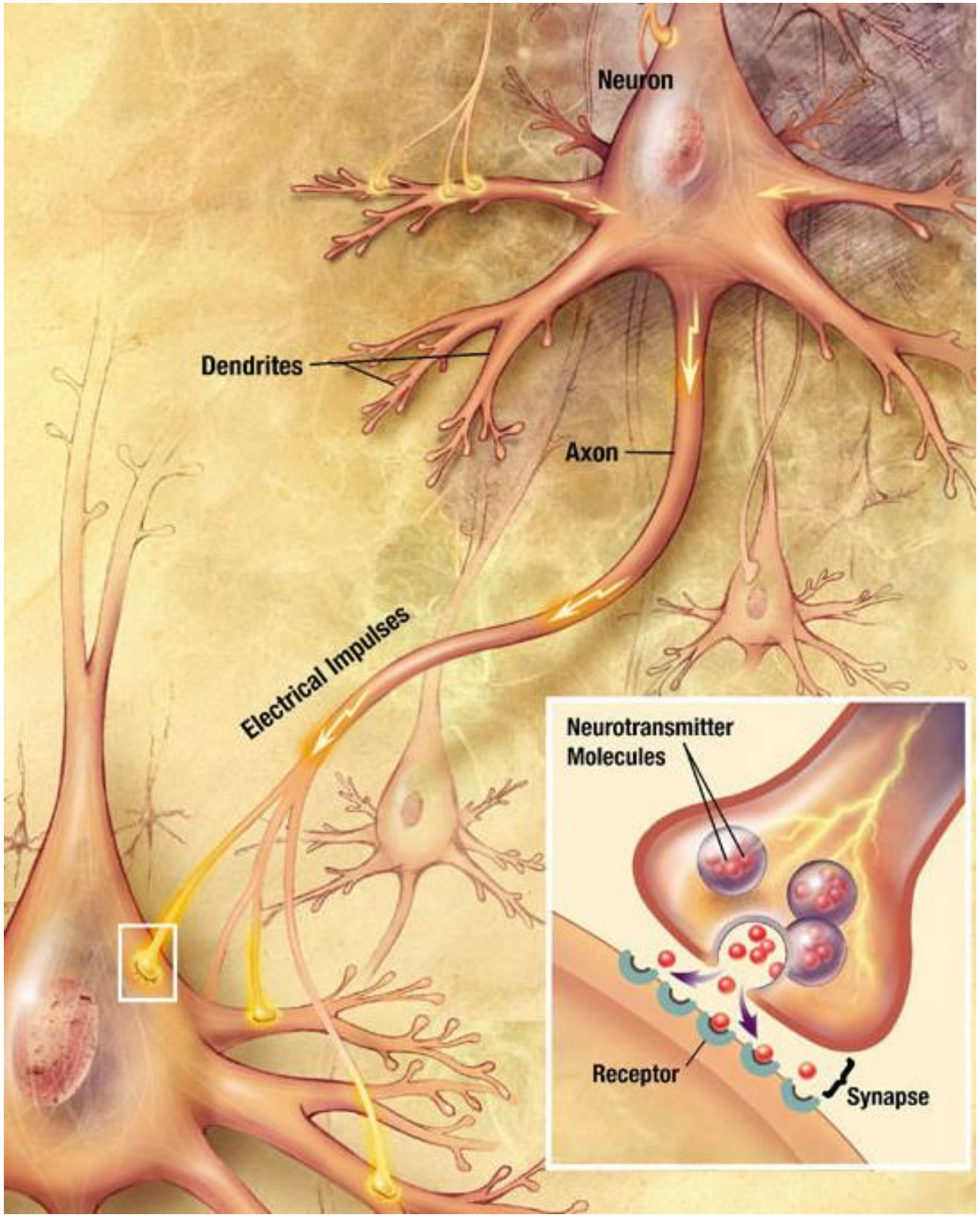
Active Wiring: Myelination of Axons





- 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

Image Source: Wikimedia Commons



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

Enter…
the Synapse

[Next Lecture]

Image Source: Wikimedia Commons