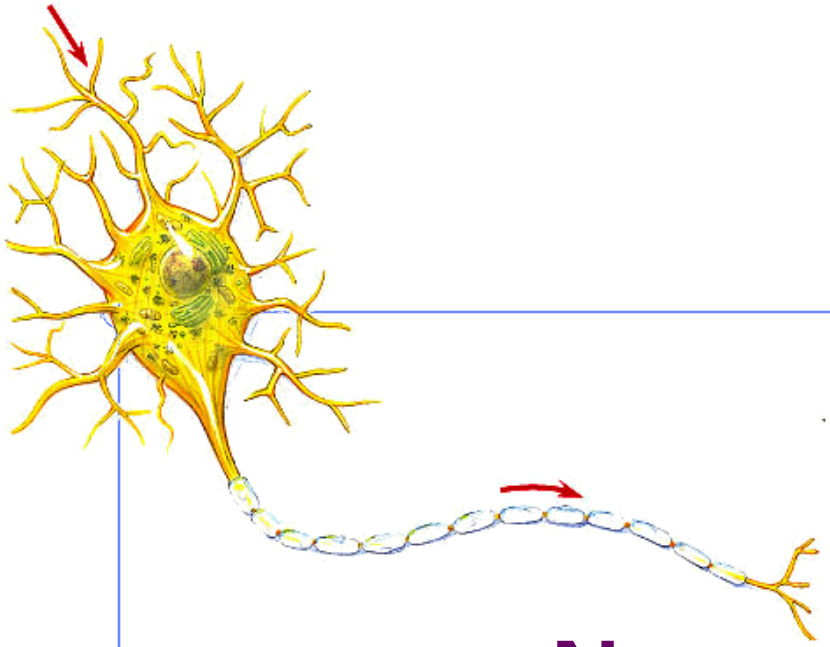
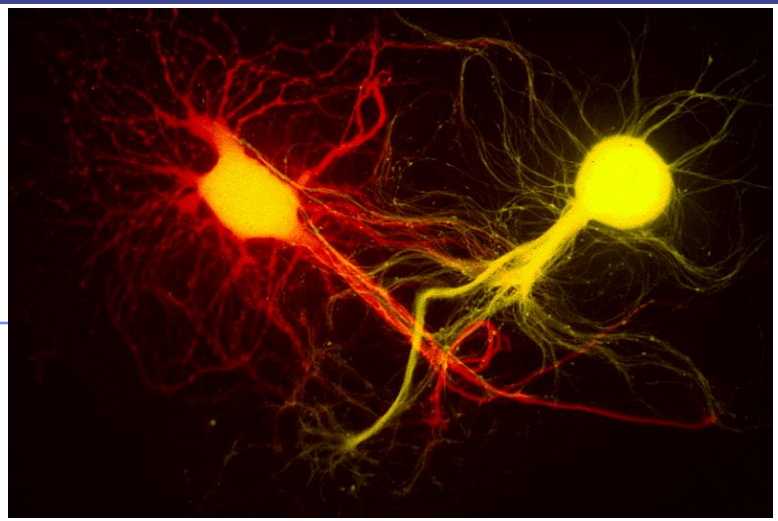
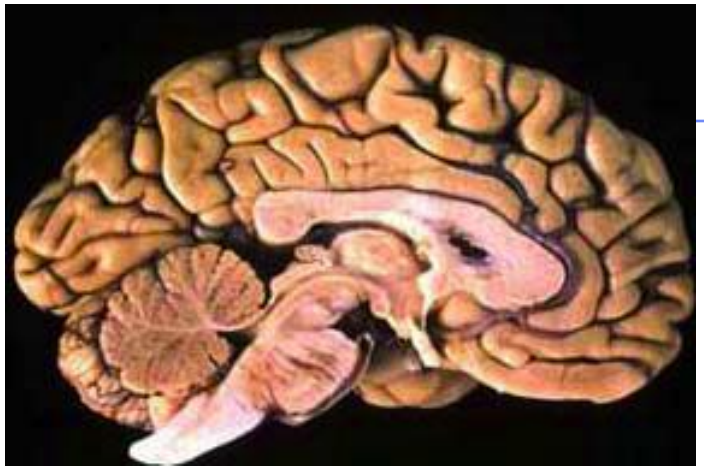
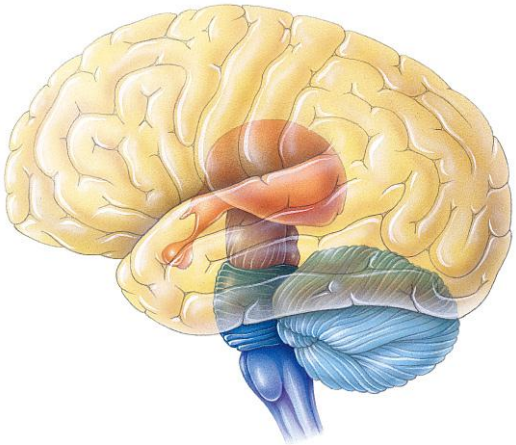




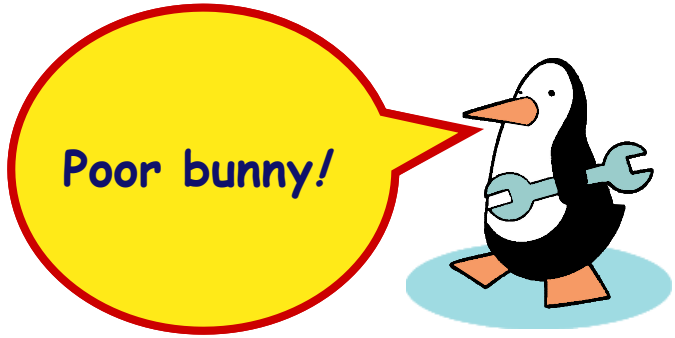
Nervous System





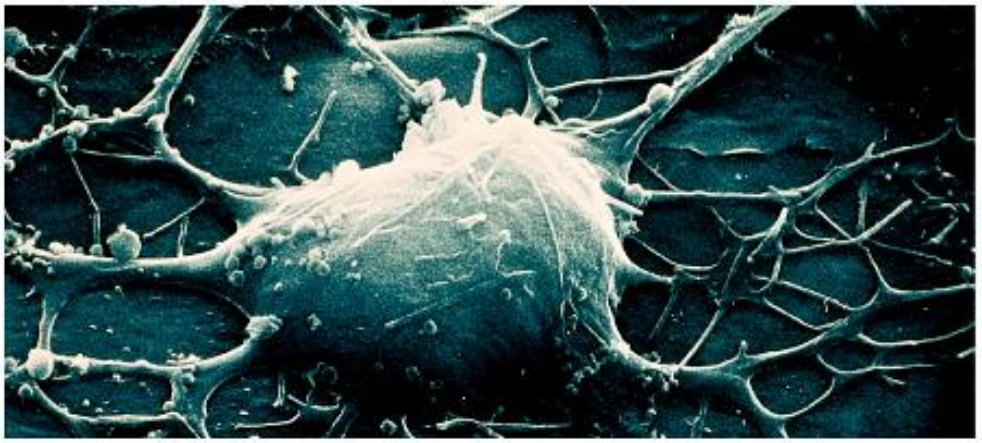
Why do animals need a nervous system?

- What characteristics do animals need in a nervous system?
  - fast
  - accurate
  - reset quickly

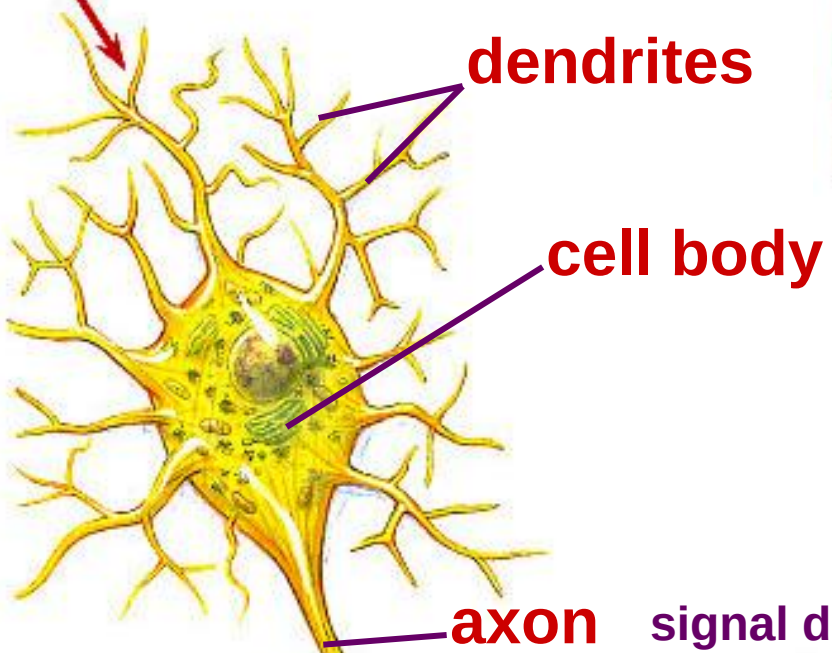


Nervous system cells

- **Neuron**
  - a nerve cell



signal direction

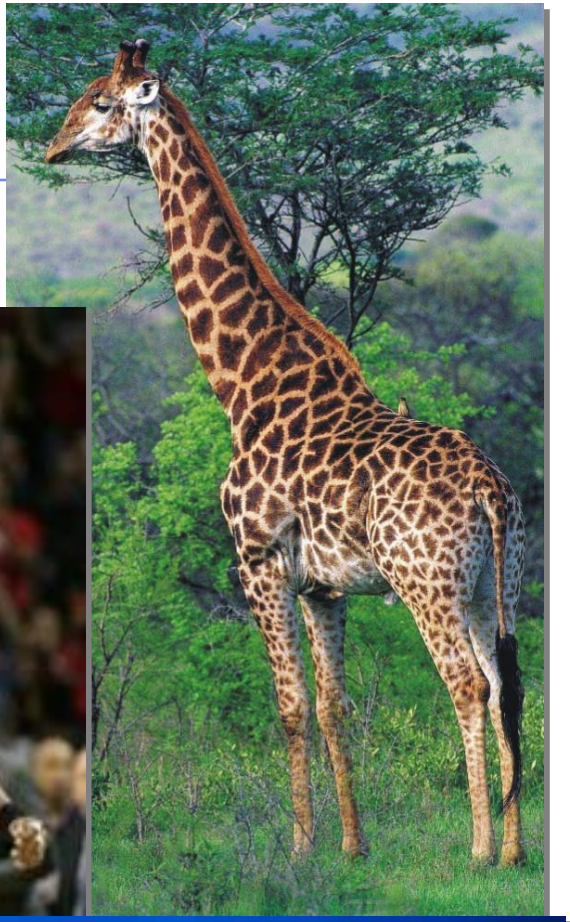


- **Structure fits function**
  - many entry points for signal
  - one path out
  - transmits signal

dendrite → cell body → axon

Fun facts about neurons

- Most specialized cell in animals
- Longest cell
  - blue whale neuron
    - 10-30 meters
  - giraffe axon
    - 5 meters
  - human neuron
    - 1-2 meters



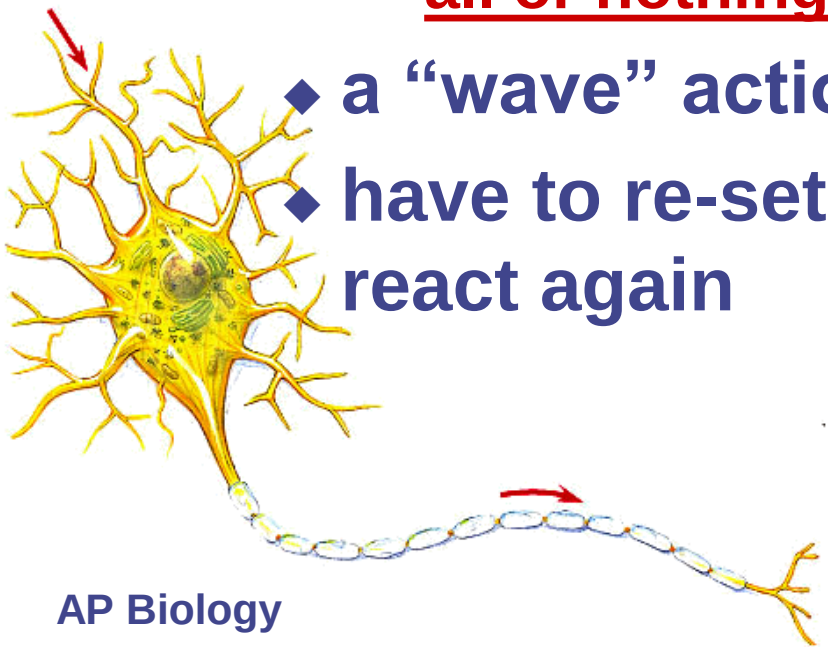
Nervous system allows for
1 millisecond response time

Transmission of a signal

- Think dominoes!
  - start the signal
    - knock down line of dominoes by tipping 1st one
      → trigger the signal
  - propagate the signal
    - do dominoes move down the line?
      → no, just a wave through them!
  - re-set the system
    - before you can do it again,
      have to set up dominoes again
      → reset the axon

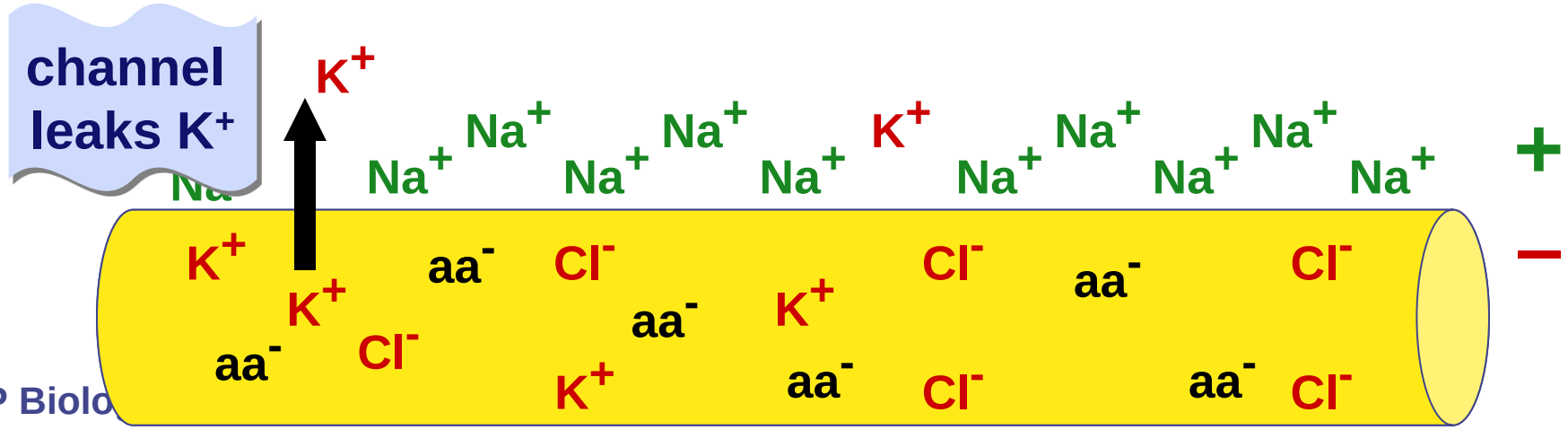
Transmission of a nerve signal

- Neuron has similar system
  - protein channels are set up
  - once first one is opened, the rest open in succession
    - all or nothing response
  - a “wave” action travels along neuron
  - have to re-set channels so neuron can react again



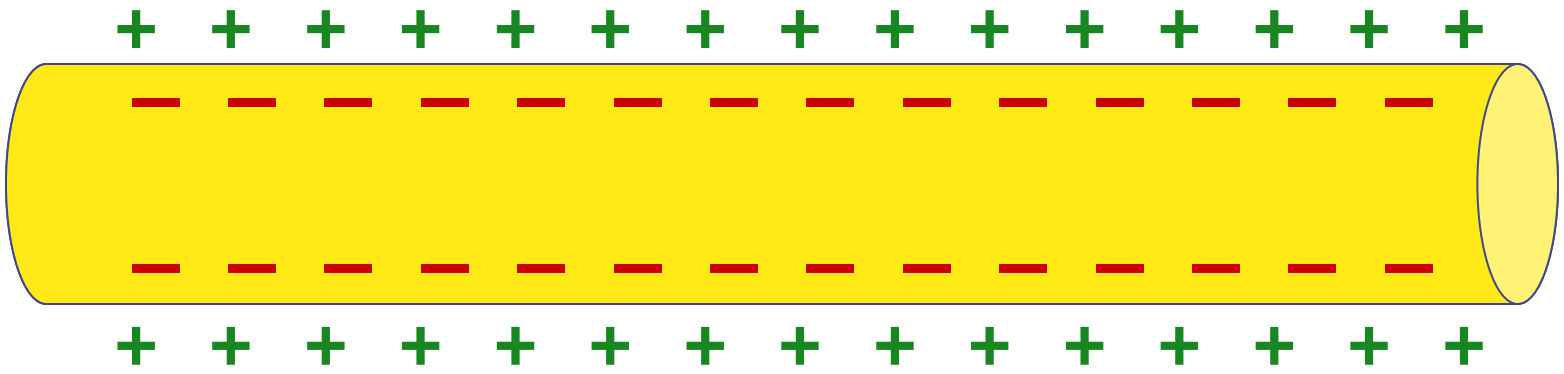
Cells: surrounded by charged ions

- Cells live in a sea of charged ions
  - anions (negative)
    - more concentrated within the cell
    - Cl^-, charged amino acids (aa^-)
  - cations (positive)
    - more concentrated in the extracellular fluid
    - Na^+

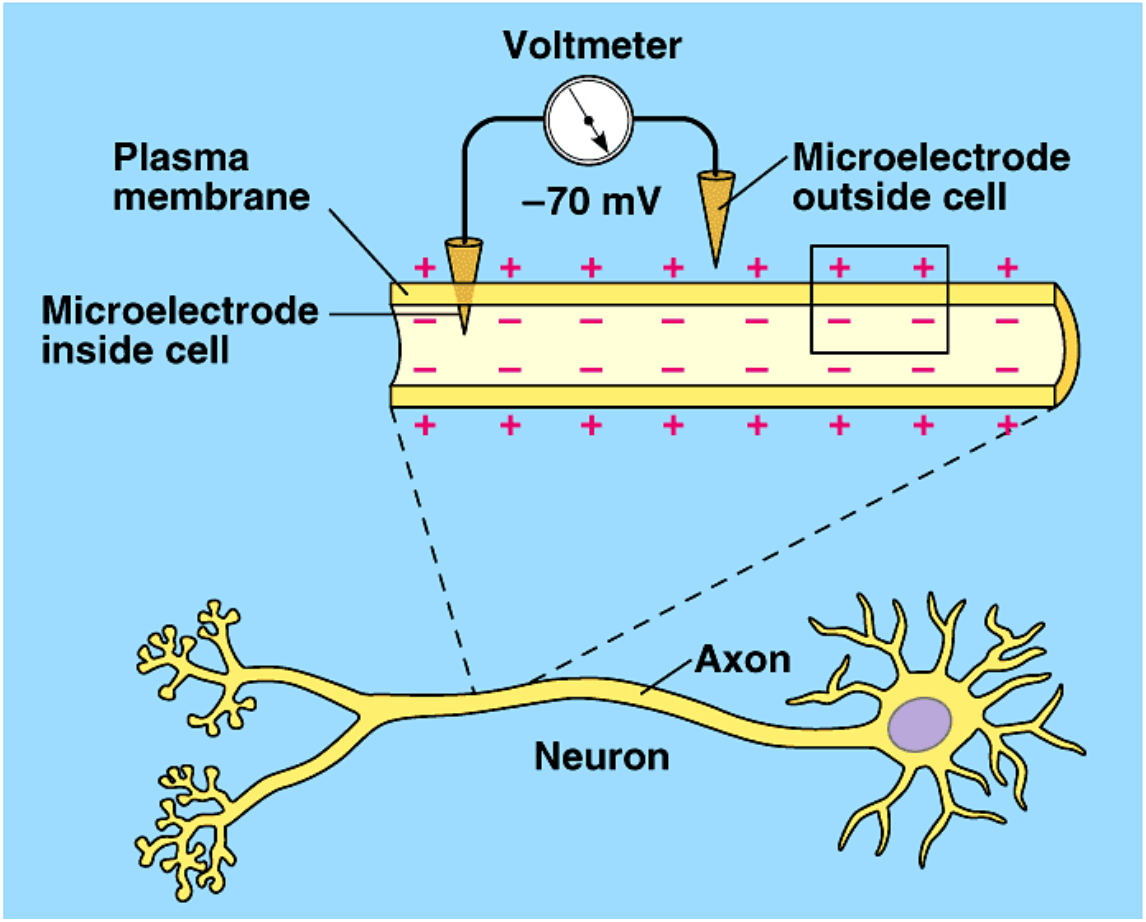


Cells have voltage!

- Opposite charges on opposite sides of cell membrane
  - membrane is **polarized**
    - negative inside; positive outside
    - charge gradient
    - stored energy (like a battery)



Measuring cell voltage

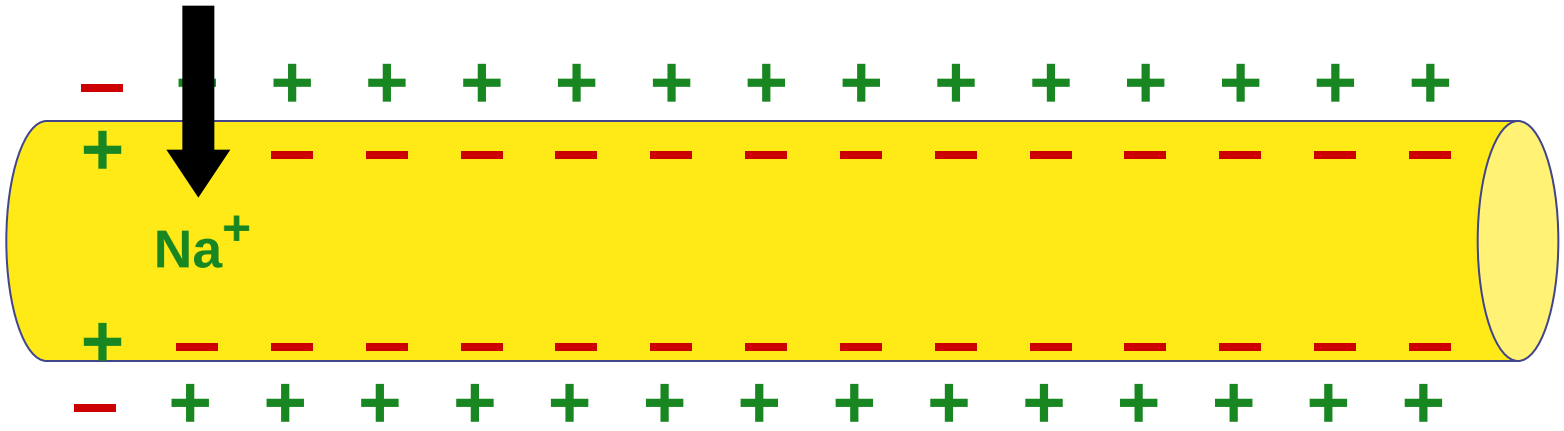


unstimulated neuron = resting potential of -70mV

Resting potential video

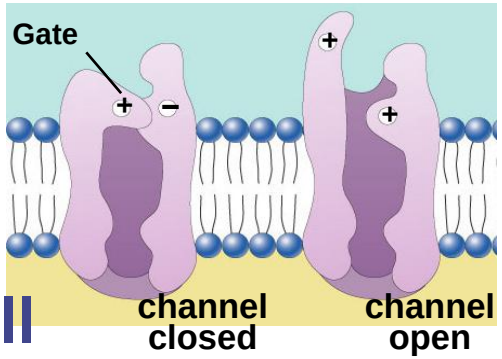
How does a nerve impulse travel?

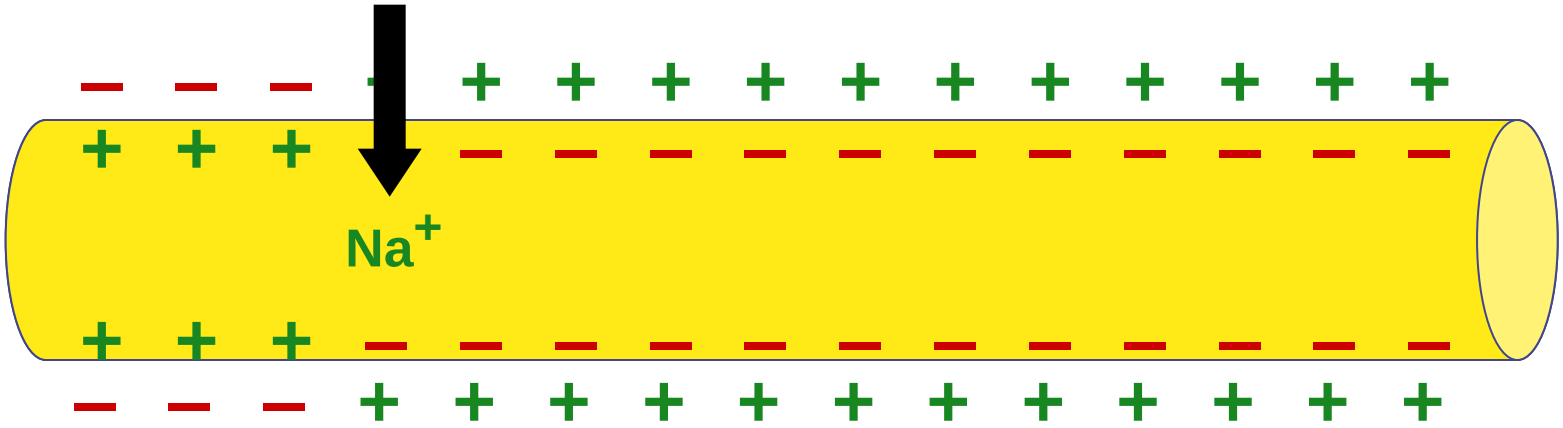
- **Stimulus**: nerve is stimulated
  - reaches **threshold potential**
    - open Na^+ **channels** in cell membrane
    - Na^+ ions diffuse **into** cell
  - charges reverse at that point on neuron
    - **positive** inside; **negative** outside
    - cell becomes **depolarized**



How does a nerve impulse travel?

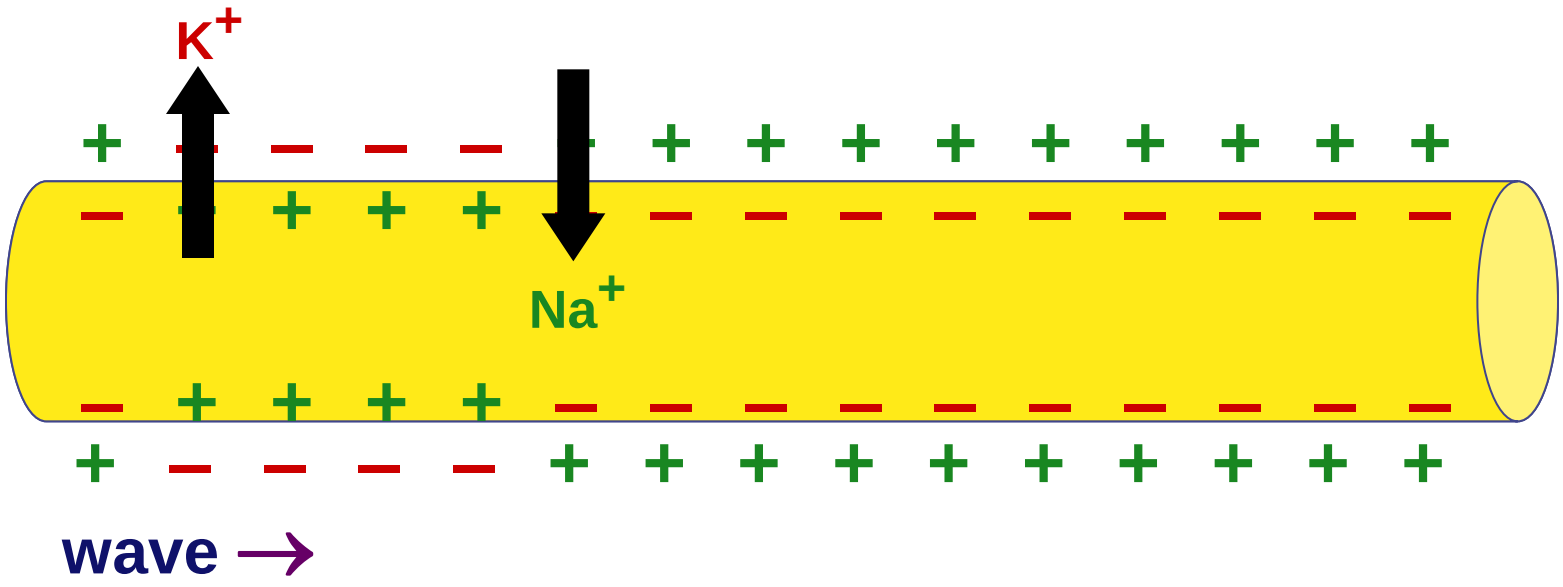
- **Wave**: nerve impulse travels down neuron
  - change in charge opens next Na^+ gates down the line
    - "voltage-gated" channels
  - Na^+ ions continue to diffuse into cell
  - "wave" moves down neuron = action potential





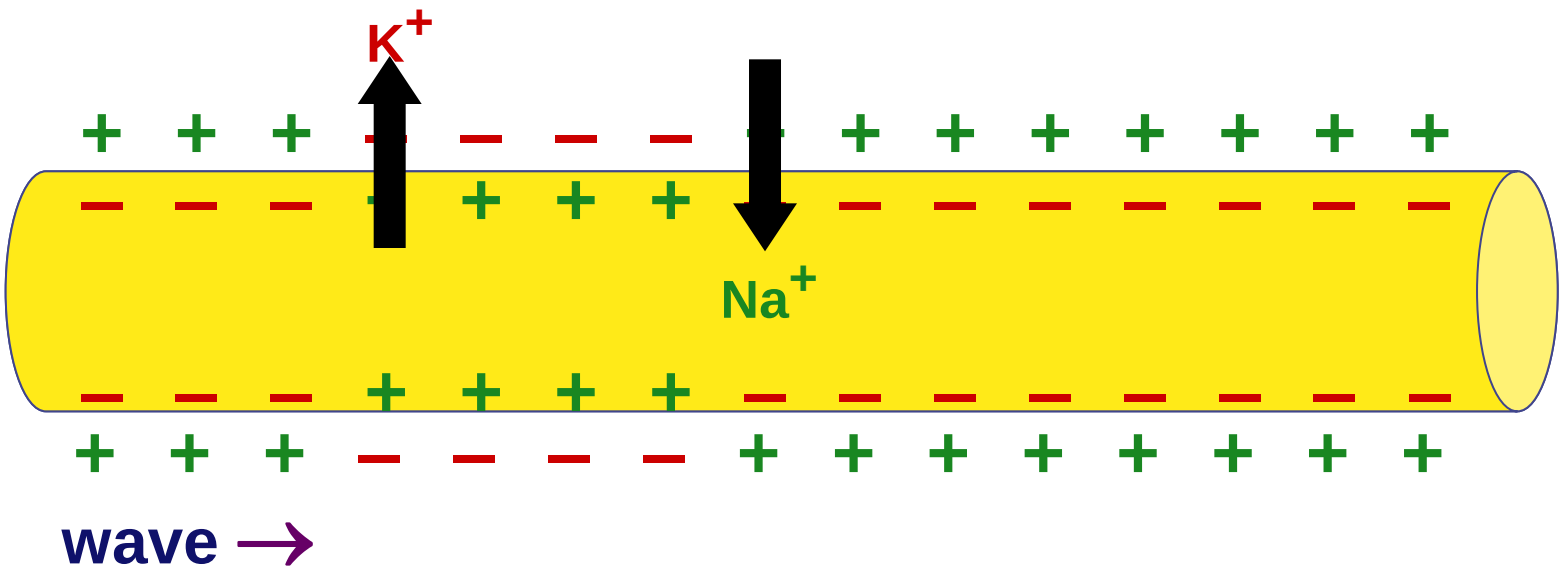
How does a nerve impulse travel?

- **Re-set**: 2nd wave travels down neuron
  - K^+ channels open
    - K^+ channels open up more slowly than Na^+ channels
  - K^+ ions diffuse out of cell
  - charges reverse back at that point
    - negative inside; positive outside



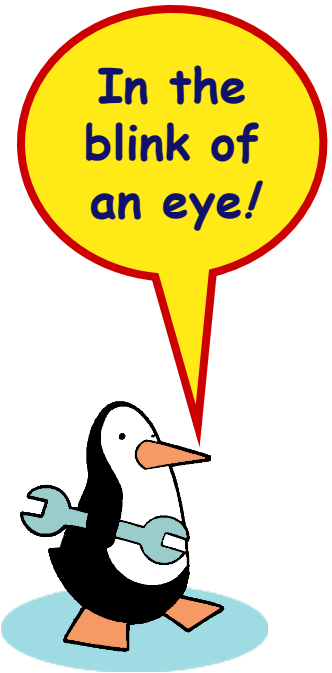
How does a nerve impulse travel?

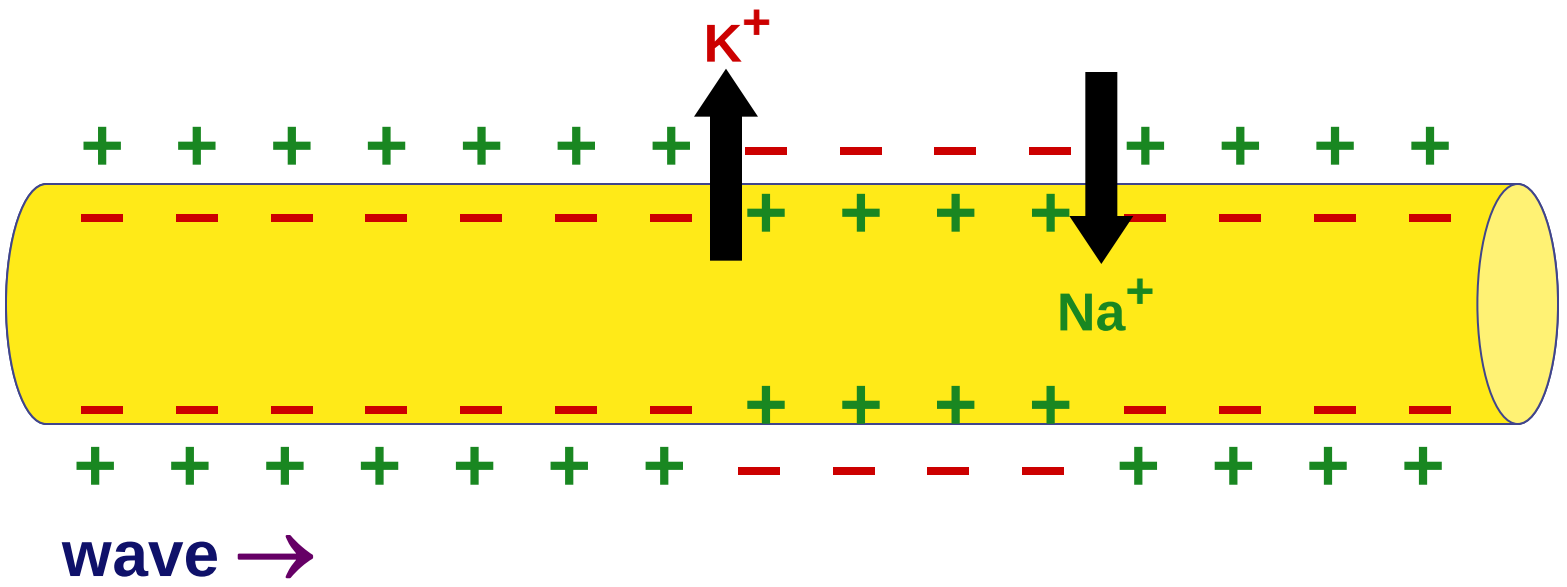
- **Combined waves travel down neuron**
  - wave of opening ion channels moves down neuron
  - signal moves in one direction → → → → →
    - flow of K^+ out of cell stops activation of Na^+ channels in wrong direction



How does a nerve impulse travel?

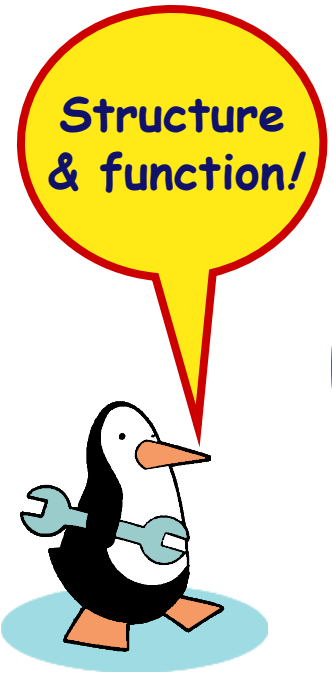
- **Action potential propagates**
  - wave = nerve impulse, or action potential
  - brain → finger tips in milliseconds!

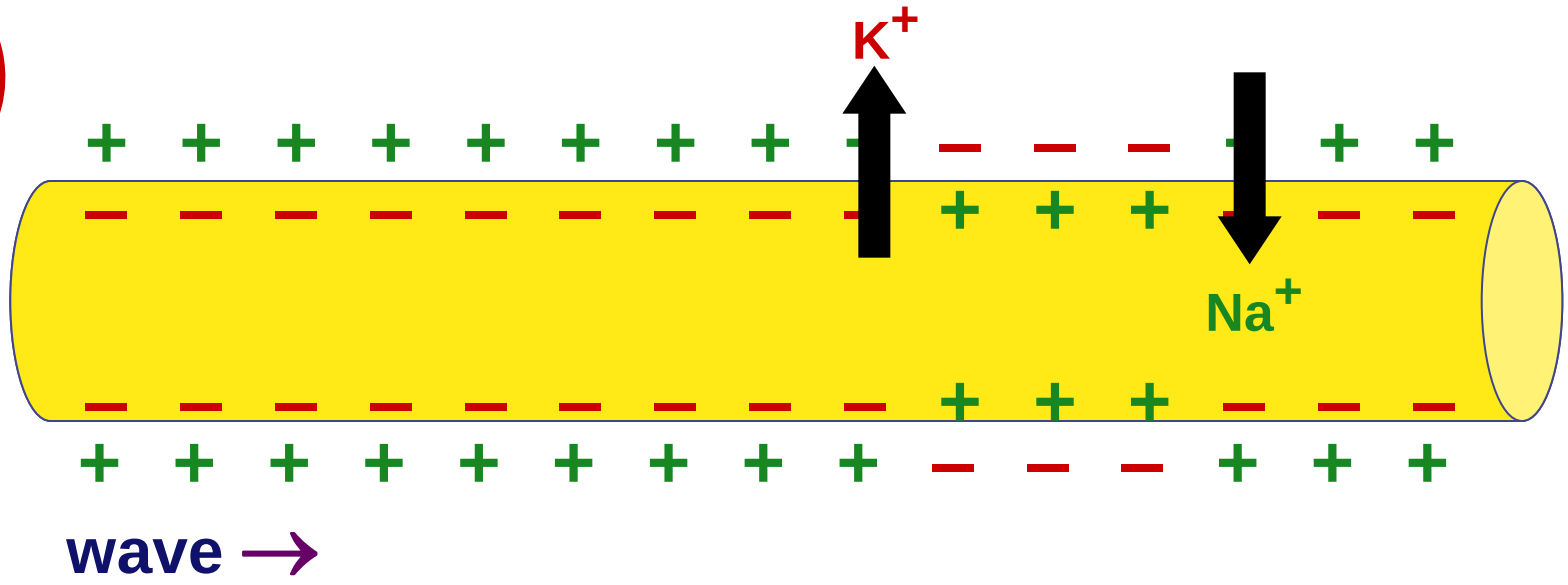




Voltage-gated channels

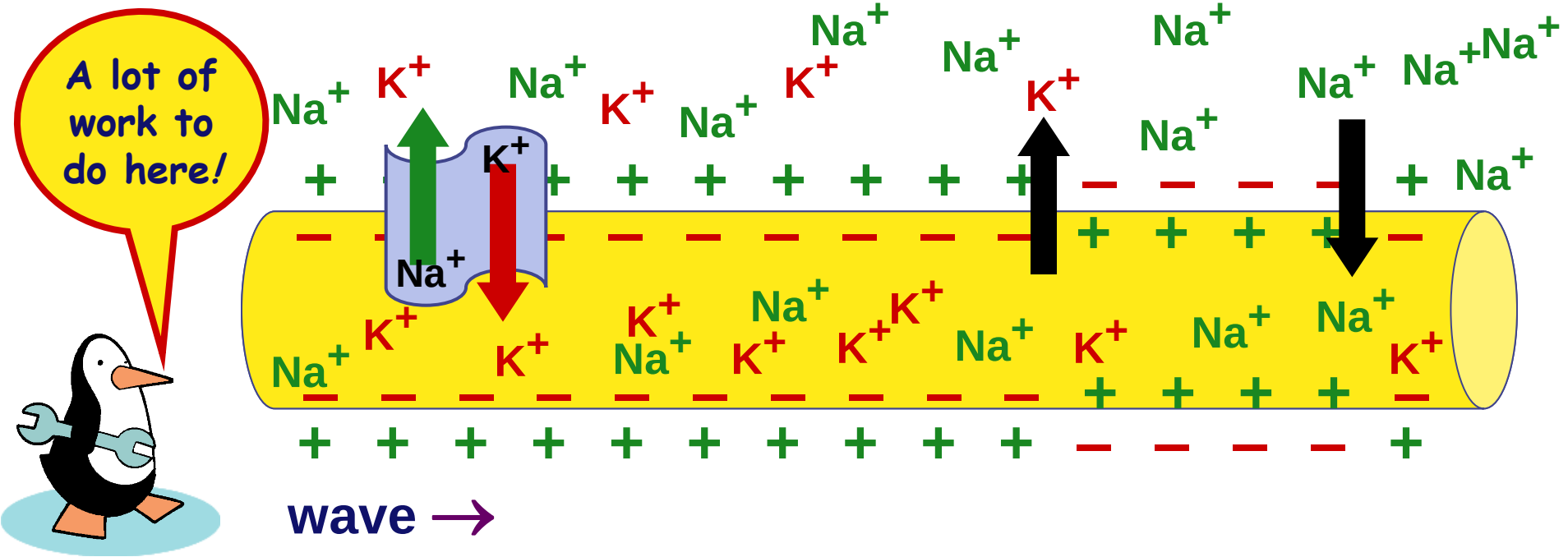
- Ion channels open & close in response to changes in charge across membrane
  - Na^+ channels <u>open quickly</u> in response to depolarization & close slowly
  - K^+ channels <u>open slowly</u> in response to depolarization & close slowly





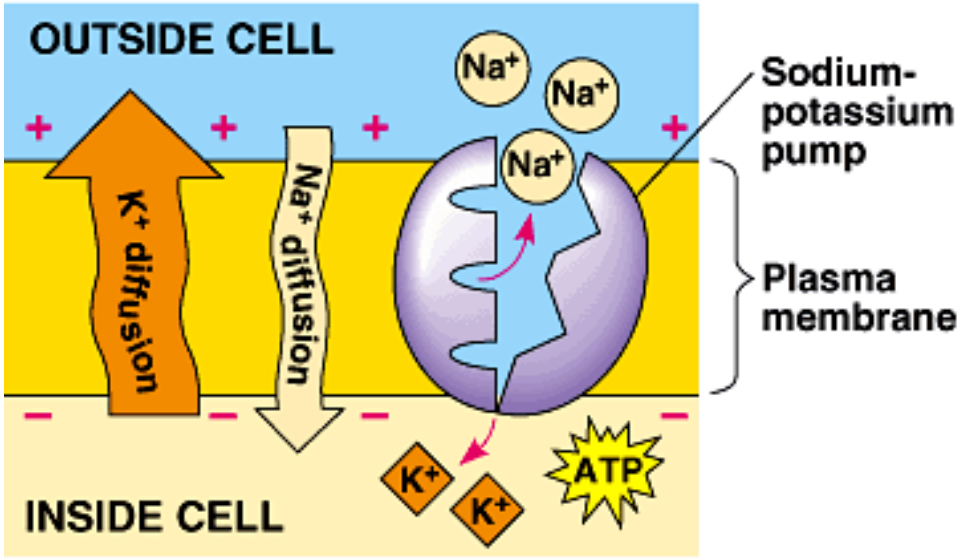
How does the nerve re-set itself?

- After firing a neuron has to re-set itself
  - Na^+ needs to move back <u>out</u>
  - K^+ needs to move back <u>in</u>
  - both are moving <u>against</u> concentration gradients
    - need a pump!!

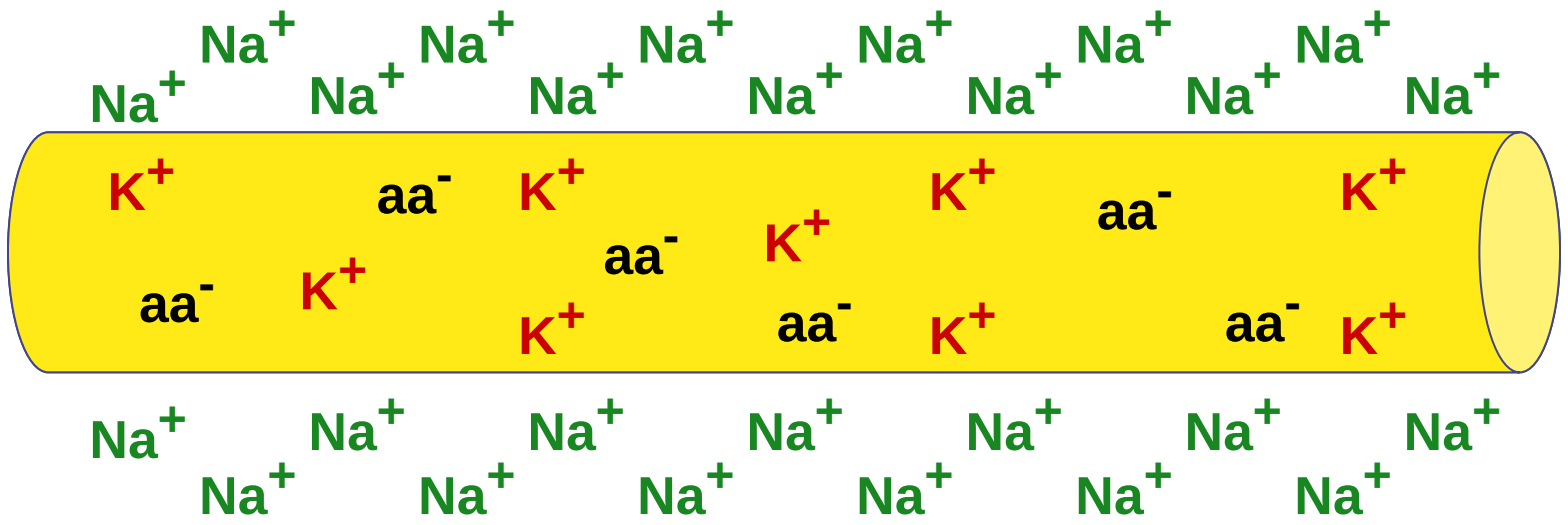


How does the nerve re-set itself?

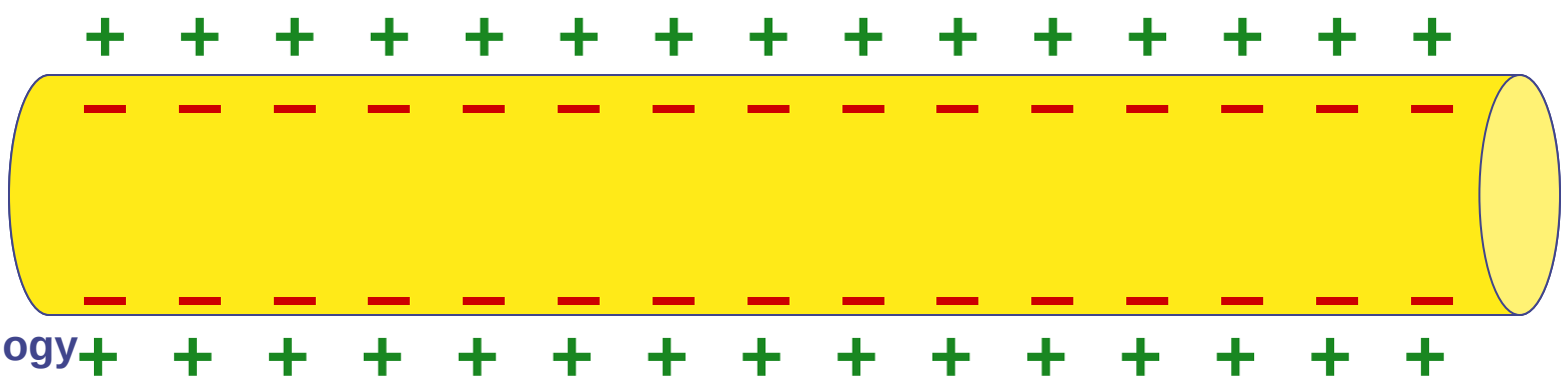
- **Sodium-Potassium pump**
  - active transport protein in membrane
    - requires ATP
  - 3 Na^+ pumped out
  - 2 K^+ pumped in
  - re-sets charge across membrane



Neuron is ready to fire again

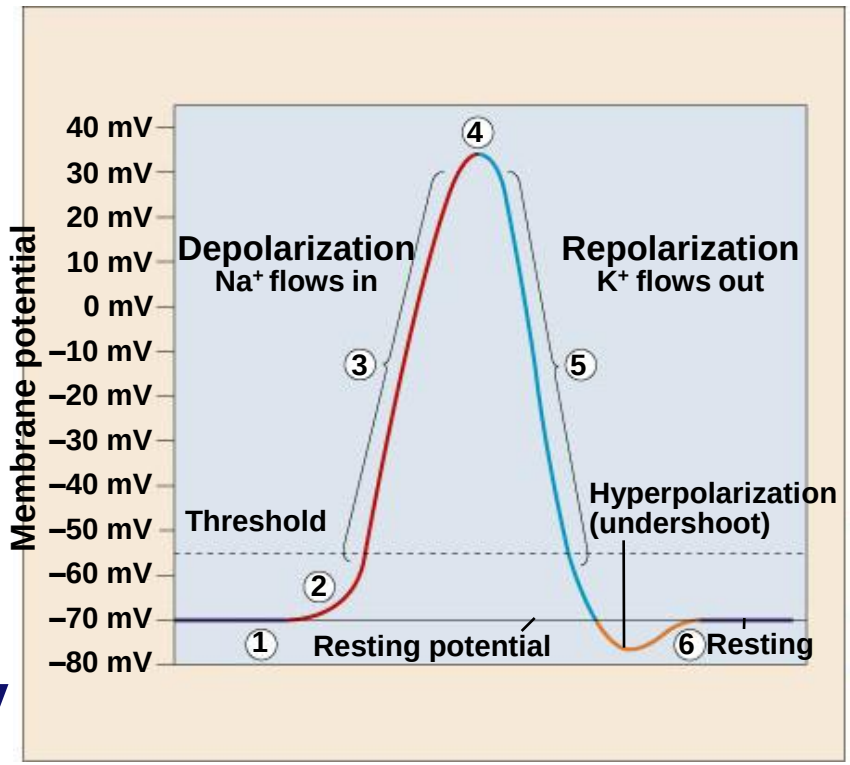


resting potential



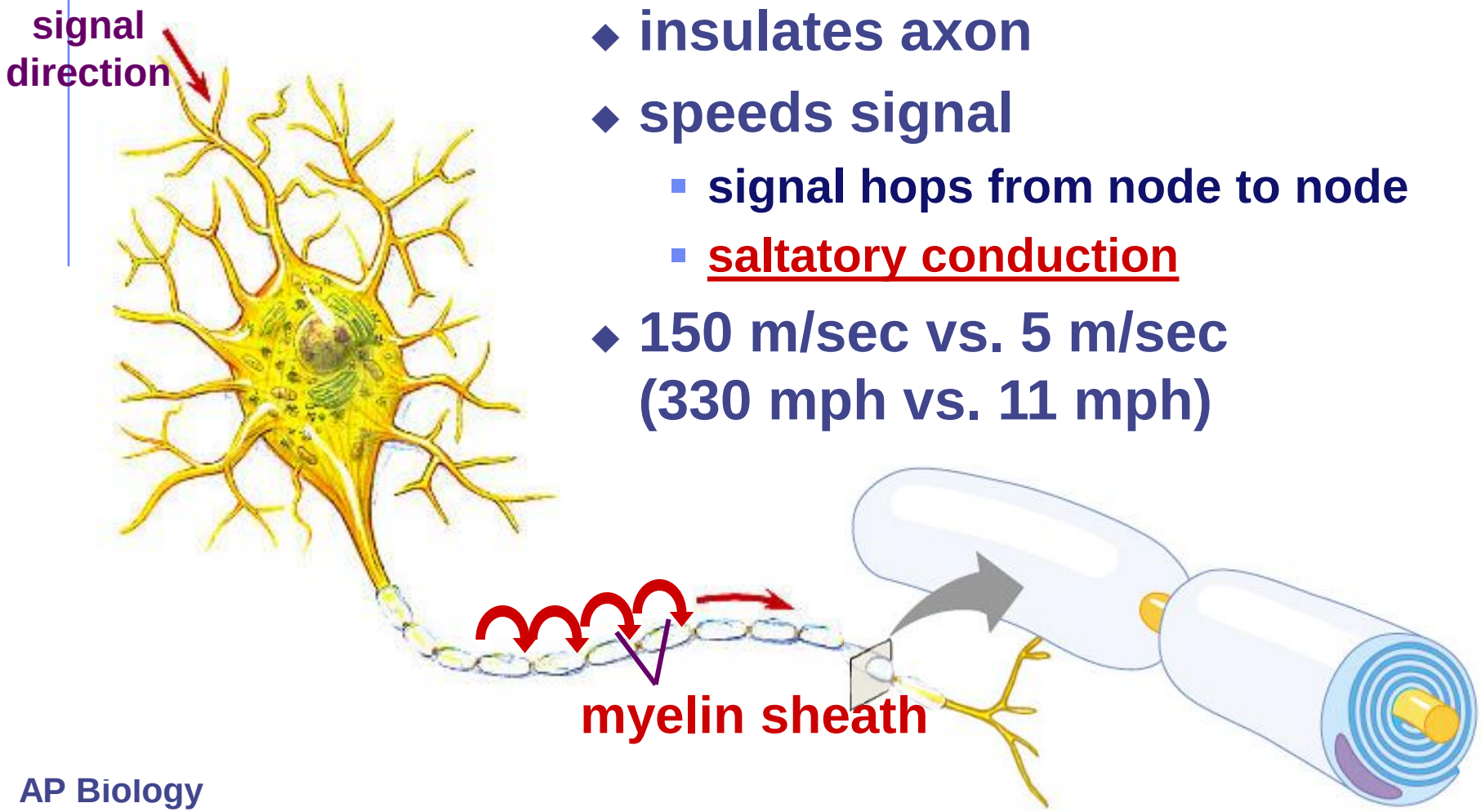
Action potential graph

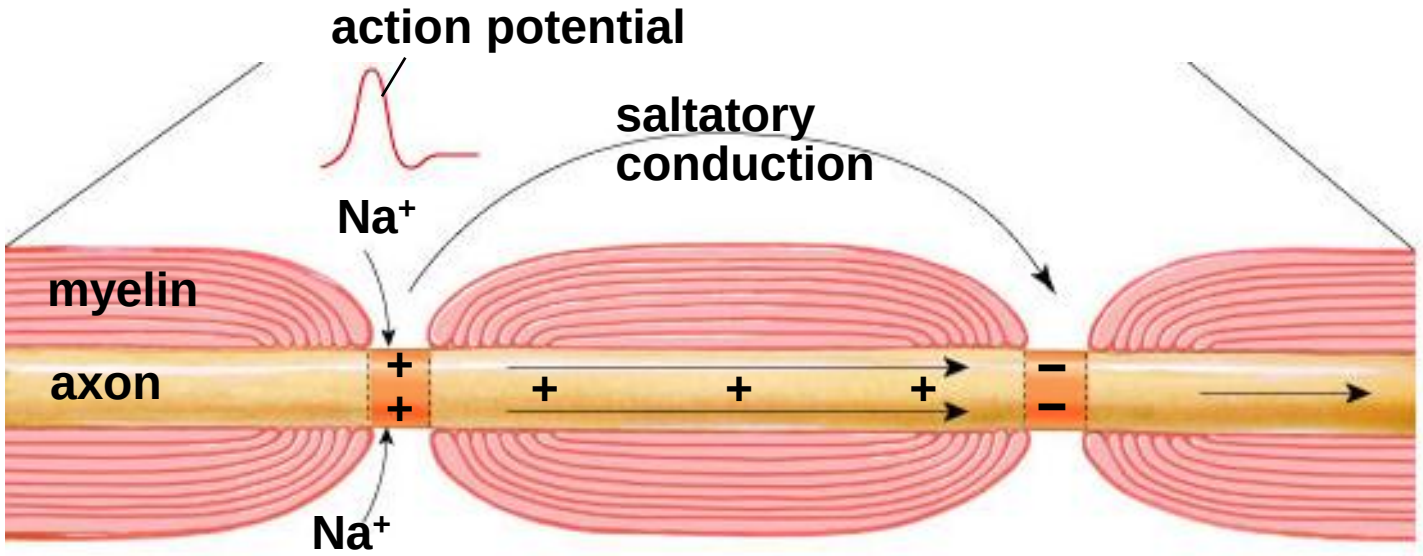
1. **Resting potential**
2. Stimulus reaches **threshold potential**
3. **Depolarization**
   Na^+ channels open;
   K^+ channels closed
4. Na^+ channels close;
   K^+ channels open
5. **Repolarization**
   reset charge gradient
6. **Undershoot**
   K^+ channels close slowly



Myelin sheath

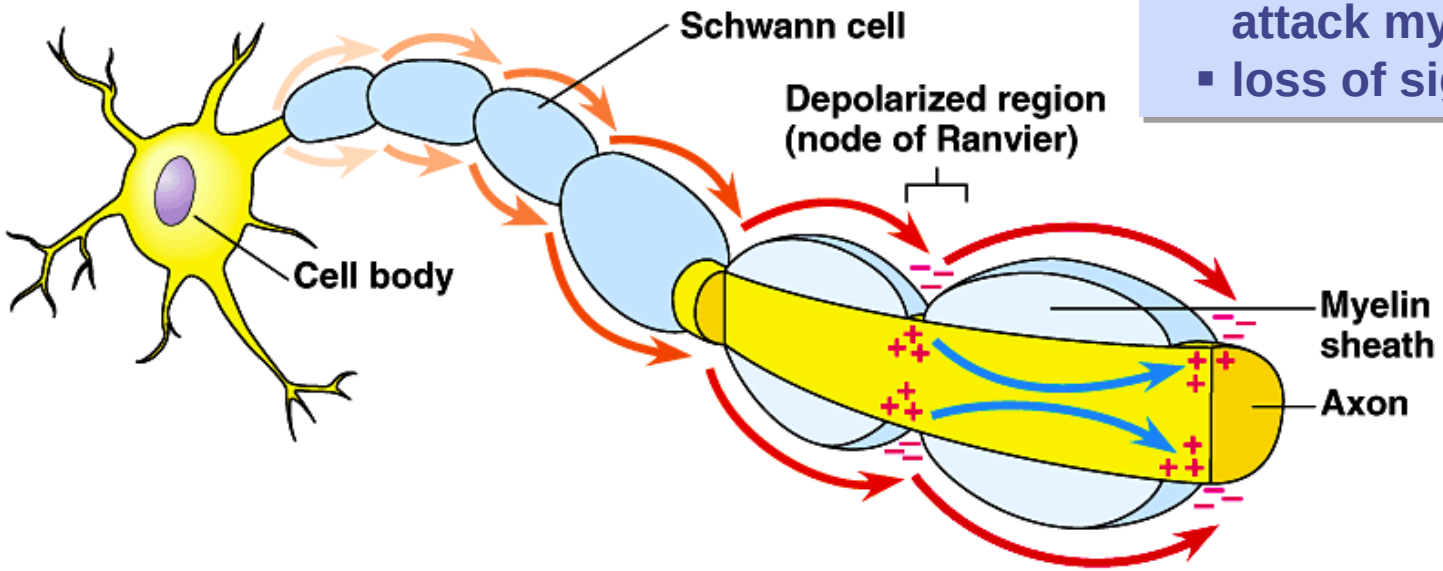
- Axon coated with **Schwann cells**
  - insulates axon
  - speeds signal
    - signal hops from node to node
    - **saltatory conduction**
  - 150 m/sec vs. 5 m/sec (330 mph vs. 11 mph)



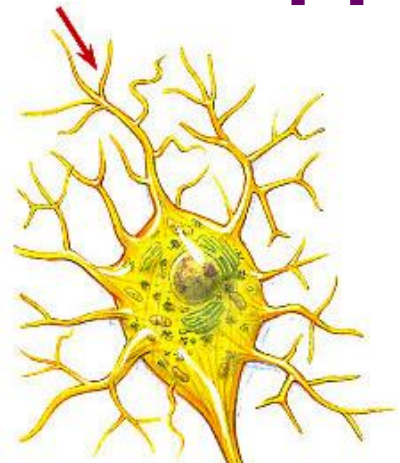


Multiple Sclerosis

- immune system (T cells) attack myelin sheath
- loss of signal

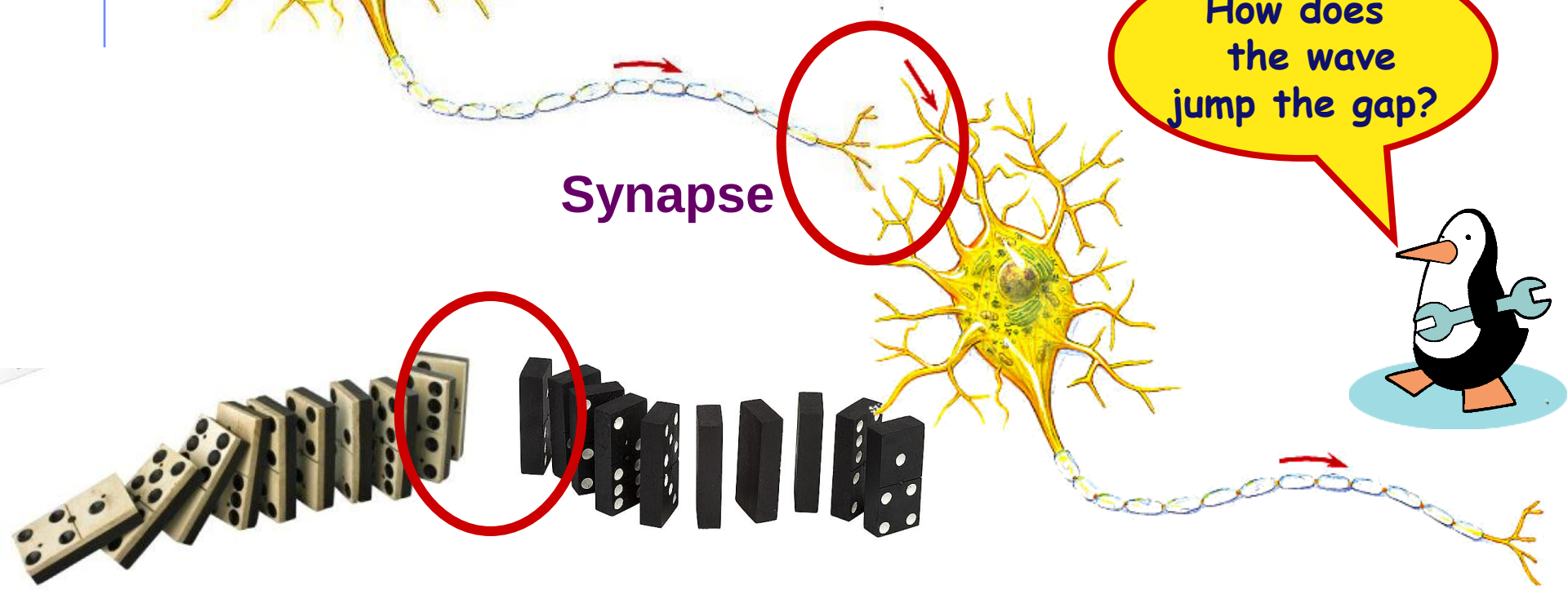


What happens at the end of the axon?

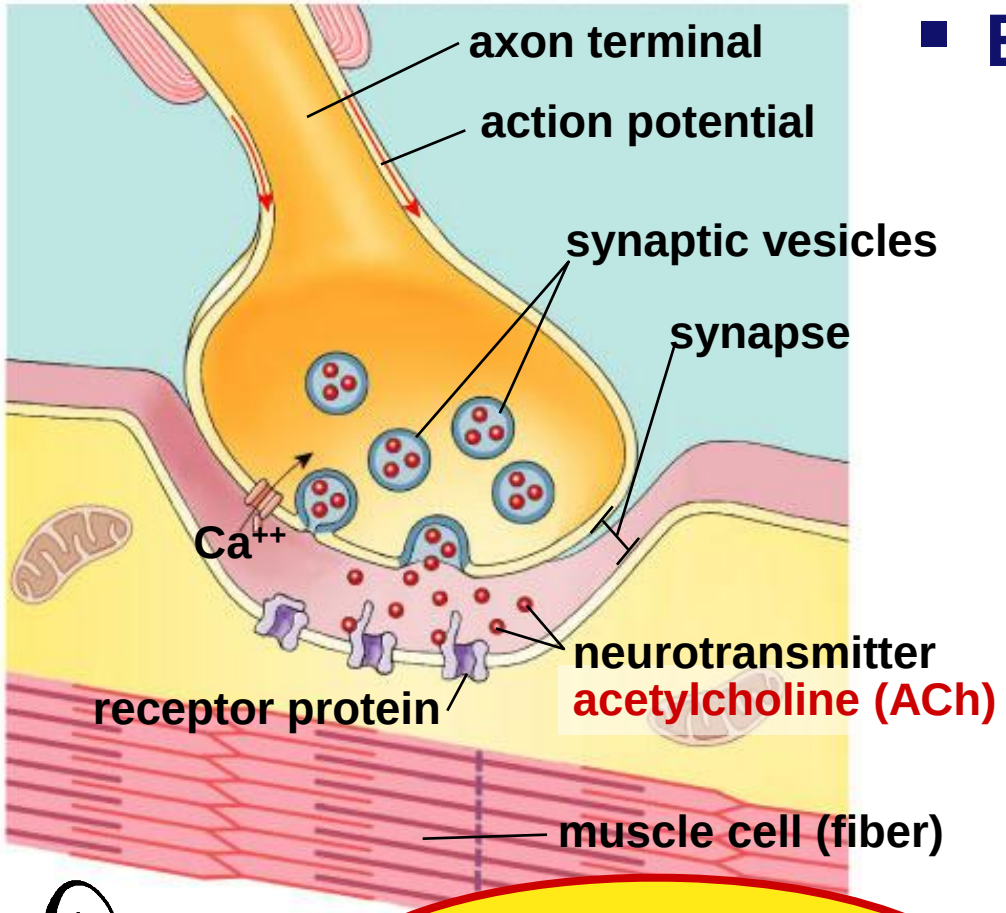


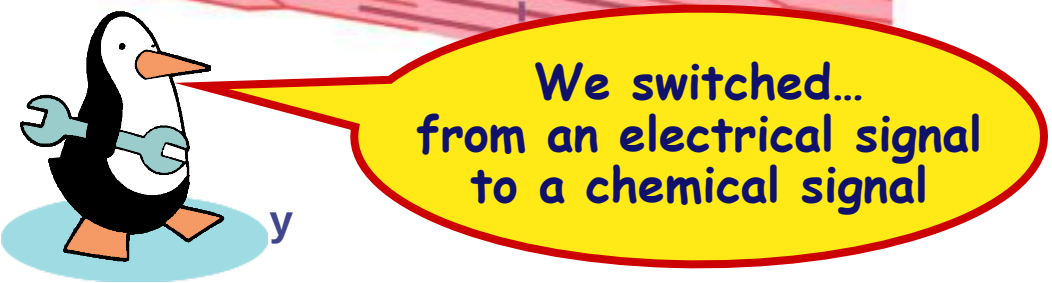
Impulse has to jump the synapse!

- junction between neurons
- has to jump quickly from one cell to next



Chemical synapse

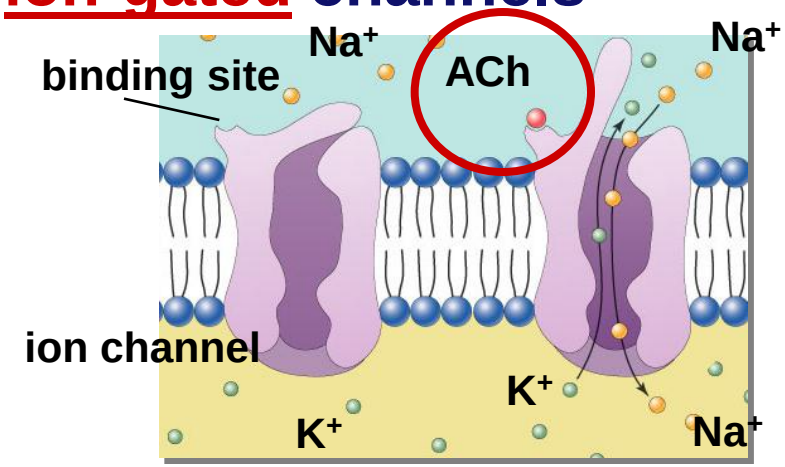


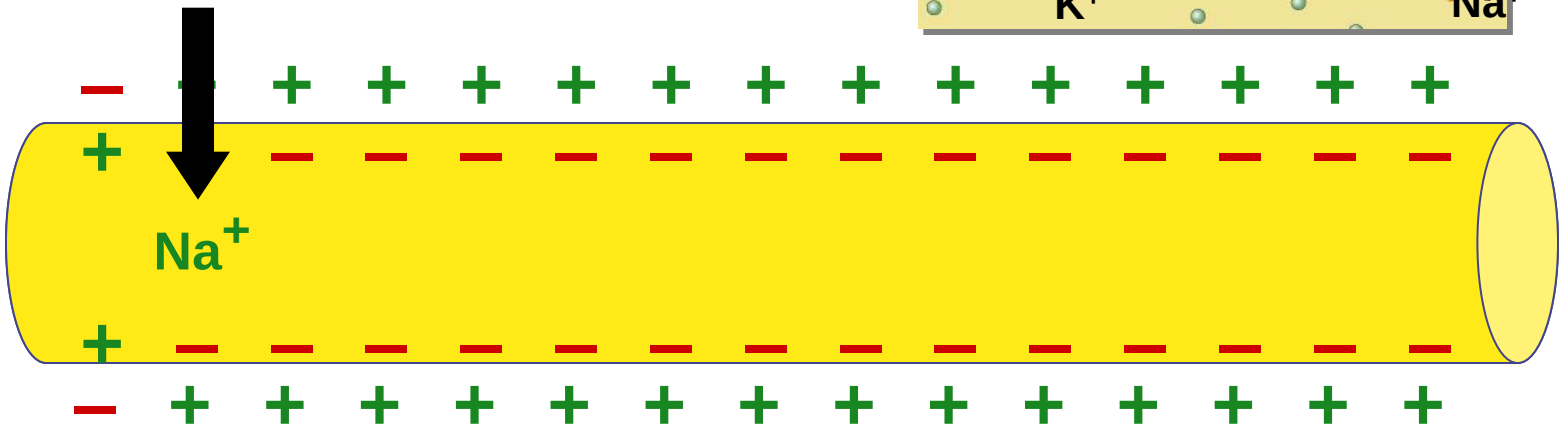


- **Events at synapse**
  - action potential depolarizes membrane
  - opens Ca^{++} channels
  - neurotransmitter vesicles fuse with membrane
  - release neurotransmitter to synapse → diffusion
  - neurotransmitter binds with protein receptor
    - ion-gated channels open
  - neurotransmitter degraded or reabsorbed

Nerve impulse in next neuron

- Post-synaptic neuron
  - triggers nerve impulse in next nerve cell
    - chemical signal opens ion-gated channels
    - Na^+ diffuses into cell
    - K^+ diffuses out of cell
      - switch back to voltage-gated channel





Neurotransmitters

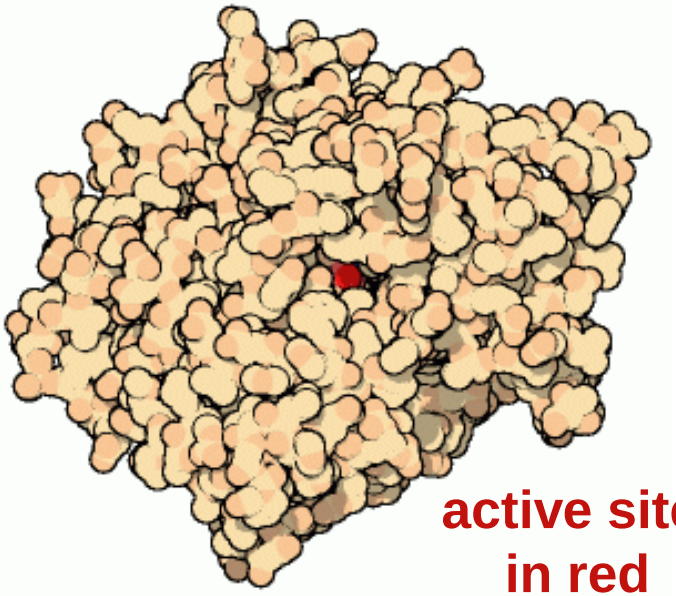
- Acetylcholine
  - transmit signal to skeletal muscle
- Epinephrine (adrenaline) & norepinephrine
  - fight-or-flight response
- Dopamine
  - widespread in brain
  - affects sleep, mood, attention & learning
  - lack of dopamine in brain associated with Parkinson's disease
  - excessive dopamine linked to schizophrenia
- Serotonin
  - widespread in brain
  - affects sleep, mood, attention & learning

Neurotransmitters

- Weak point of nervous system
  - any substance that affects neurotransmitters or mimics them affects nerve function
    - gases: nitrous oxide, carbon monoxide
    - mood altering drugs:
      - stimulants
        - amphetamines, caffeine, nicotine
      - depressants
        - quaaludes, barbiturates
    - hallucinogenic drugs: LSD, peyote
    - SSRIs: Prozac, Zoloft, Paxil
    - poisons

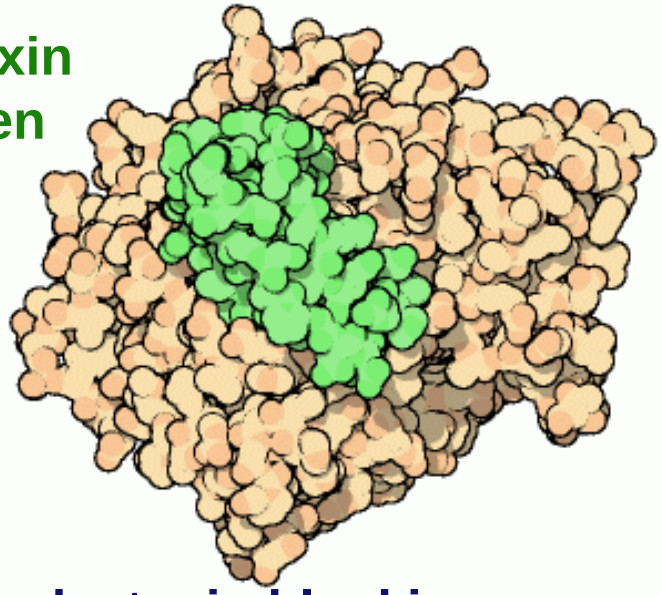
Acetylcholinesterase

- Enzyme which breaks down acetylcholine neurotransmitter
  - acetylcholinesterase inhibitors = neurotoxins
    - snake venom, sarin, insecticides



acetylcholinesterase

neurotoxin
in green

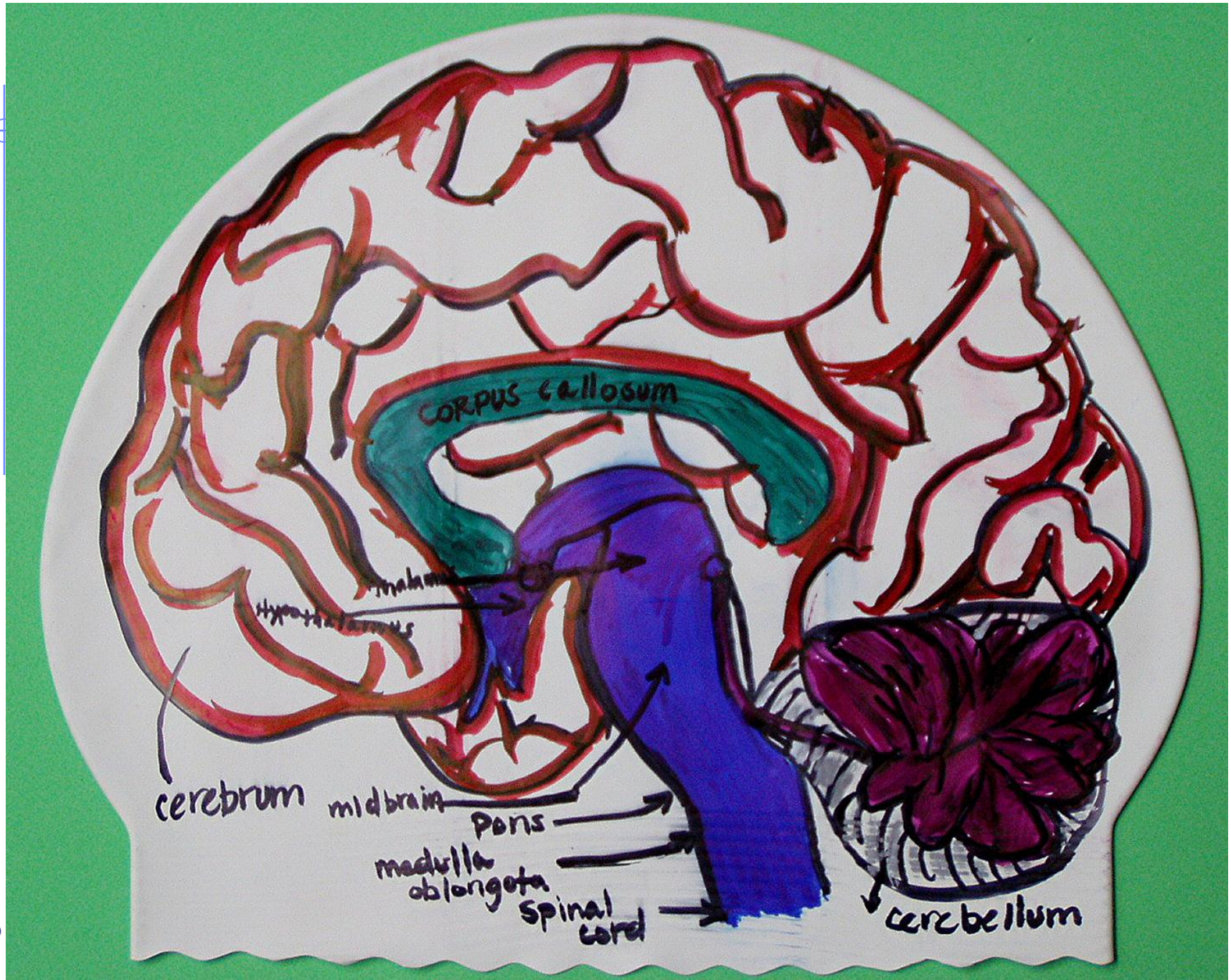


snake toxin blocking
acetylcholinesterase active site

Questions to ponder…

- Why are axons so long?
- Why have synapses at all?
- How do “mind altering drugs” work?
  - caffeine, alcohol, nicotine, marijuana…
- Do plants have a nervous system?
  - Do they need one?

Ponder this…
Any Questions??


CORPUS callosum
cerebrum
midbrain
Pons
medulla oblongata
spinal cord
cerebellum

AP