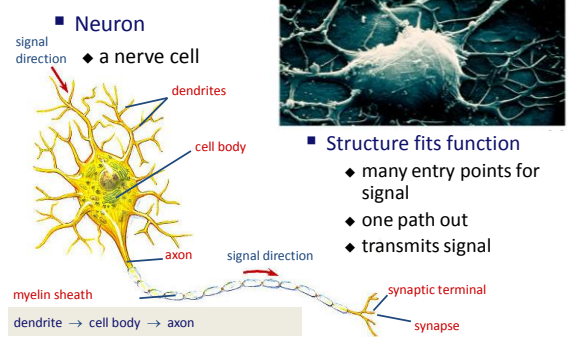


Nervous System

### Nervous system cells



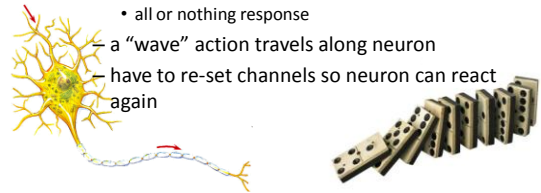
### Transmission of a signal

- 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



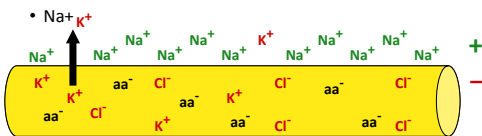
### Transmission of a nerve signal

- 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



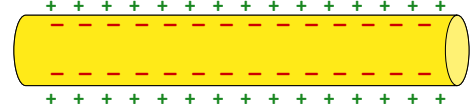
### Cells: surrounded by charged ions

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

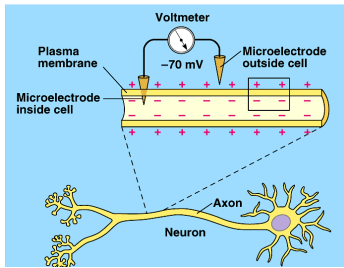


### Cells have voltage!

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



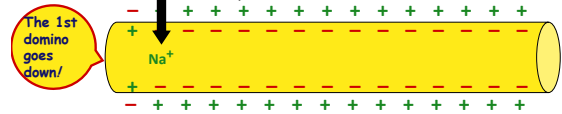
## Measuring cell voltage



unstimulated neuron = **resting potential of -70mV**

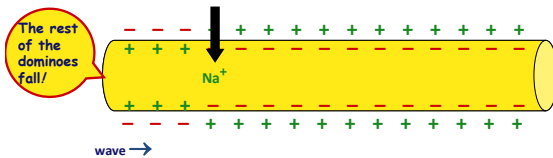
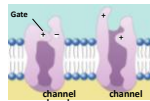
## How does a nerve impulse travel?

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



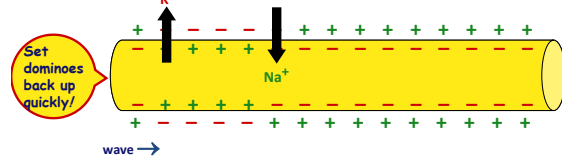
## How does a nerve impulse travel?

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



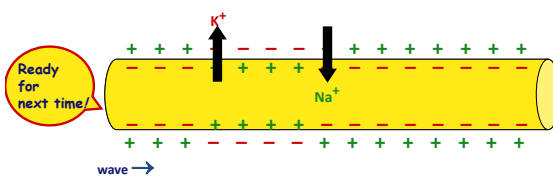
## How does a nerve impulse travel?

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



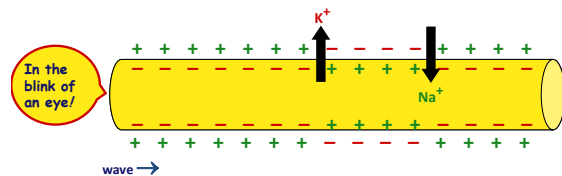
## How does a nerve impulse travel?

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



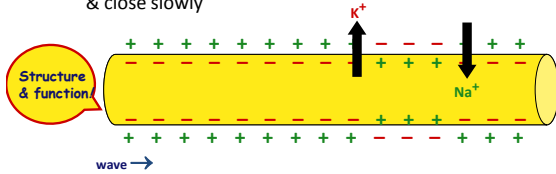
## How does a nerve impulse travel?

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



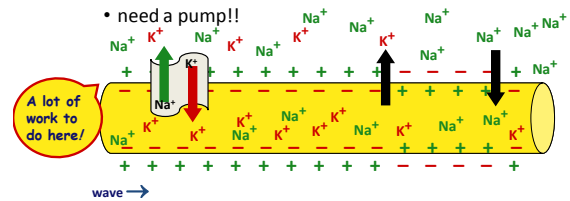
## Voltage-gated channels

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



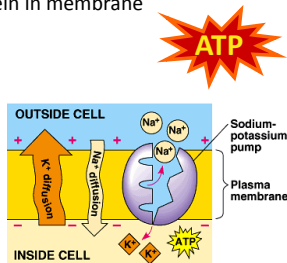
## How does the nerve re-set itself?

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

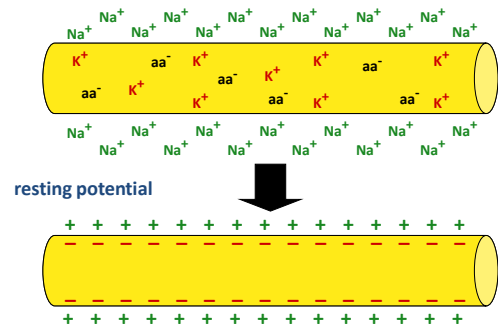


## How does the nerve re-set itself?

- Sodium-Potassium pump
  - active transport protein in membrane
    - requires ATP
  - 3 Na<sup>+</sup> pumped out
  - 2 K<sup>+</sup> pumped in
  - re-sets charge across membrane

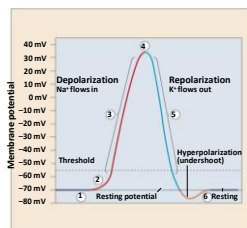


## Neuron is ready to fire again



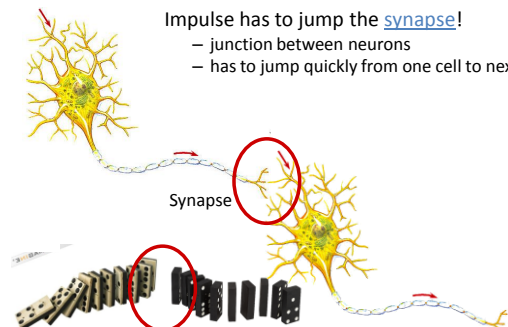
## Action potential graph

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

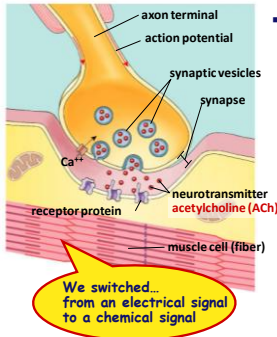


## What happens at the end of the axon?

- Impulse has to jump the synapse!
- junction between neurons
  - has to jump quickly from one cell to next



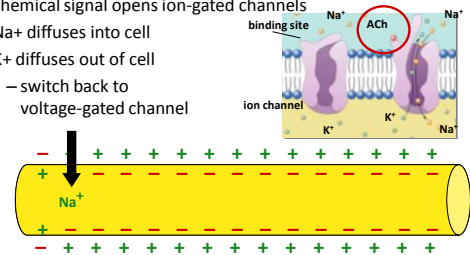
## Chemical synapse



- Events at synapse
  - action potential depolarizes membrane
  - opens  $\text{Ca}^{2+}$  channels
  - neurotransmitter vesicles fuse with membrane
  - release neurotransmitter to synapse  $\rightarrow$  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
  - $\text{Na}^+$  diffuses into cell
  - $\text{K}^+$  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
- [Mouse Party](#)

## 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