




### 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
- 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





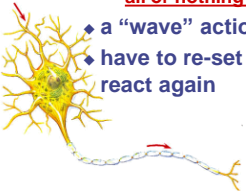

### Transmission of a signal

- Think dominoes!
  - start the signal**
    - knock down line of dominoes by tipping 1<sup>st</sup> 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



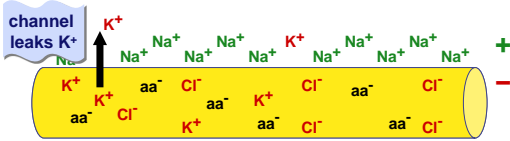
### Transmission of a nerve signal

- 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

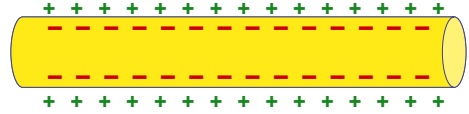
## Cells: surrounded by charged ions

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

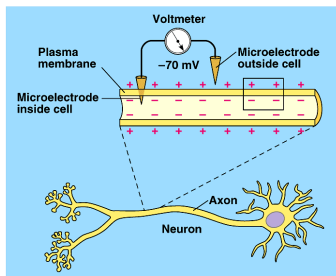


## Cells have voltage!

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



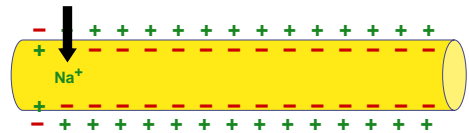
## Measuring cell voltage



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

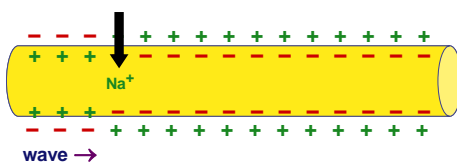
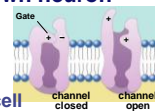
## How does a nerve impulse travel?

- 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**



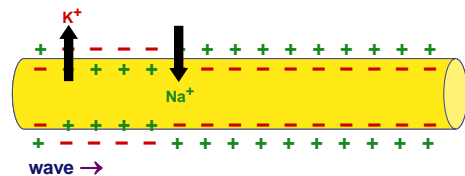
## How does a nerve impulse travel?

- 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**



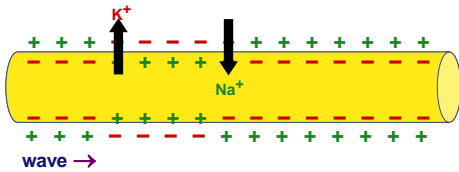
## How does a nerve impulse travel?

- 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**



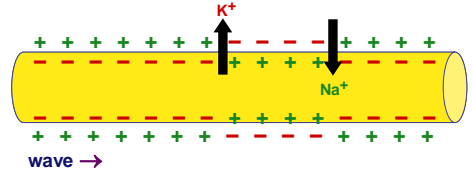
## How does a nerve impulse travel?

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



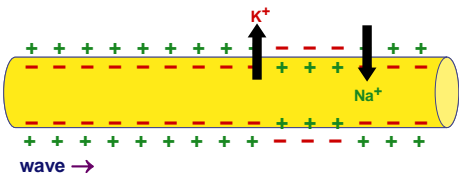
## How does a nerve impulse travel?

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



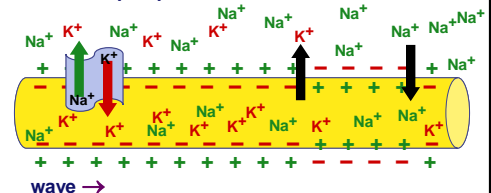
## Voltage-gated channels

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



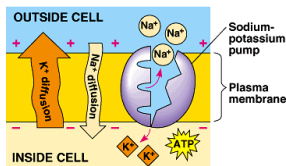
## How does the nerve re-set itself?

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

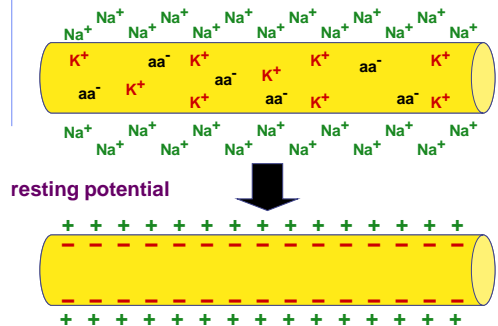


## How does the nerve re-set itself?

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

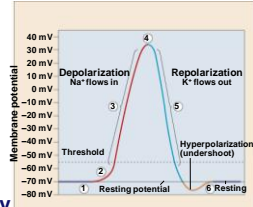


## Neuron is ready to fire again



## Action potential graph

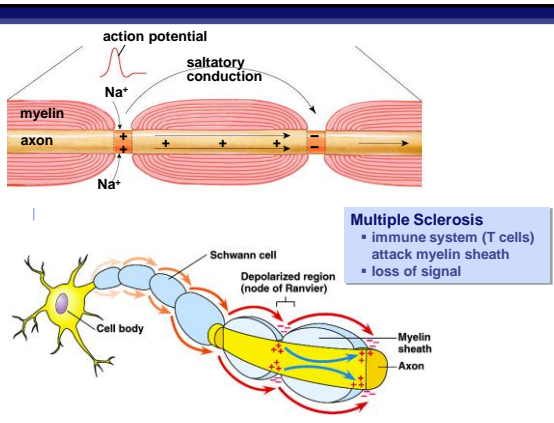
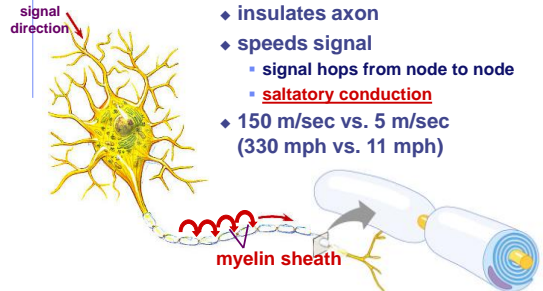
- Resting potential**
- Stimulus reaches threshold potential**
- Depolarization**  
Na<sup>+</sup> channels open;  
K<sup>+</sup> channels closed
- Na<sup>+</sup> channels close; K<sup>+</sup> channels open**
- Repolarization**  
reset charge gradient
- Undershoot**  
K<sup>+</sup> channels close slowly



## Myelin sheath

- Axon coated with **Schwann cells**

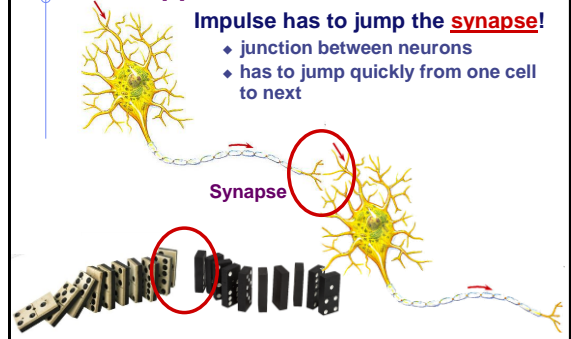
- insulates axon
- speeds signal
  - signal hops from node to node
  - saltatory conduction**
- 150 m/sec vs. 5 m/sec (330 mph vs. 11 mph)



## What happens at the end of the axon?

Impulse has to jump the **synapse!**

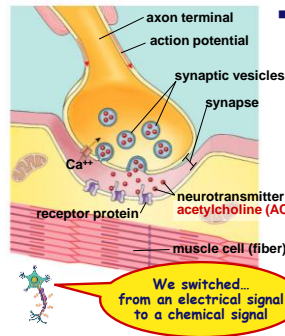
- junction between neurons
- has to jump quickly from one cell to next



## Chemical synapse

- Events at synapse

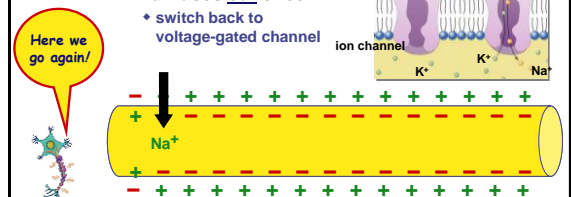
- action potential depolarizes membrane
- opens Ca<sup>++</sup> channels**
- neurotransmitter vesicles fuse with membrane**
- release neurotransmitter to synapse → diffusion**
- neurotransmitter binds with protein receptor
  - ion-gated channels open**
- neurotransmitter degraded or reabsorbed



## Nerve impulse in next neuron

- Post-synaptic neuron

- triggers nerve impulse in next nerve cell
  - chemical signal opens **ion-gated channels**
  - Na<sup>+</sup> diffuses **into** cell
  - K<sup>+</sup> 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

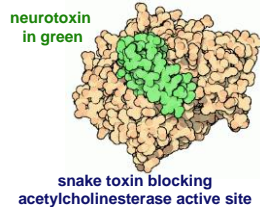
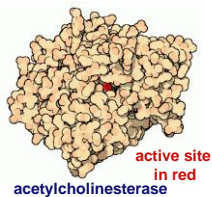
## Neurotransmitters

- **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



Any Questions??

