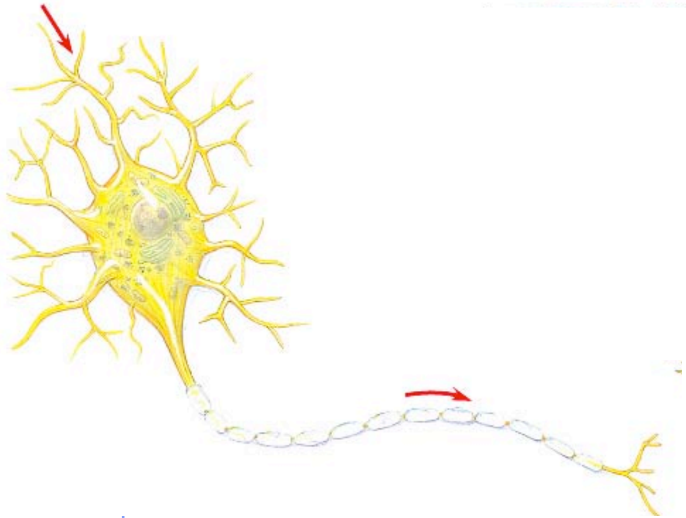
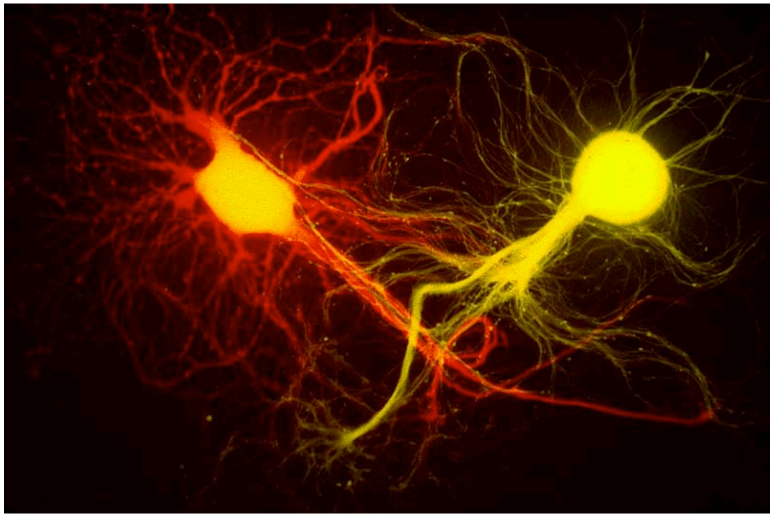
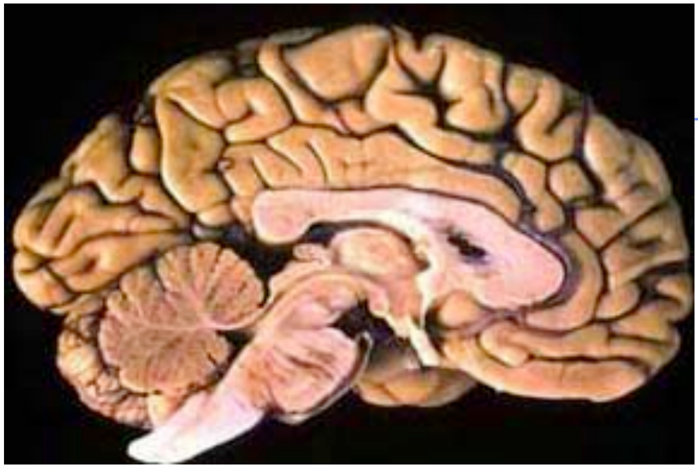
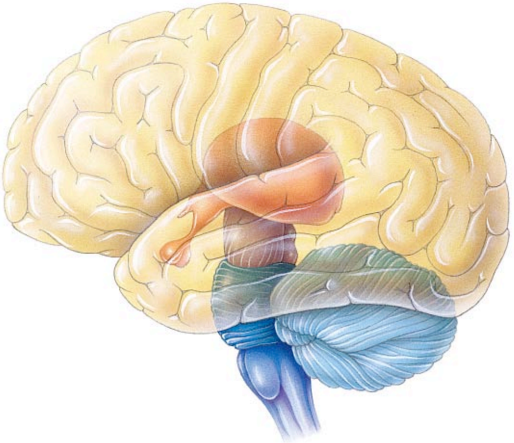




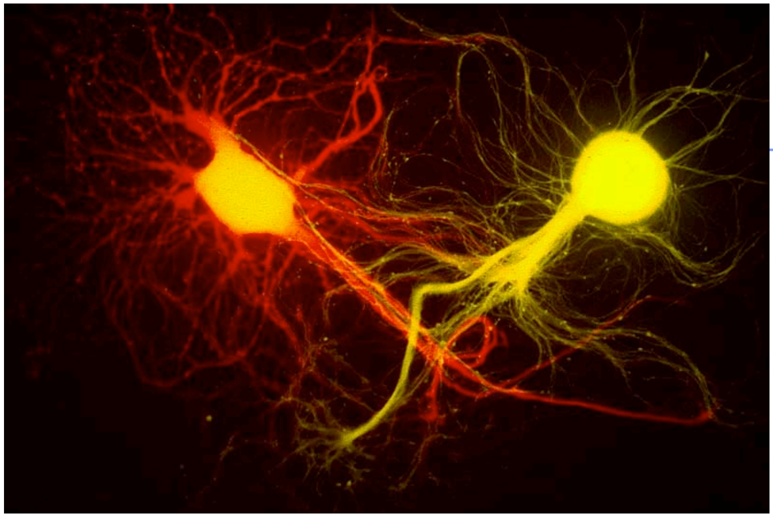
Chapter 48.

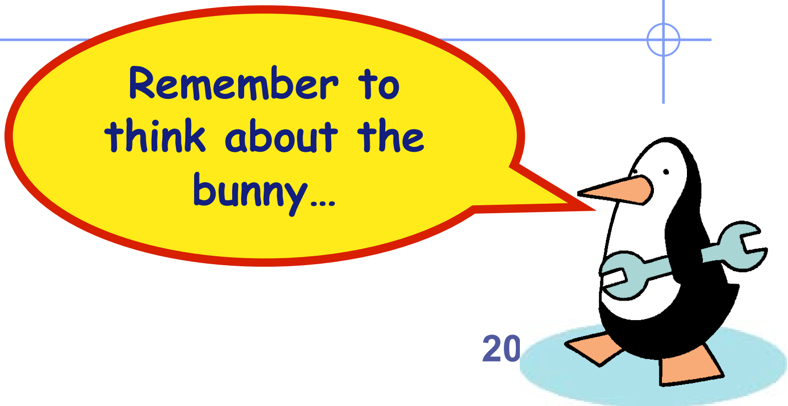
Nervous System





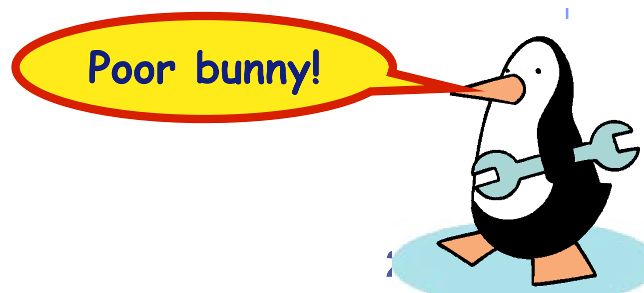
Why do animals need a nervous system?





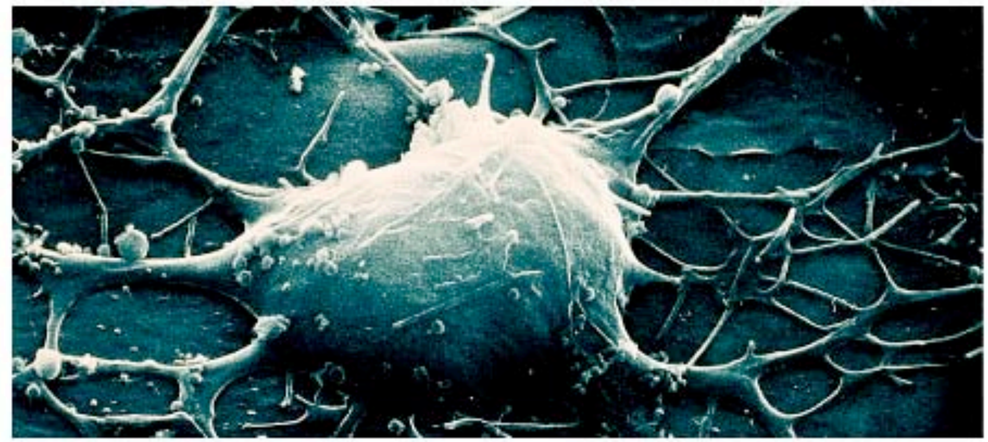
What characteristics do animals need in a nervous system?

- fast
- accurate
- reset quickly

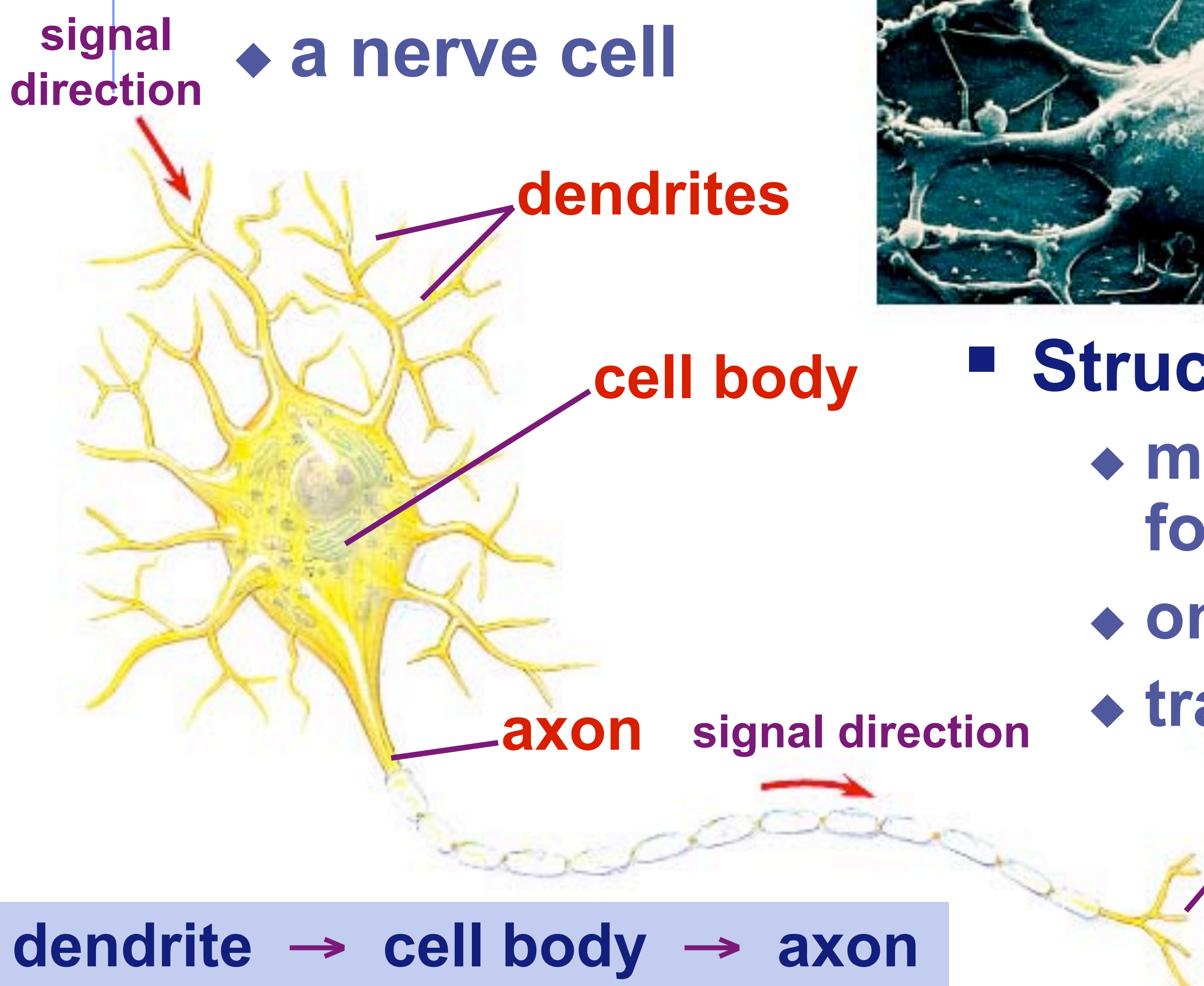


Nervous system cells

- Neuron
  - a nerve cell



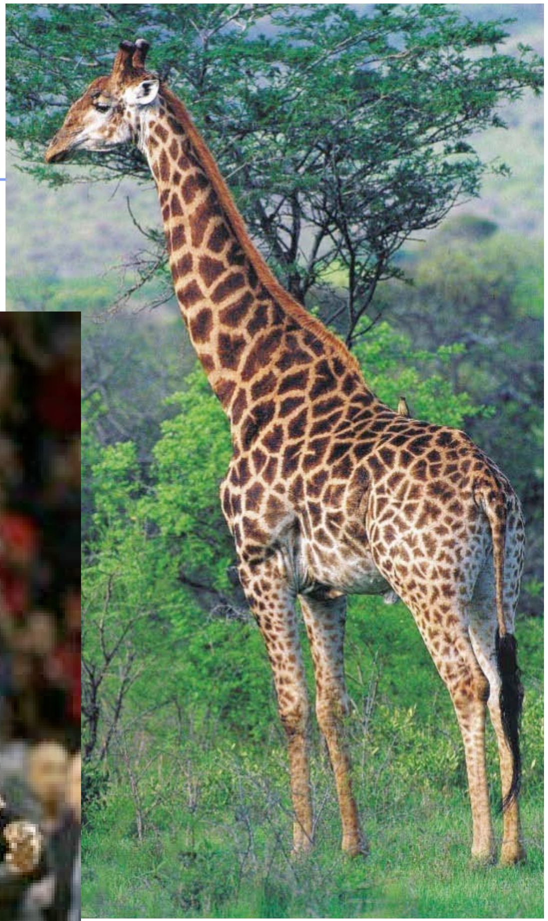
- Structure fits function
  - many entry points for signal
  - one path out
  - transmits signal



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**

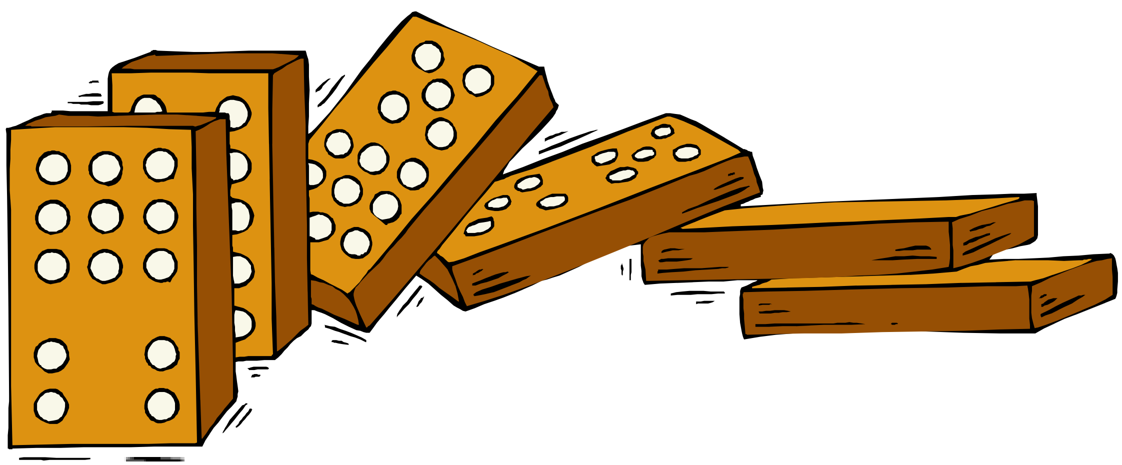


Nervous system allows for 1 millisecond response time

Transmission of a signal

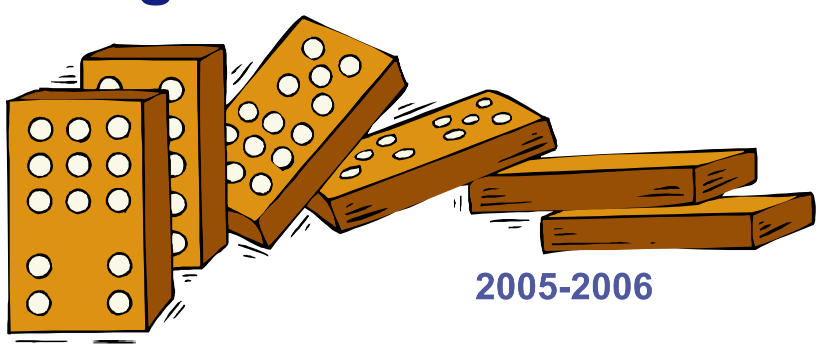
- How is a signal transmitted down neuron?

Think Dominoes!



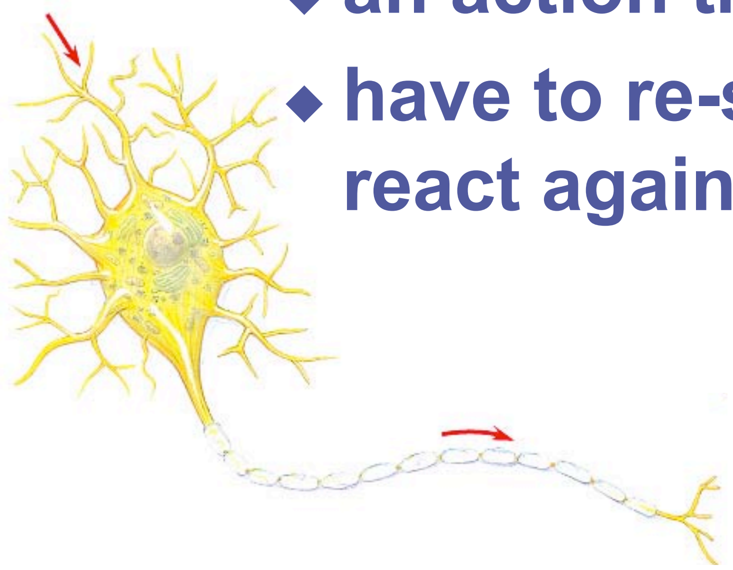
Transmission of a signal

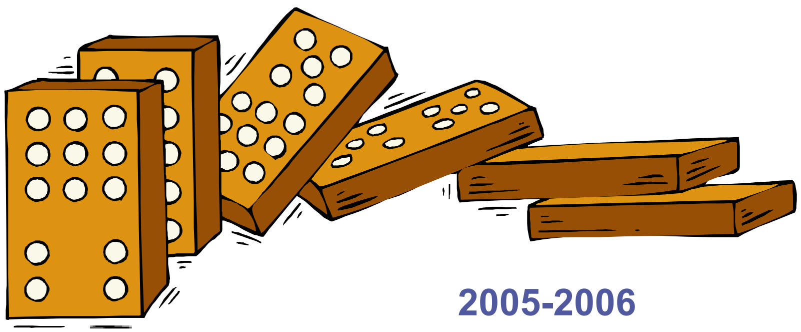
- Dominoes
  - start the signal
    - knock down line of dominoes by tipping 1st one
      → send message
  - propagate the signal
    - do dominoes move down the line?
      → no, just a wave through them!
  - re-set the system
    - before you can do it again,
      have to set up dominoes again
 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



Transmission of a nerve signal

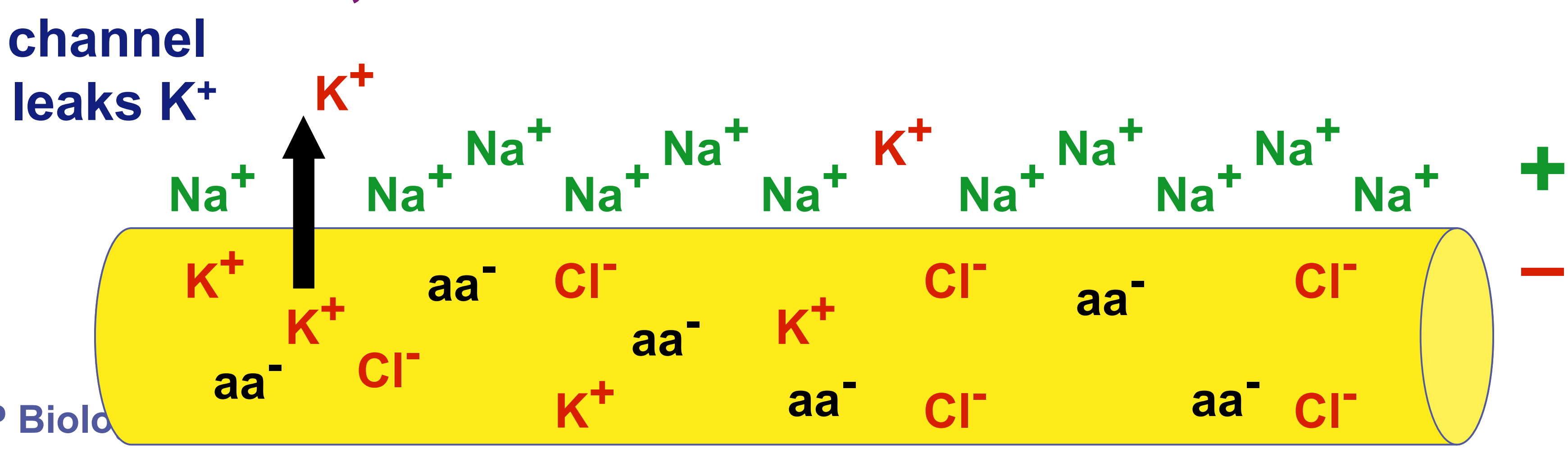
- **Neuron has similar system**
  - channels are set up
  - once 1st is opened, the rest open in succession
    - all or nothing response
  - an action travels along neuron
  - have to re-set channels so neuron can react again





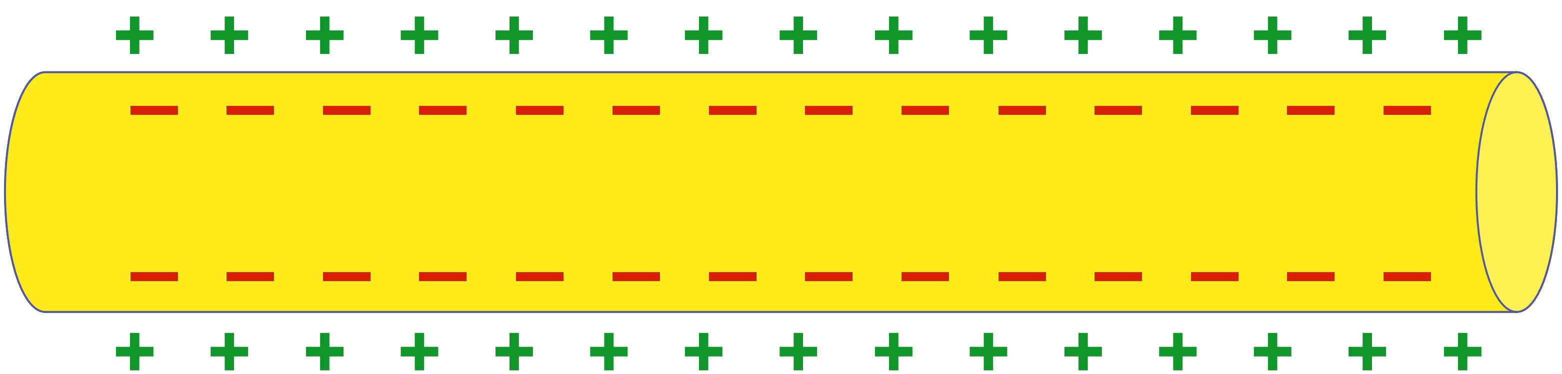
Cells: surrounded by charged ions

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

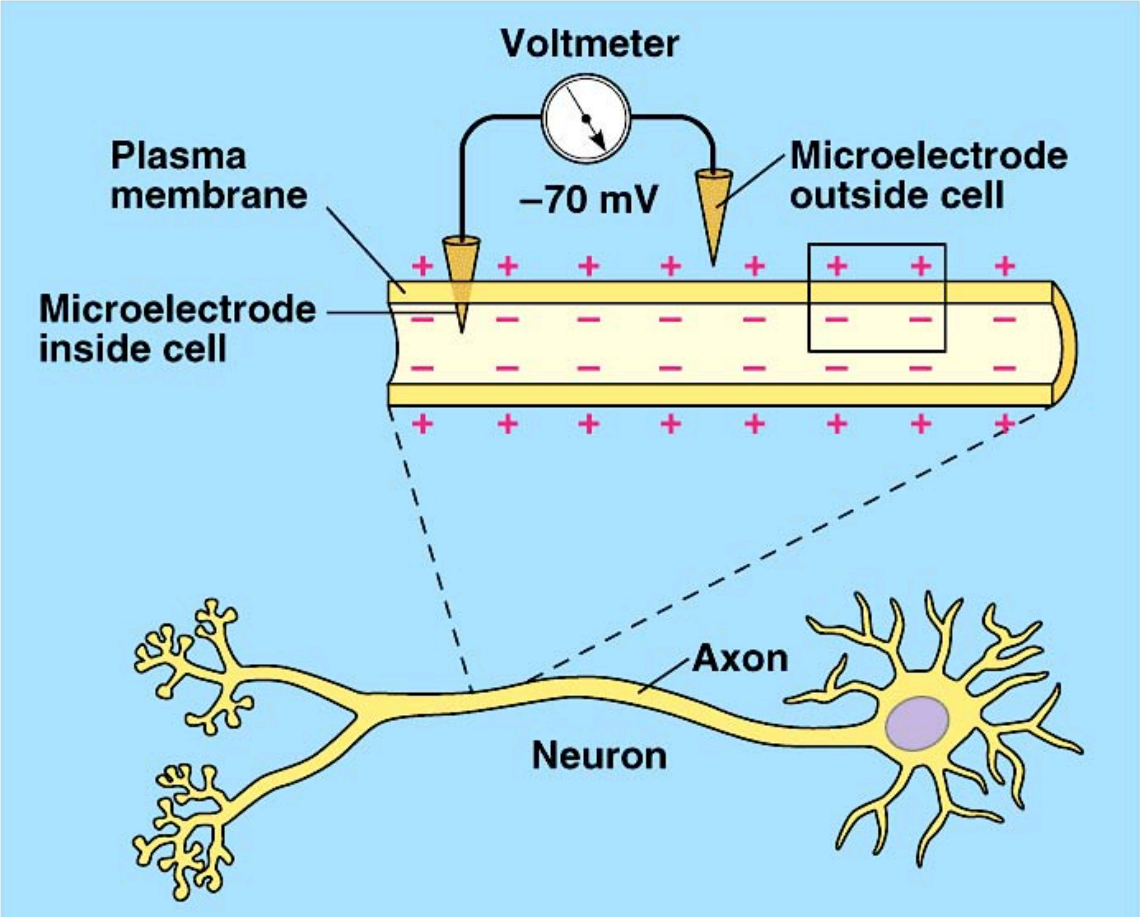


Cells have voltage!

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



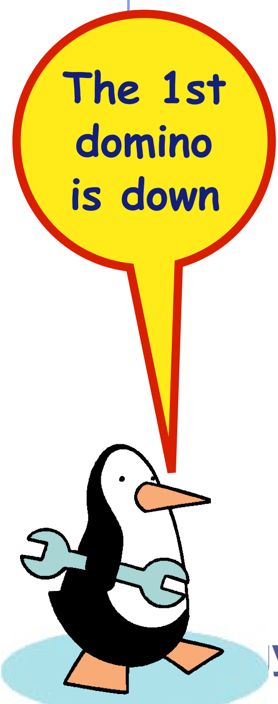
Measuring cell voltage

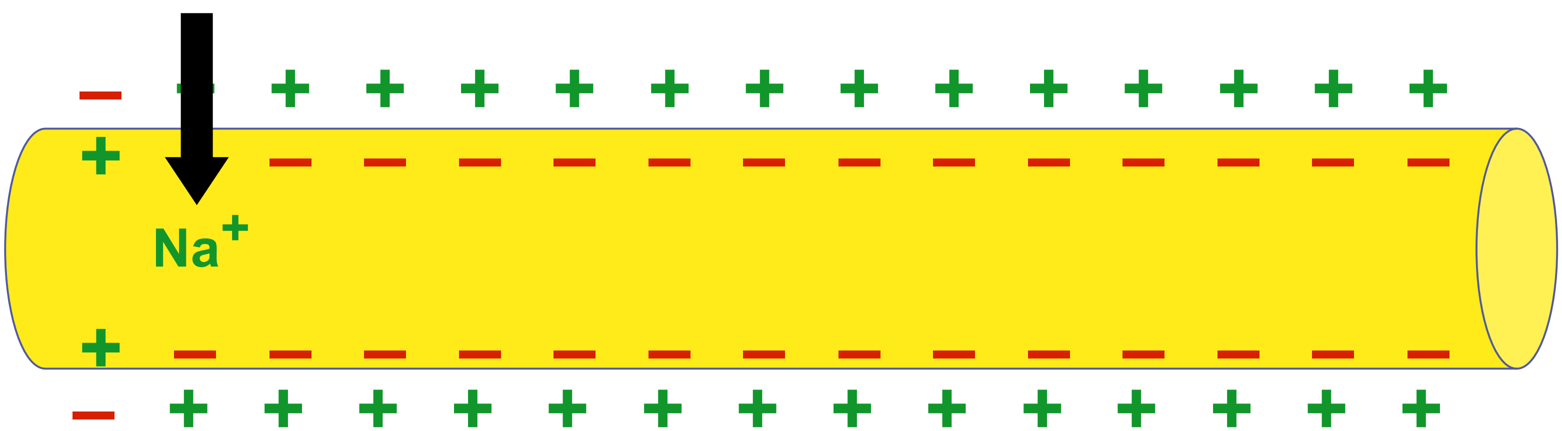


unstimulated neuron = resting potential of -70mV

How does a nerve impulse travel?

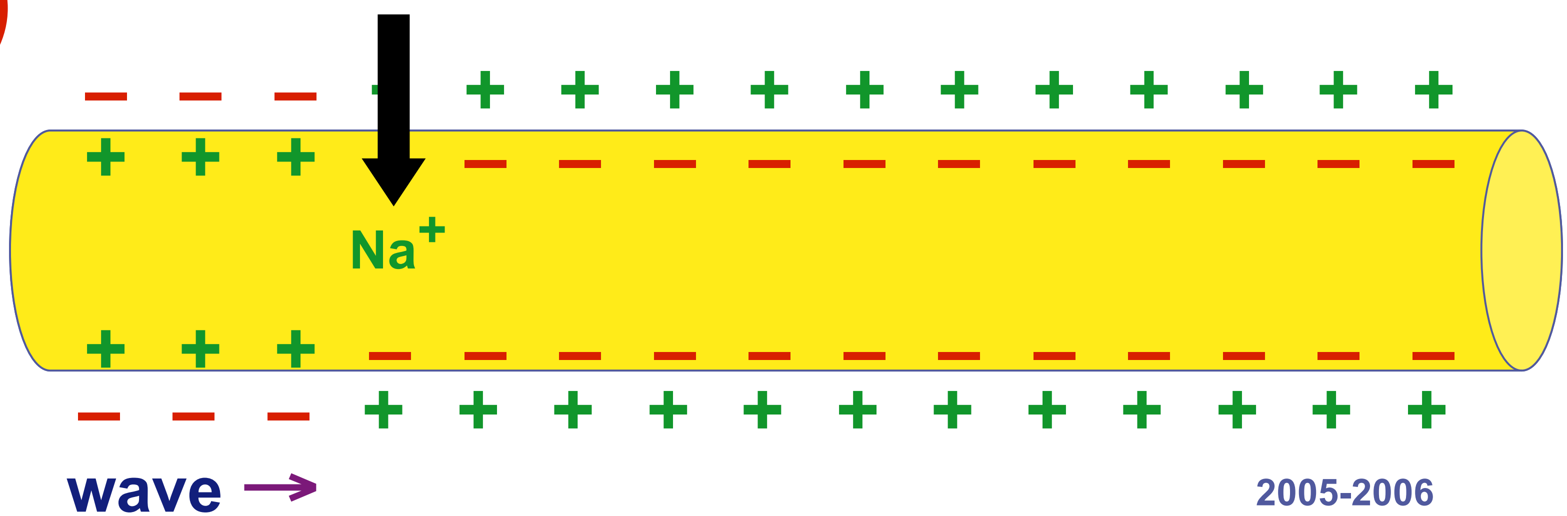
- **Stimulus: nerve is stimulated**
  - open Na^+ channels in cell membrane
    - reached threshold potential
    - membrane becomes very permeable to Na^+
    - Na^+ ions diffuse into cell
  - charges reverse at that point on neuron
    - positive inside; negative outside
    - cell becomes depolarized





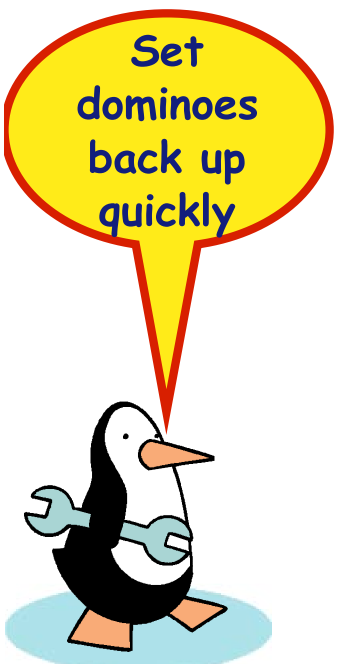
How does a nerve impulse travel?

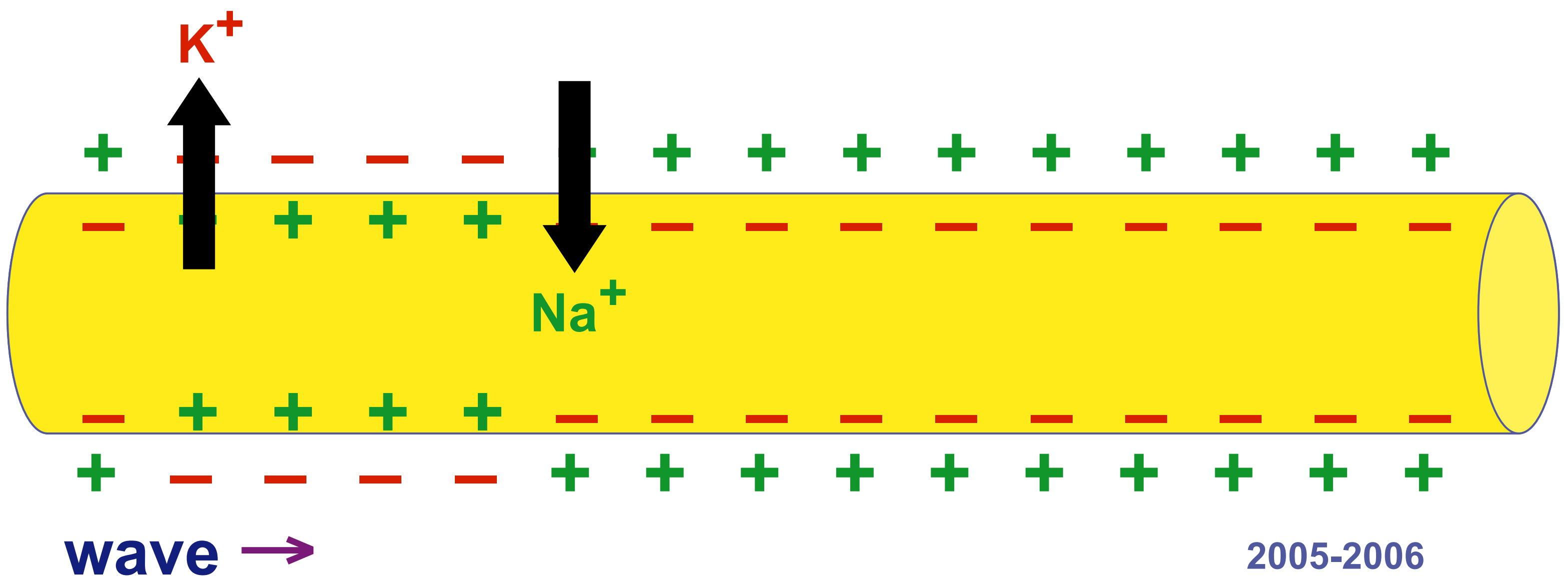
- **Wave**: nerve impulse travels down neuron
  - change in charge opens other Na^+ gates in next section of cell
    - “voltage-gated” channels
  - Na^+ ions continue to move into cell
  - “wave” moves down neuron = action potential



How does a nerve impulse travel?

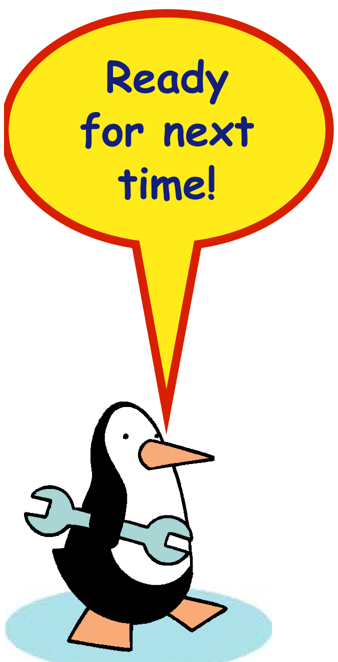
- **Re-set**: 2nd wave travels down neuron
  - K^+ channels open up slowly
  - K^+ ions diffuse out of cell
  - charges reverse back at that point
    - negative inside; positive outside

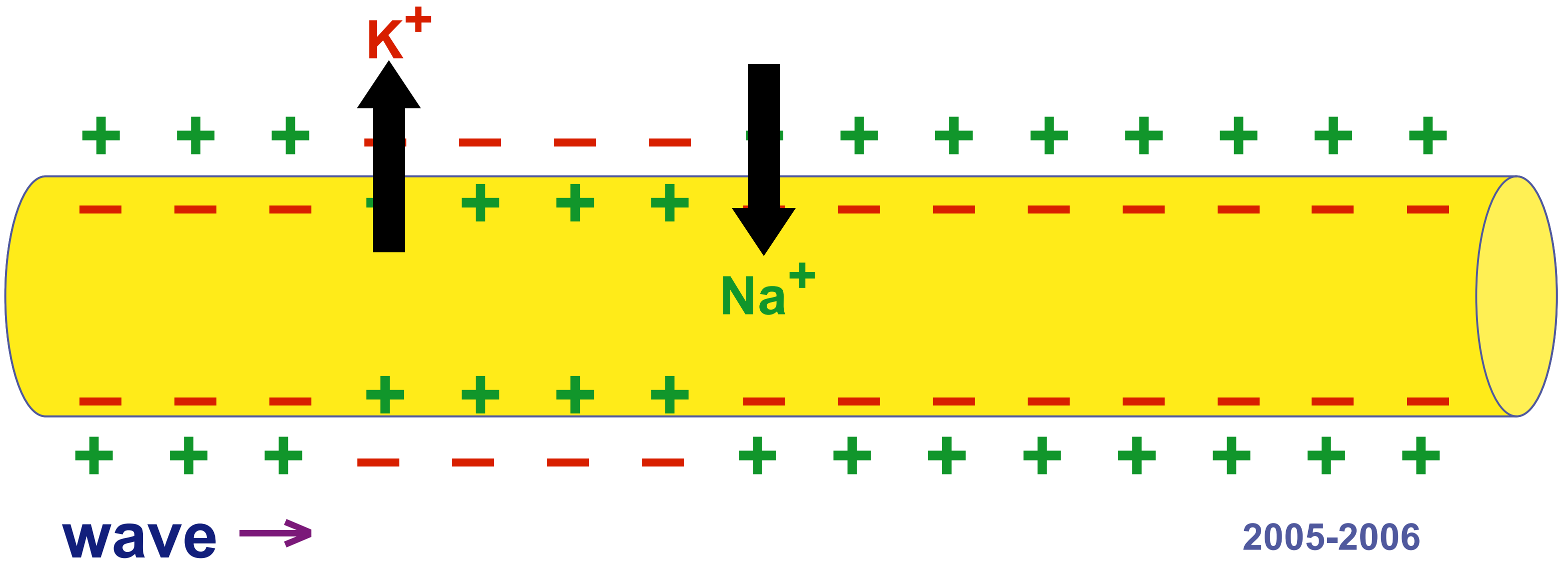




How does a nerve impulse travel?

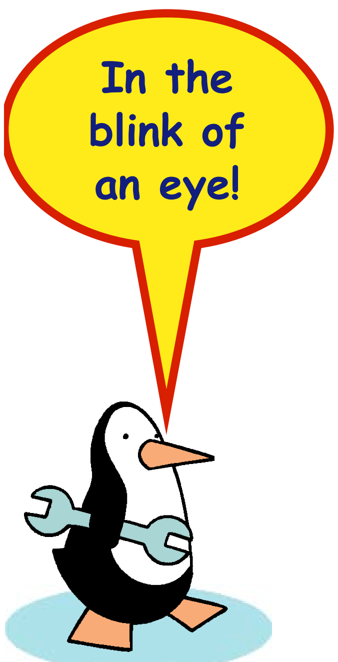
- Combined waves travel down neuron
  - wave of opening ion channels moves down neuron
  - signal moves in one direction → → →
    - flow of K^+ out of cell stops activation of Na^+ channels in wrong direction

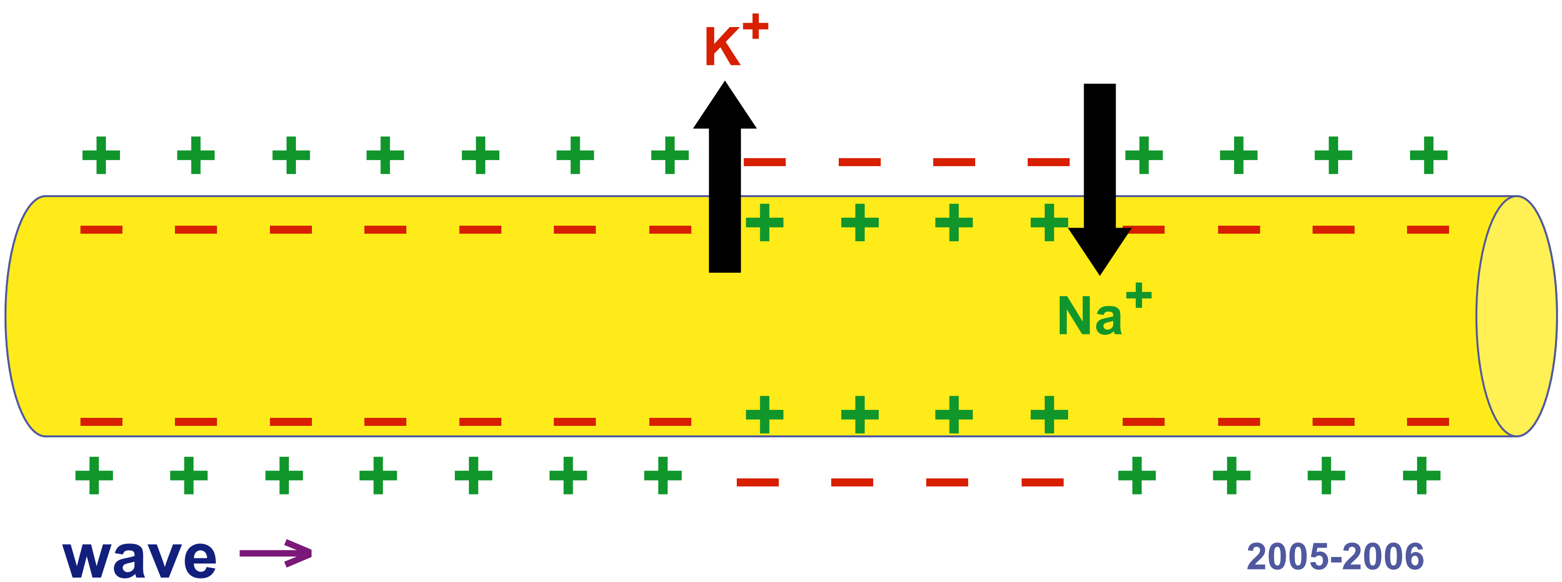




How does a nerve impulse travel?

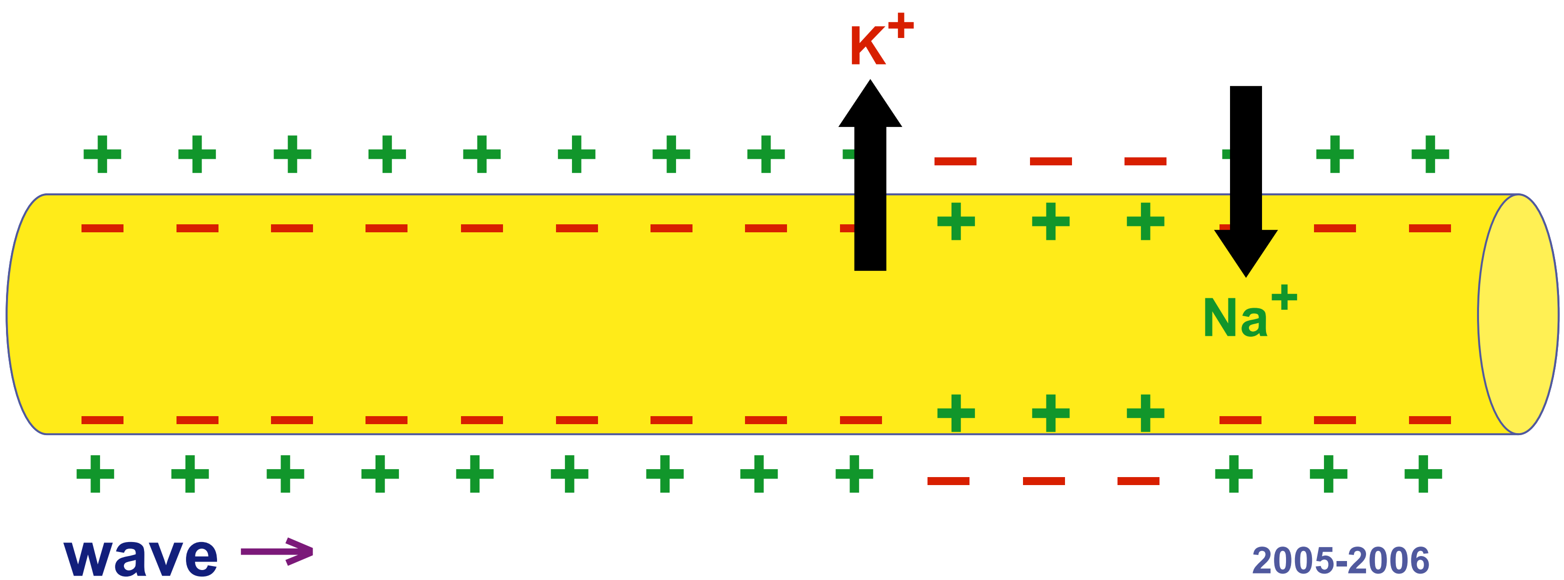
- **Action potential propagates**
  - wave = <u>nerve impulse</u>, or <u>action potential</u>
  - brain → finger tips in <u>milliseconds</u>!





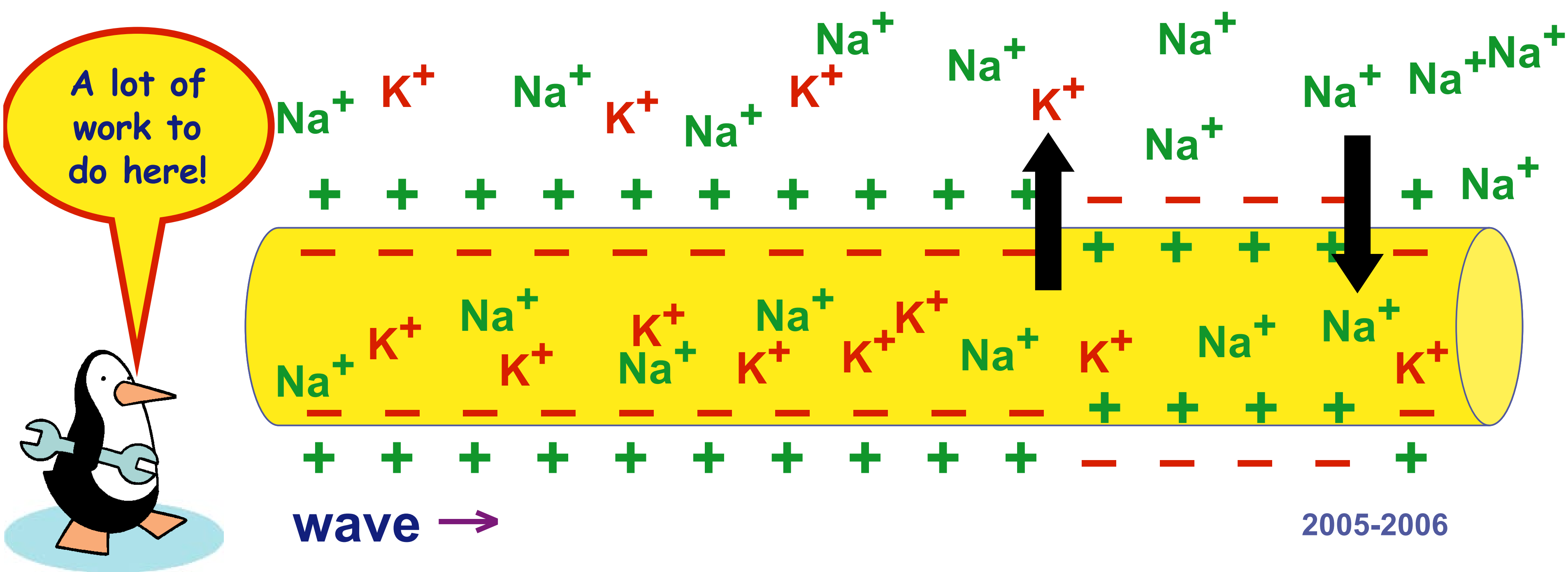
Voltage-gated channels

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



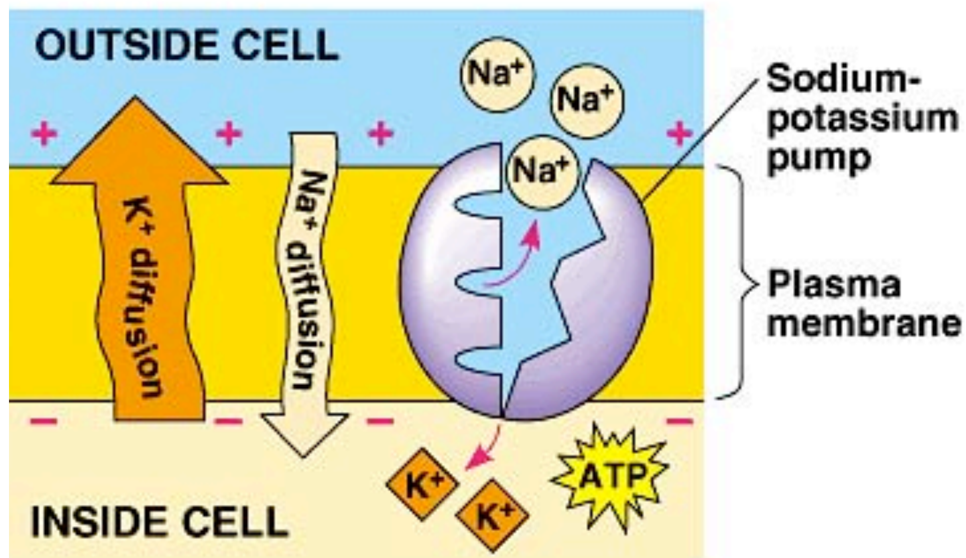
How does the nerve re-set itself?

- 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!!

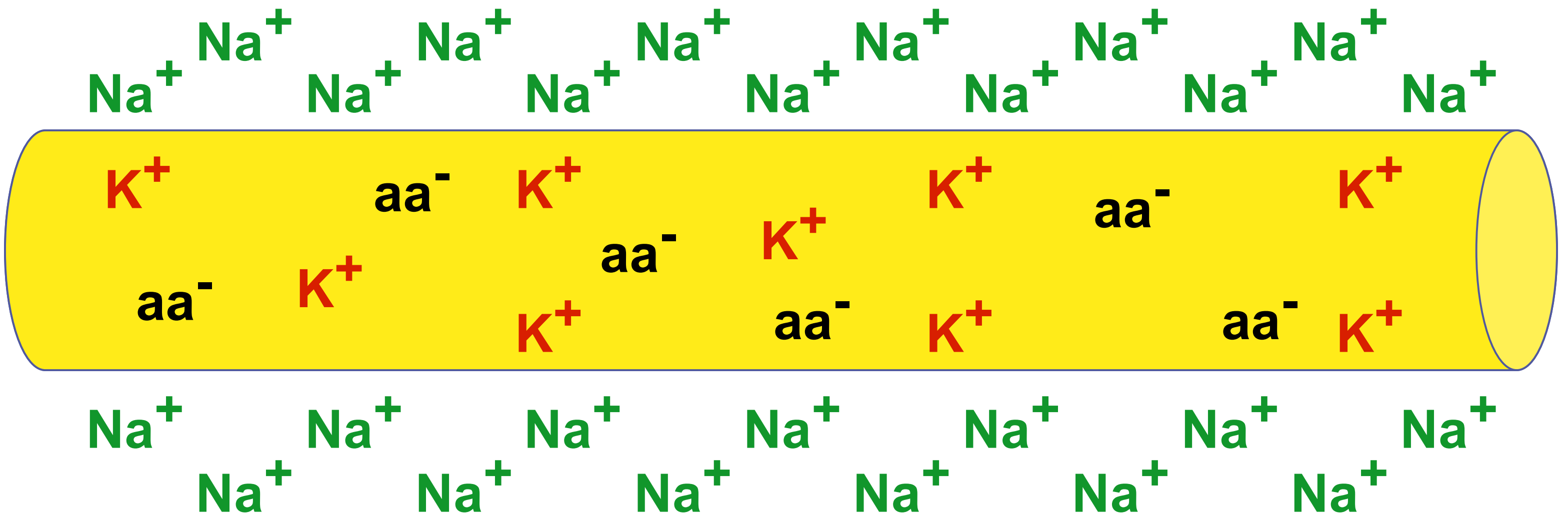


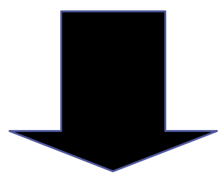
How does the nerve re-set itself?

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

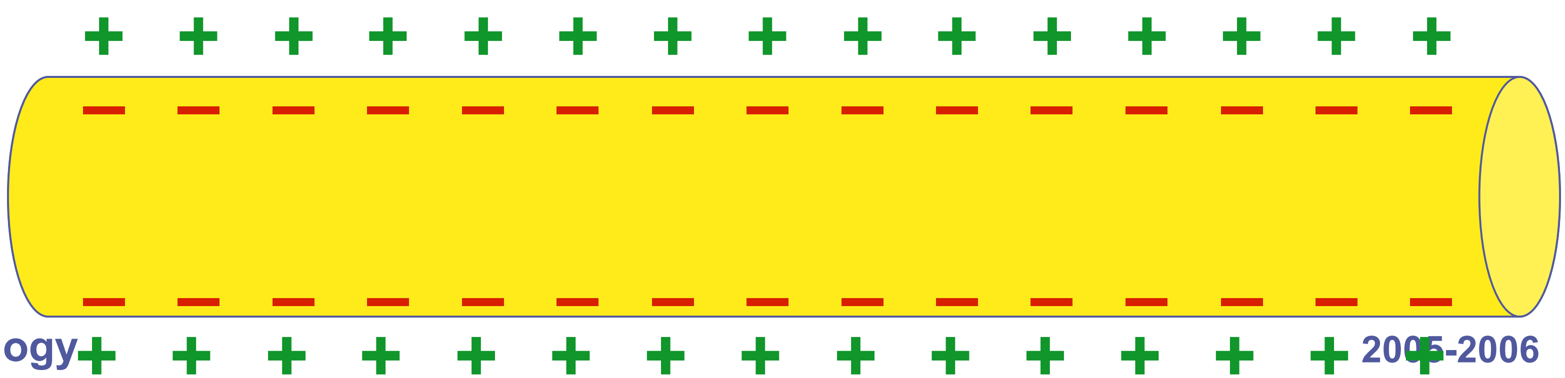


Neuron is ready to fire again



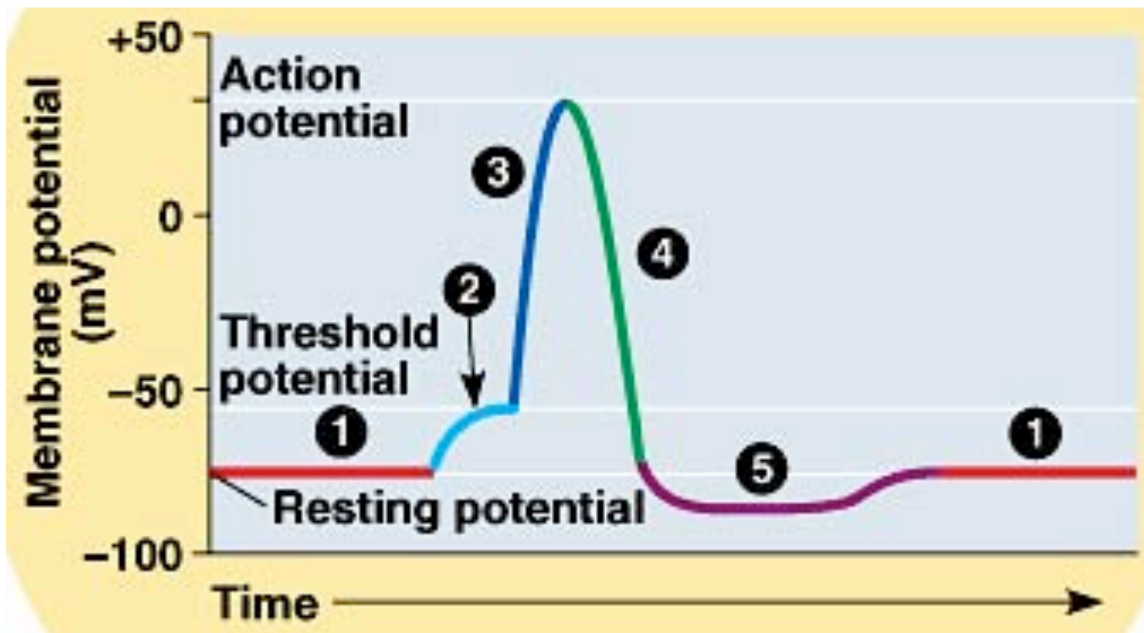


resting potential



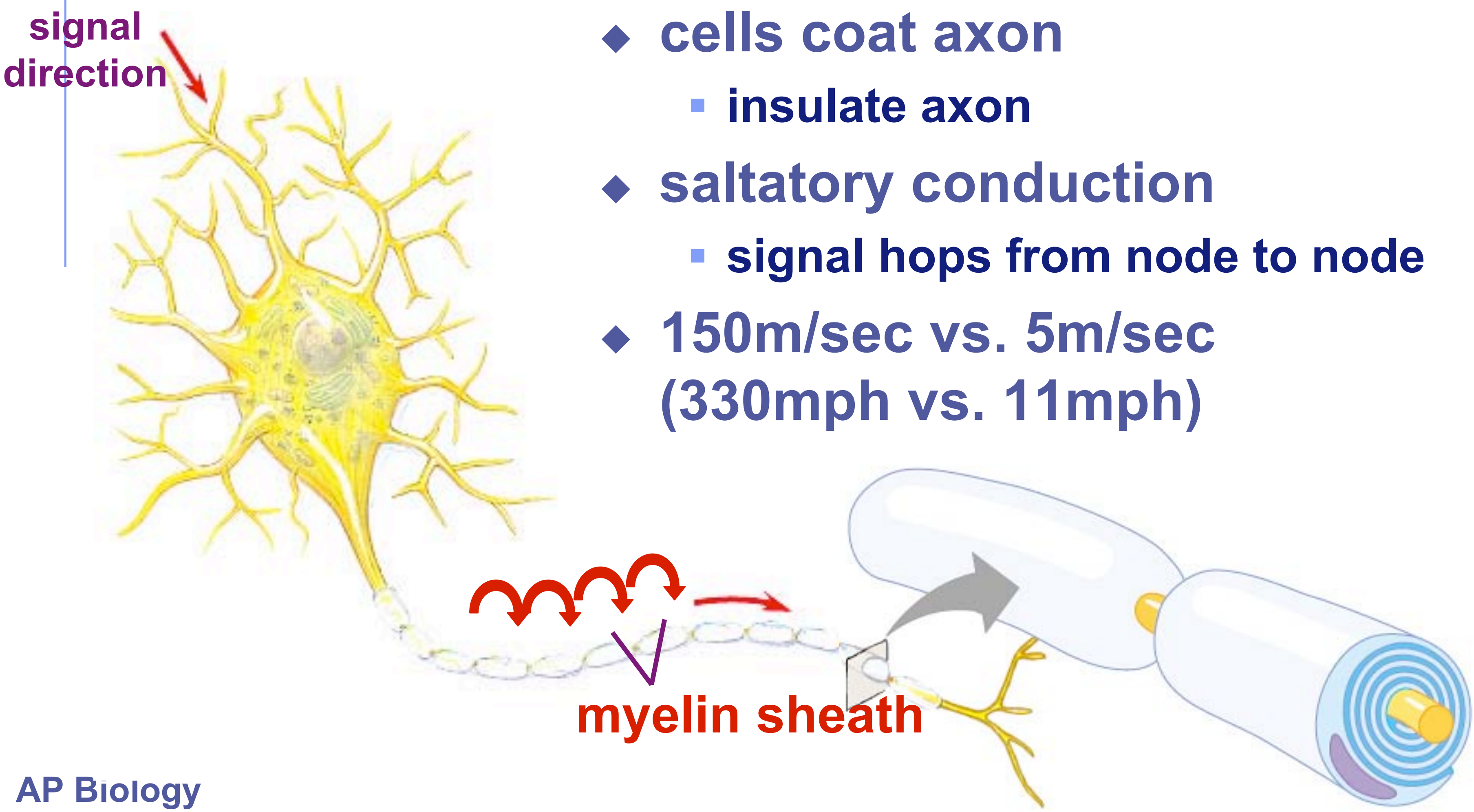
Action potential graph

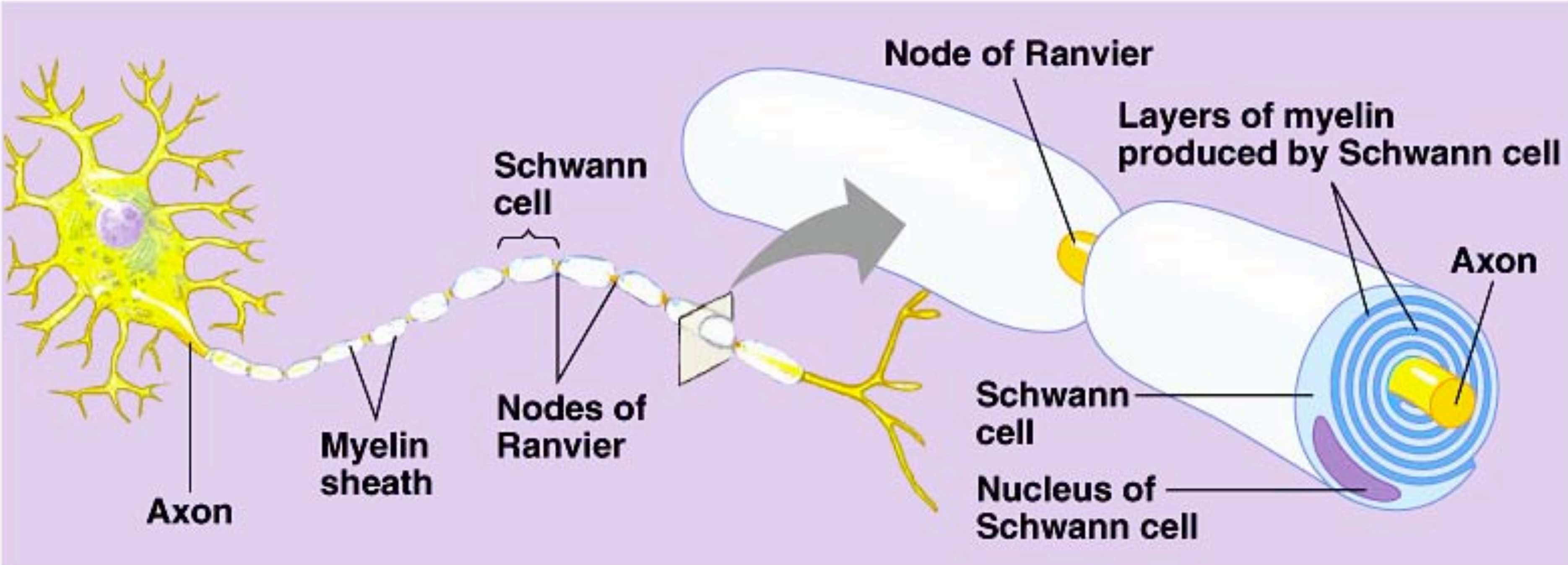
1. Resting potential
2. Stimulus reaches threshold potential
3. Na^+ channels open; K^+ channels closed
4. Na^+ channels close; K^+ channels open
5. Undershoot: K^+ channels close slowly

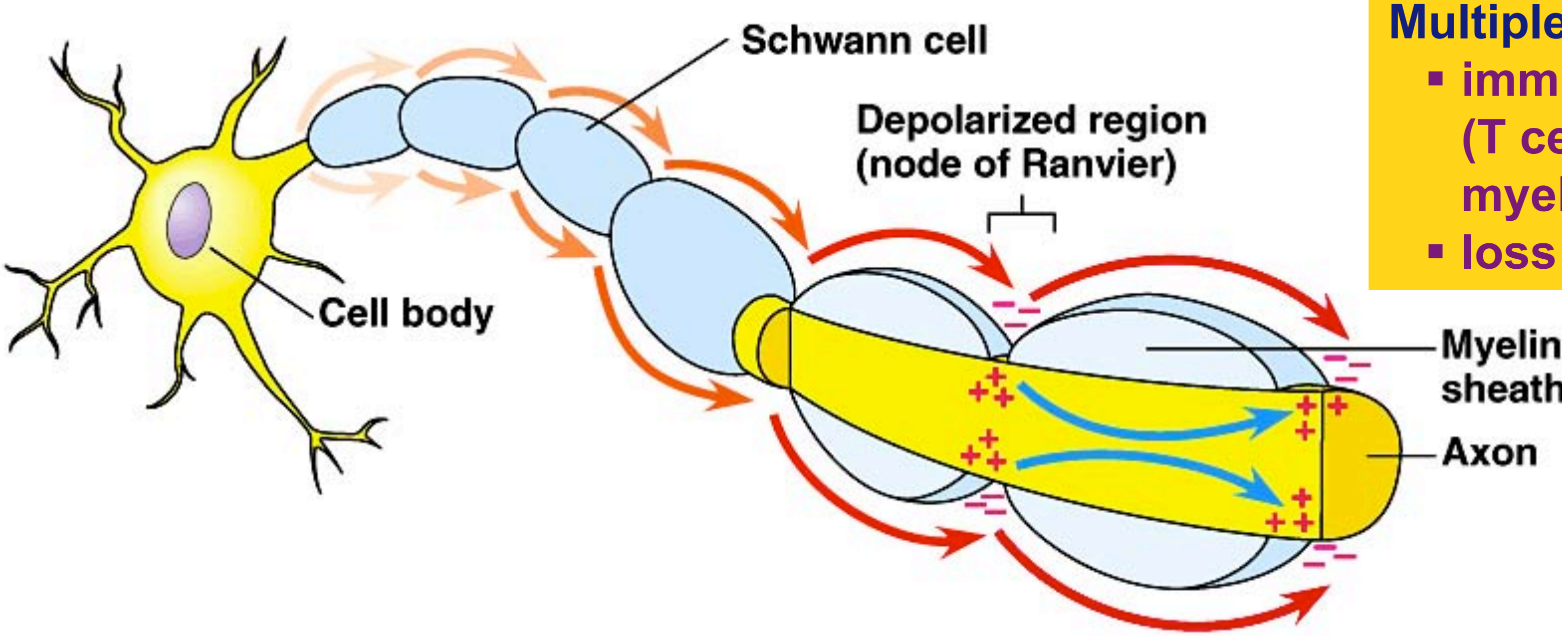


Myelin sheath

- made of Schwann cells
  - cells coat axon
    - insulate axon
  - saltatory conduction
    - signal hops from node to node
  - 150m/sec vs. 5m/sec (330mph vs. 11mph)







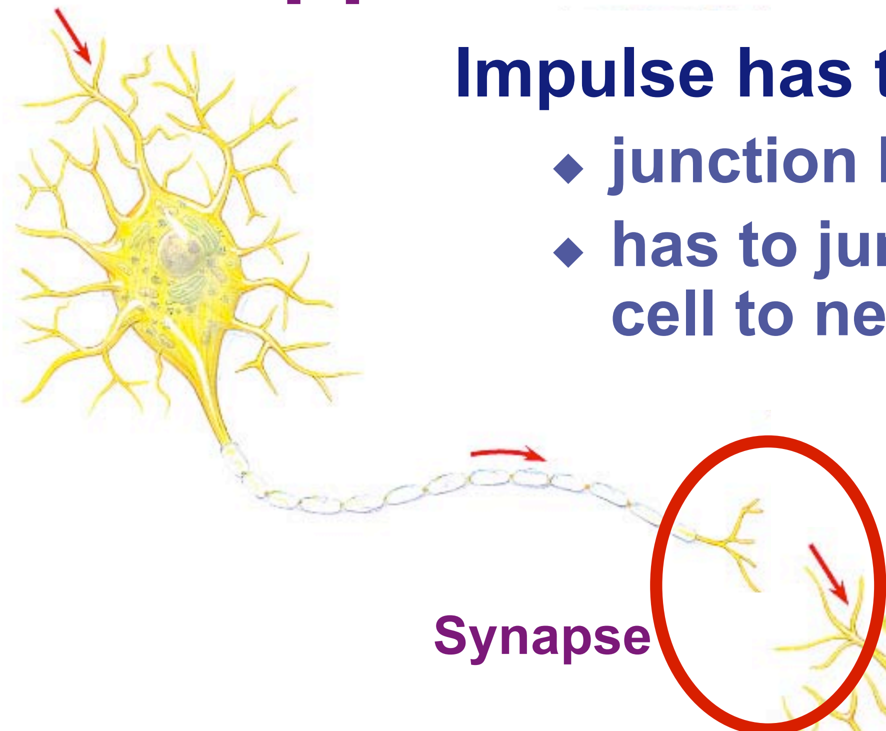
Multiple Sclerosis

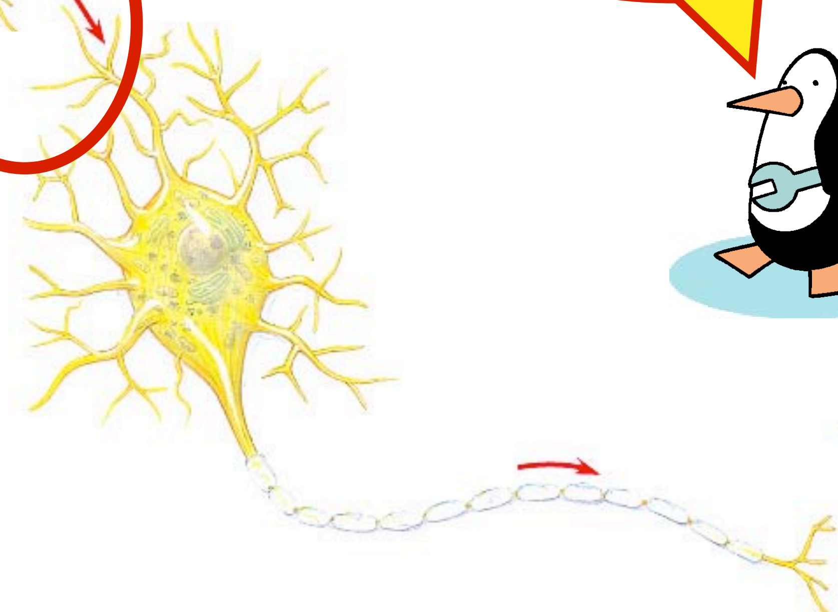
- **immune system (T cells) attack myelin sheath**
- **loss of signal**

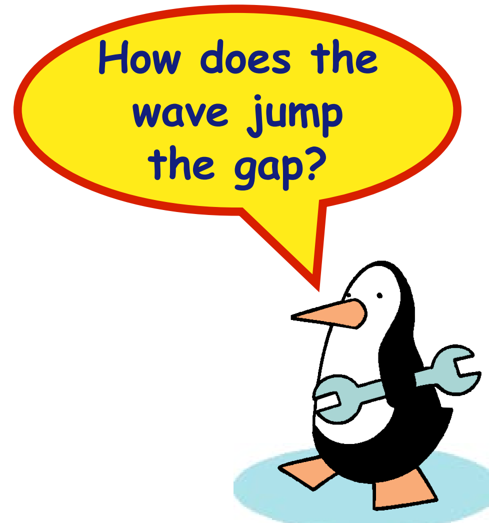
What happens at the end of the axon?

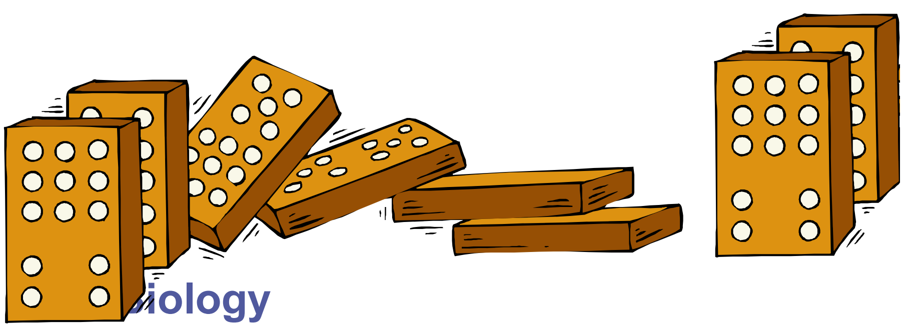
Impulse has to jump the synapse!

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



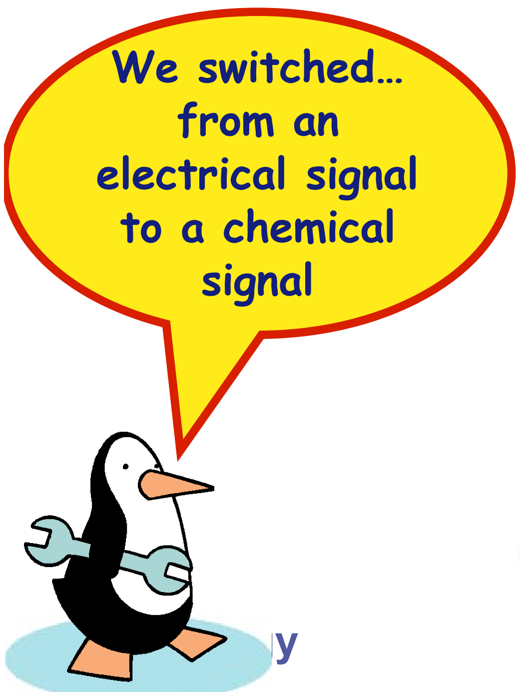


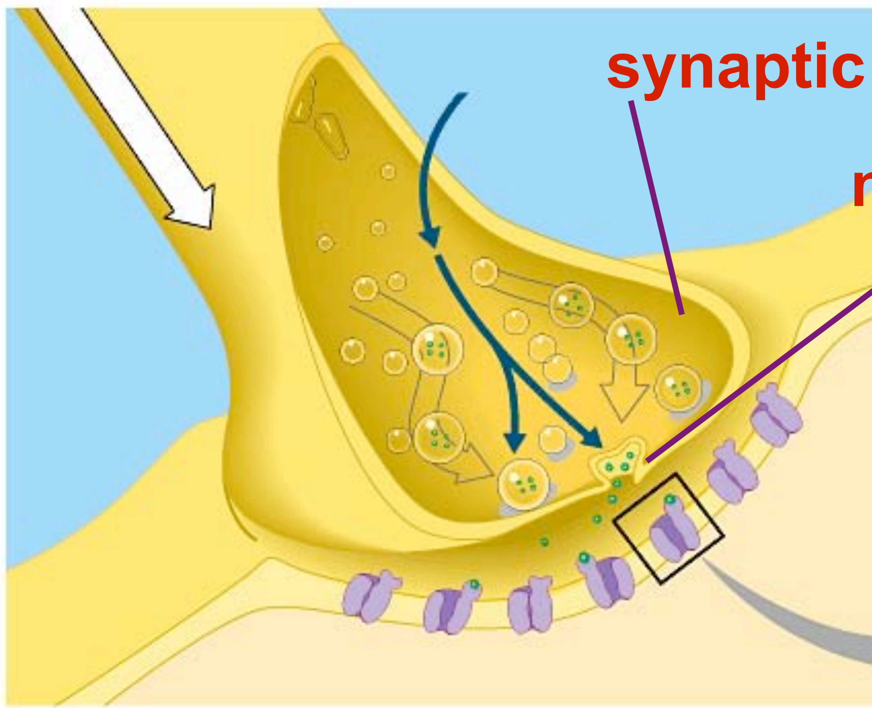


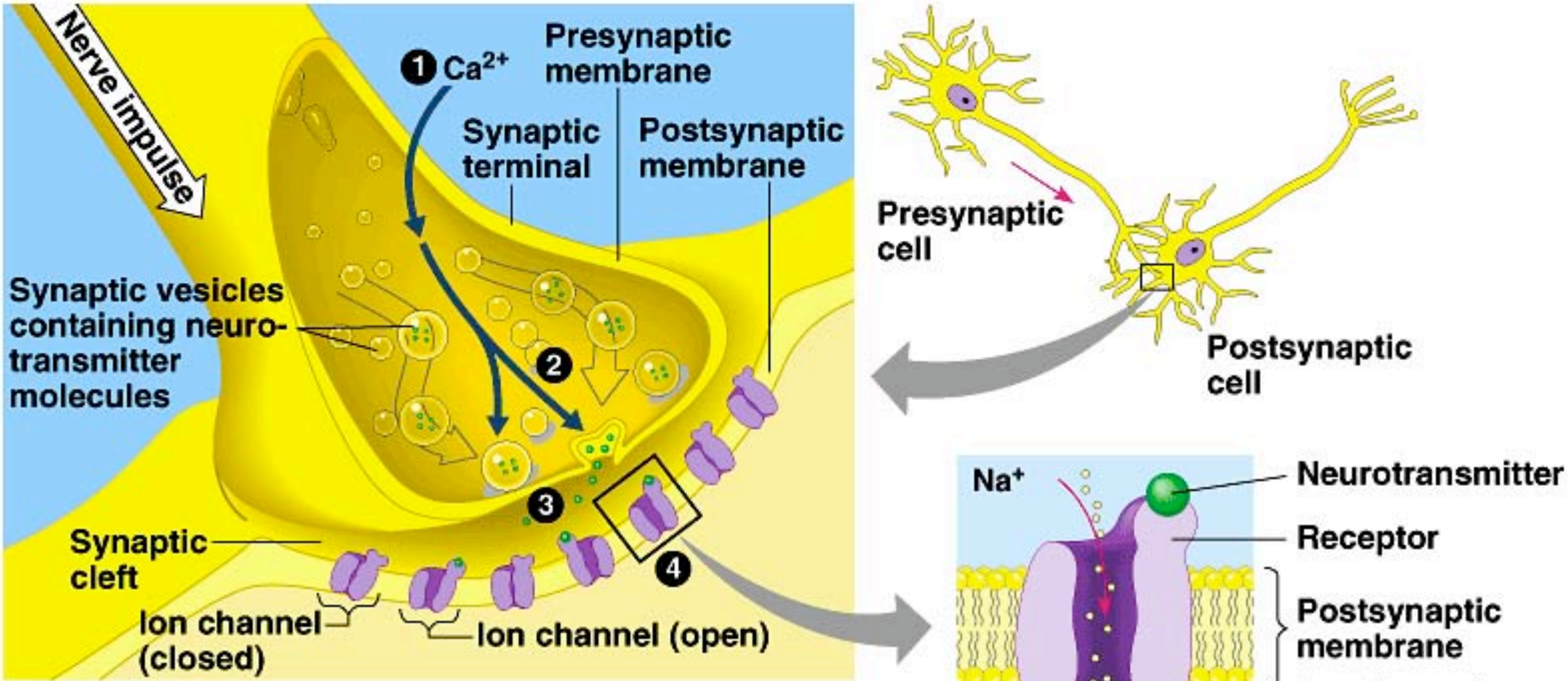


Synaptic terminal

- Chemicals stored in vesicles
  - release <u>neurotransmitters</u>
    - diffusion of chemical across synapse conducts the signal — <u>chemical signal</u> — across synapse
    - stimulus for receptors on dendrites of next neuron

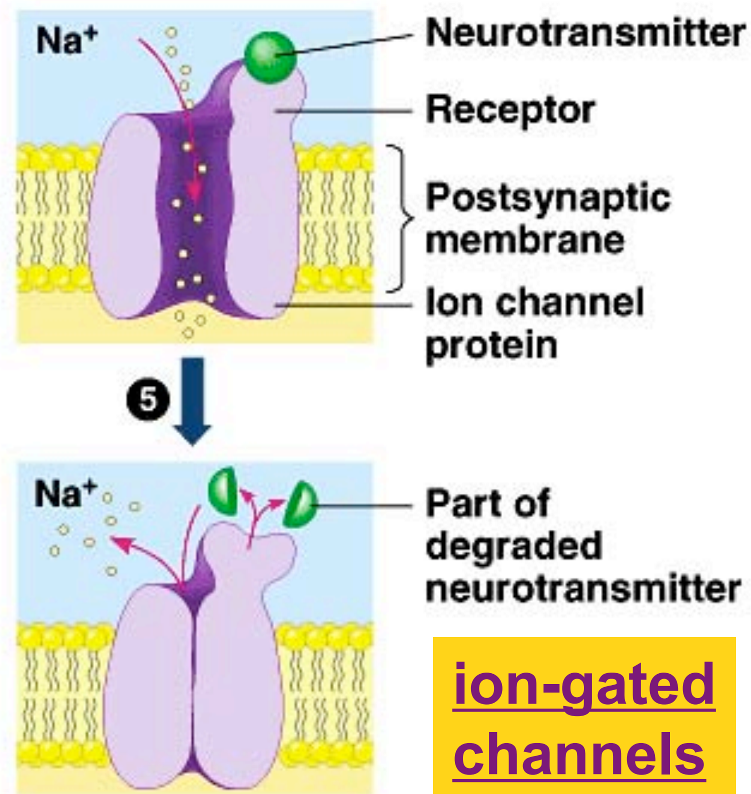






Chemical synapse: follow the path

- action depolarizes membrane
- triggers influx of Ca+
- vesicles fuse with membrane
- release neurotransmitter to cleft
- neurotransmitter bind with receptor
- neurotransmitter degraded / reabsorbed



[ion-gated channels]

Nerve impulse in next neuron

- **Post-synaptic neuron**
  - triggers nerve impulse in next nerve cell
    - chemical signal opens "<u>ion-gated</u>" channels
    - Na^+ diffuses <u>into</u> cell
    - K^+ diffuses <u>out</u> of cell

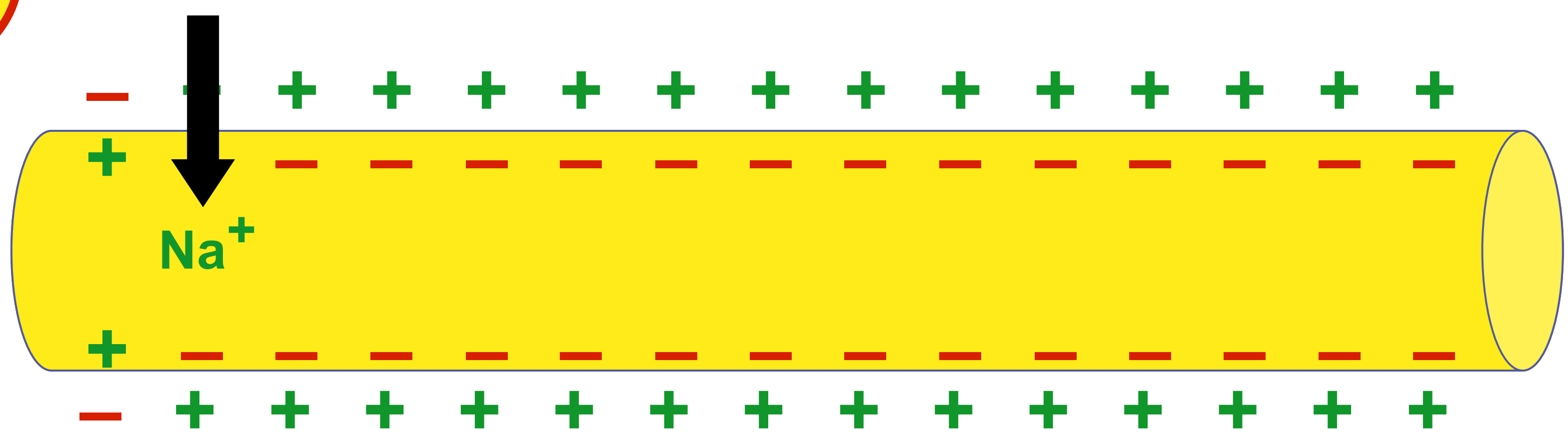
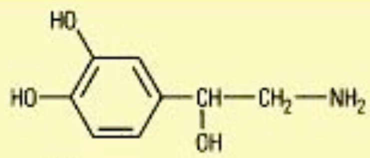
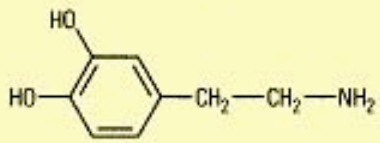
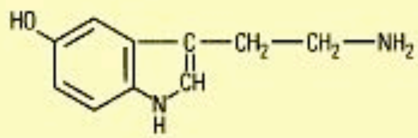


Table 48.1 The Major Known Neurotransmitters

Neurotransmitter	Structure	Functional Class	Secretion Sites
Acetylcholine	$H_3C-\overset{\overset{O}{\|}}{C}-O-CH_2-CH_2-N^+-(CH_3)_3$	Excitatory to vertebrate skeletal muscles; excitatory or inhibitory at other sites	CNS; PNS; vertebrate neuromuscular junction
Biogenic Amines			
Norepinephrine		Excitatory or inhibitory	CNS; PNS
Dopamine		Generally excitatory; may be inhibitory at some sites	CNS; PNS
Serotonin		Generally inhibitory	CNS
Amino Acids			
GABA (gamma aminobutyric acid)	$H_2N-CH_2-CH_2-CH_2-COOH$	Inhibitory	CNS; invertebrate neuromuscular junction
Glycine	H_2N-CH_2-COOH	Inhibitory	CNS
Glutamate	$H_2N-\underset{\underset{COOH}{\|}}{CH}-CH_2-CH_2-COOH$	Excitatory	CNS; invertebrate neuromuscular junction
Aspartate	$H_2N-\underset{\underset{COOH}{\|}}{CH}-CH_2-COOH$	Excitatory	CNS
Neuropeptides			
Substance P	Arg—Pro—Lys—Pro—Gln—Gln—Phe—Phe—Gly—Leu—Met	Excitatory	CNS; PNS
Met-enkephalin (an endorphin)	Tyr—Gly—Gly—Phe—Met	Generally inhibitory	CNS

Neurotransmitters

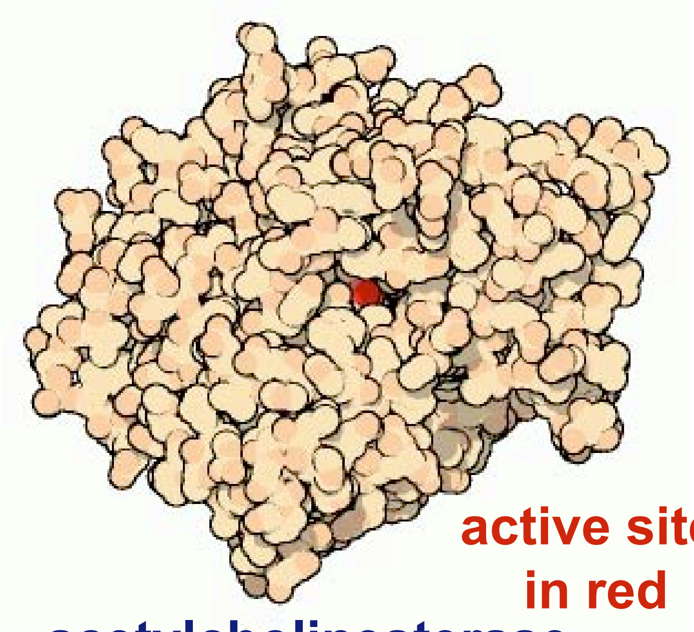
- Acetylcholine
  - transmit signal to skeletal muscle
- Epinephrine (adrenaline) & norepinephrine
  - fight-or-flight response
- Dopamine
  - widespread in brain
  - affects sleep, mood, attention & learning
  - lack of dopamine in brain associated with Parkinson's disease
  - excessive dopamine linked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

Neurotransmitters

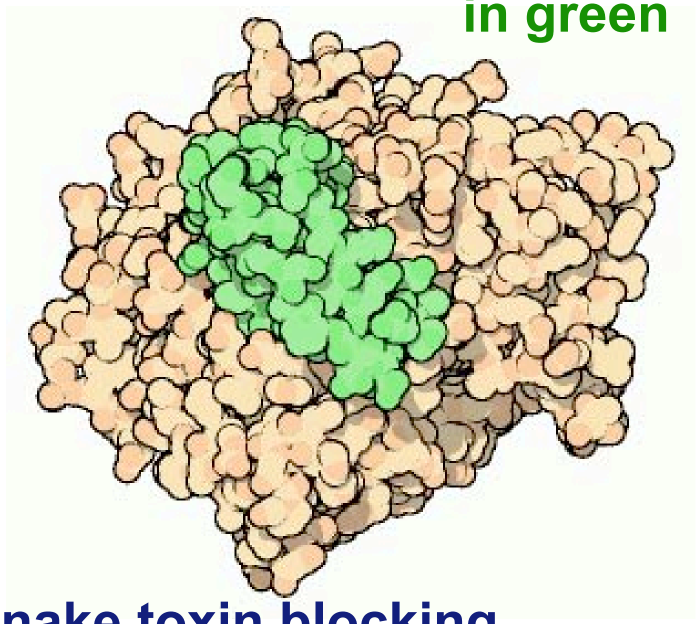
- Weak point of nervous system
  - any substance that affects neurotransmitters or mimics them affects nerve function
    - gases: nitric oxide, carbon monoxide
    - mood altering drugs:
      - stimulants
        - amphetamines, caffeine, nicotine
      - depressants
    - hallucinogenic drugs
    - Prozac
    - poisons

Acetylcholinesterase

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



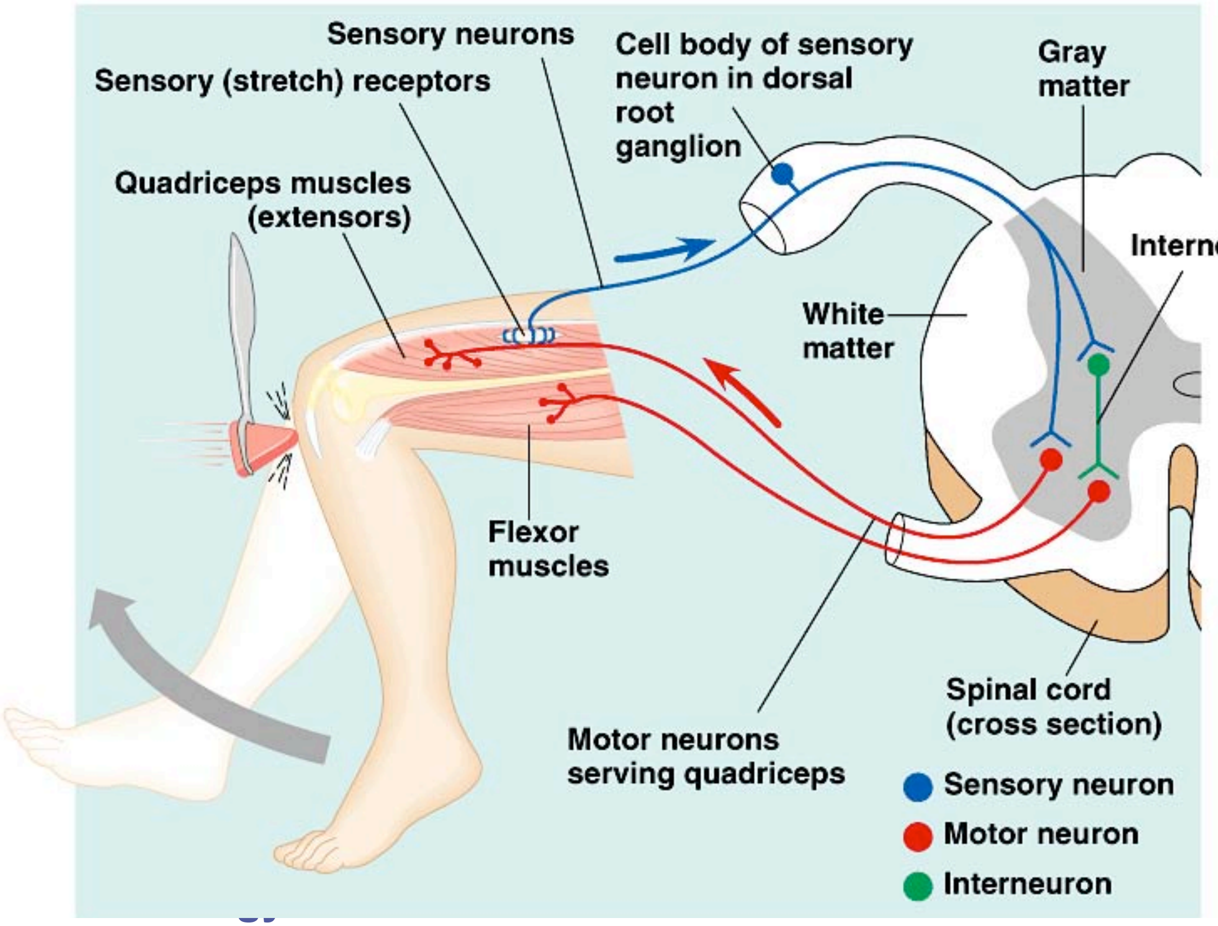
acetylcholinesterase



snake toxin blocking acetylcholinesterase active site

Simplest Nerve Circuit

- Reflex, or automatic response



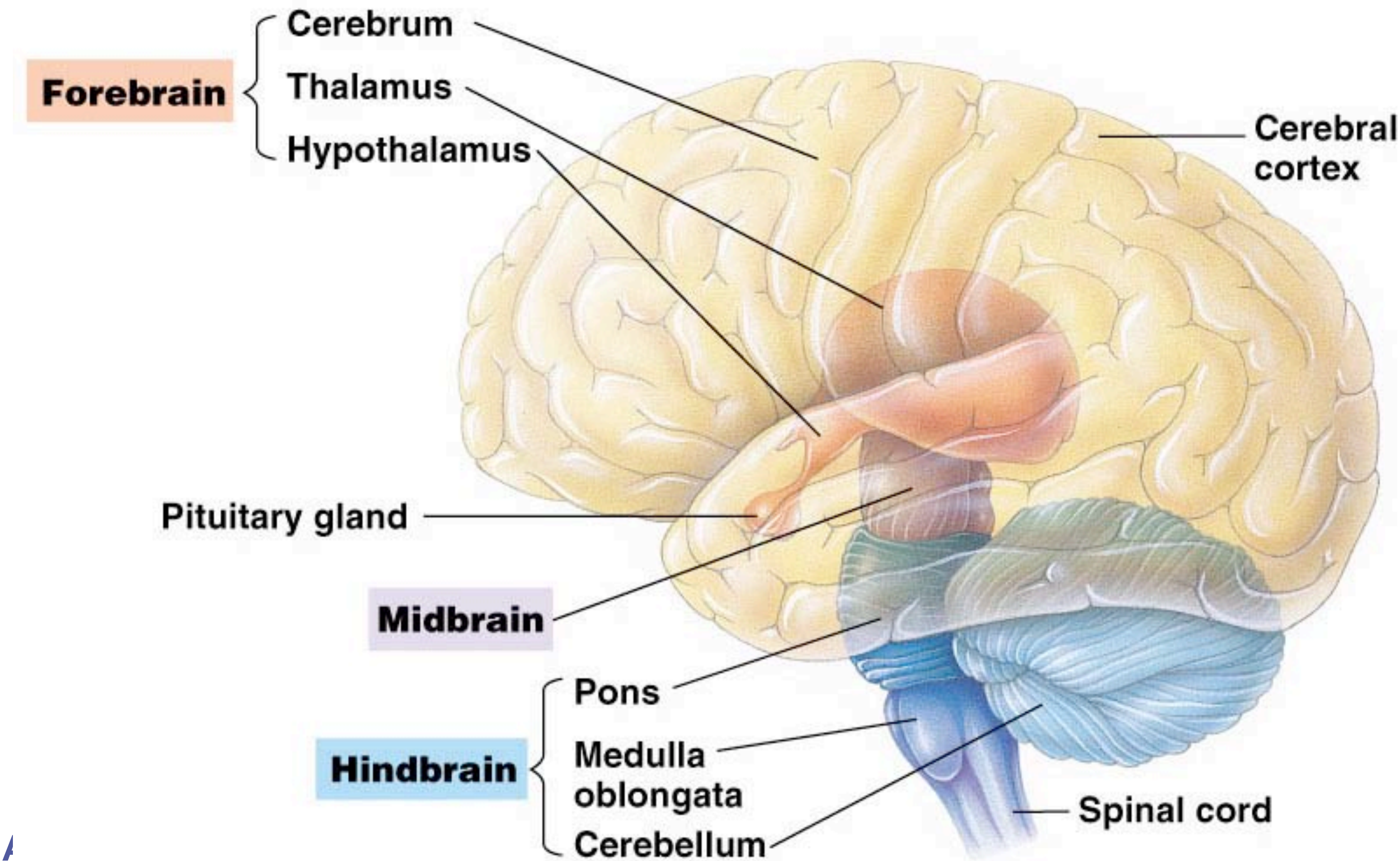
- rapid response
  - automated
- signal only goes to spinal cord
- adaptive value
  - essential actions
  - don't need to think or make decisions about
    - blinking
    - balance
    - pupil dilation
    - startle

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?

Any Questions??

Human brain

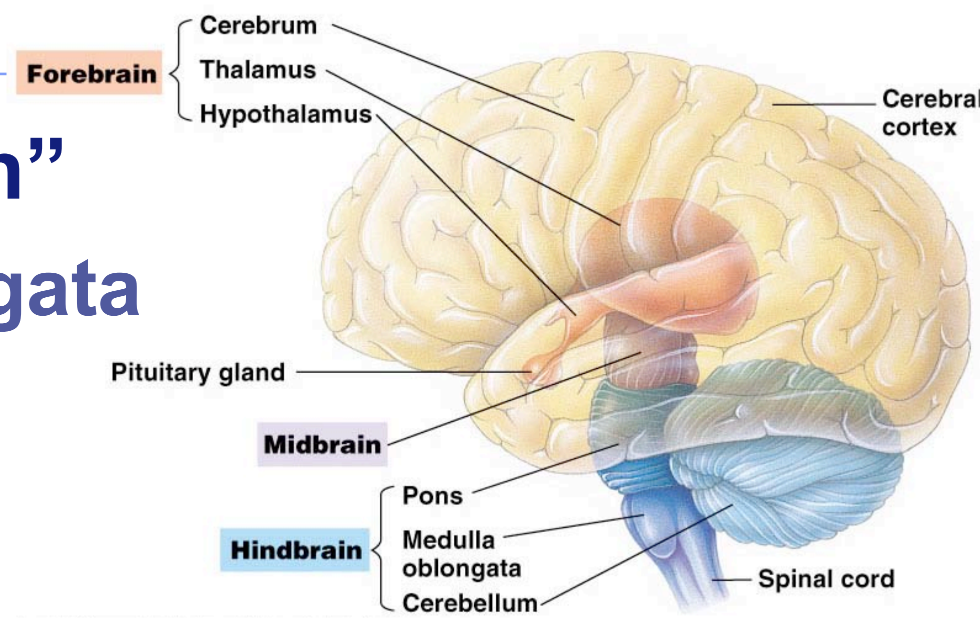

Forebrain
Cerebrum
Thalamus
Hypothalamus
Cerebral cortex
Pituitary gland
Midbrain
Hindbrain
Pons
Medulla oblongata
Cerebellum
Spinal cord

Evolutionary older structures

- Evolutionary older structures of the brain regulate essential autonomic & integrative functions
  - brainstem
    - pons
    - medulla oblongata
    - midbrain
  - cerebellum
  - thalamus, hypothalamus, epithalamus

Brainstem

- The “lower brain”
  - medulla oblongata
  - pons
  - midbrain
- Functions
  - homeostasis
  - coordination of movement
  - conduction of impulses to higher brain centers

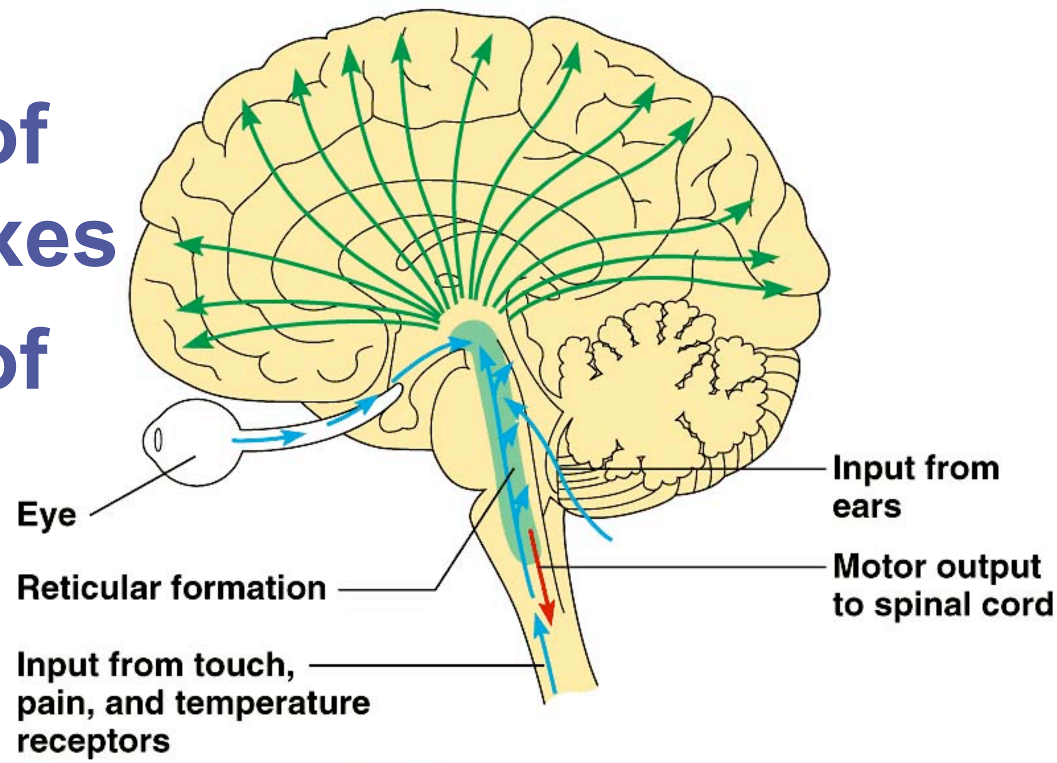


Medulla oblongata & Pons

- Controls autonomic homeostatic functions
  - breathing
  - heart & blood vessel activity
  - swallowing
  - vomiting
  - digestion
- Relays information to & from higher brain centers

Midbrain

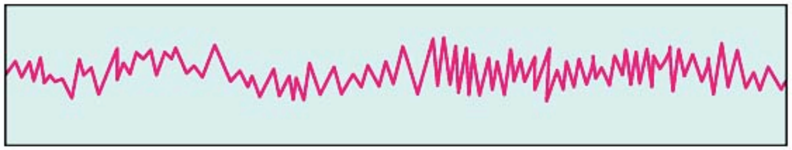
- Involved in the integration of sensory information
  - regulation of visual reflexes
  - regulation of auditory reflexes

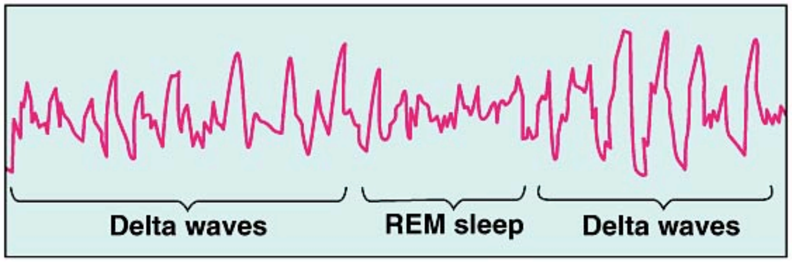


Reticular Formation

- **Sleep & wakefulness produces patterns of electrical activity in the brain**
  - recorded as an electroencephalogram (EEG)
  - most dreaming during REM (rapid eye movement) sleep


(b) Awake but quiet (alpha waves)

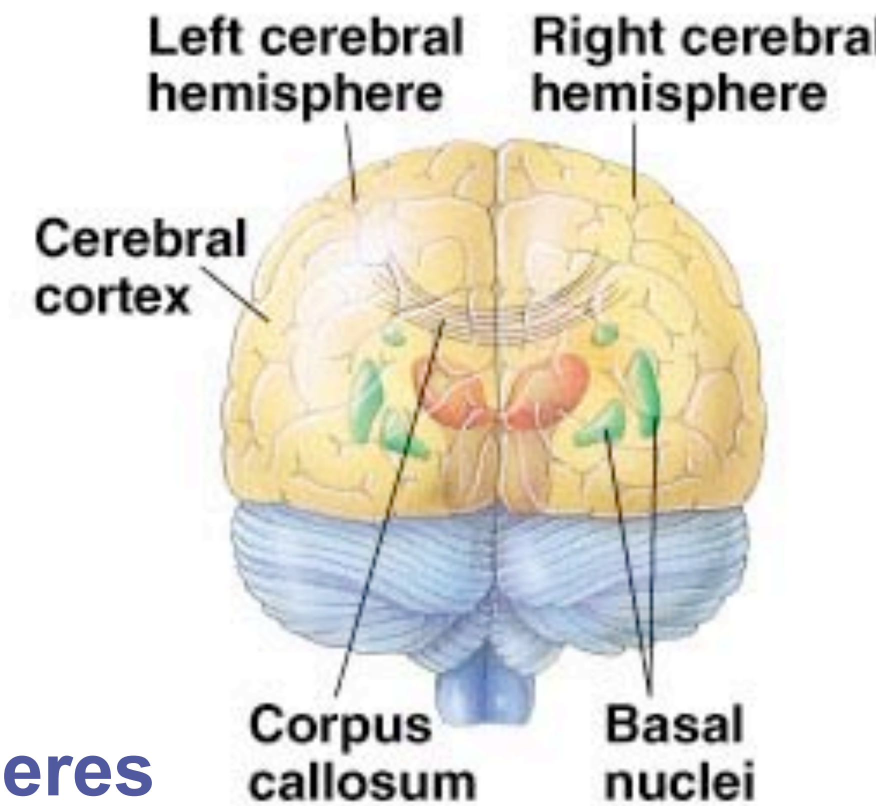

(c) Awake during intense mental activity (beta waves)



(d) Asleep

Cerebrum

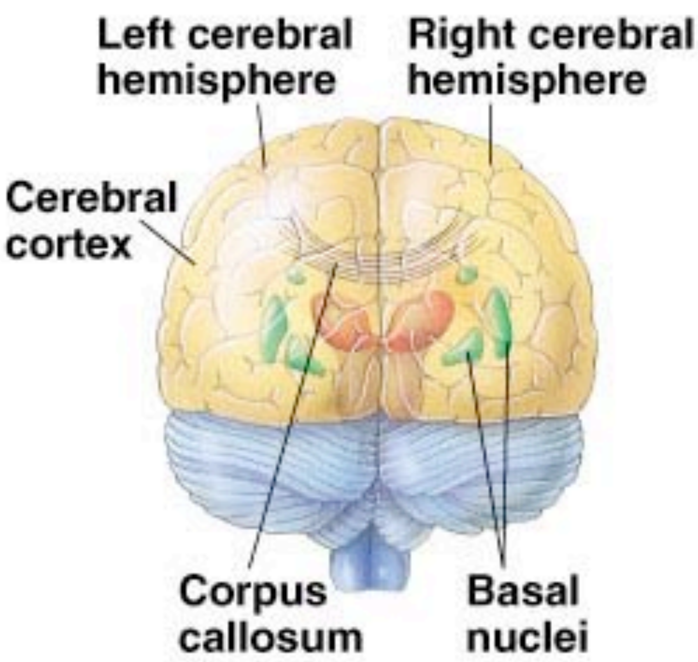
- Most highly evolved structure of mammalian brain
- Cerebrum divided
  - hemispheres
  - left = right side of body
  - right = left side of body
- Corpus callosum
  - major connection between 2 hemispheres



(a) Back of brain

Lateralization of Brain Function

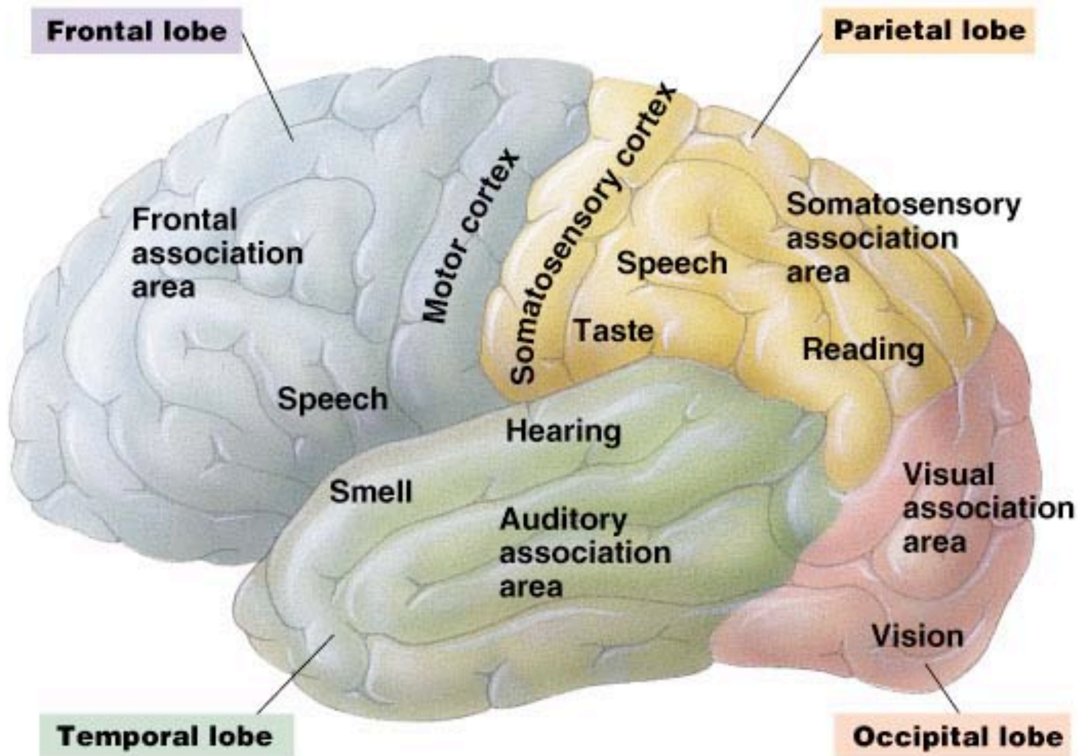
- **Left hemisphere**
  - language, math, logic operations, processing of serial sequences of information, visual & auditory details
  - detailed activities required for motor control
- **Right hemisphere**
  - pattern recognition, spatial relationships, non-verbal ideation, emotional processing, parallel processing of information



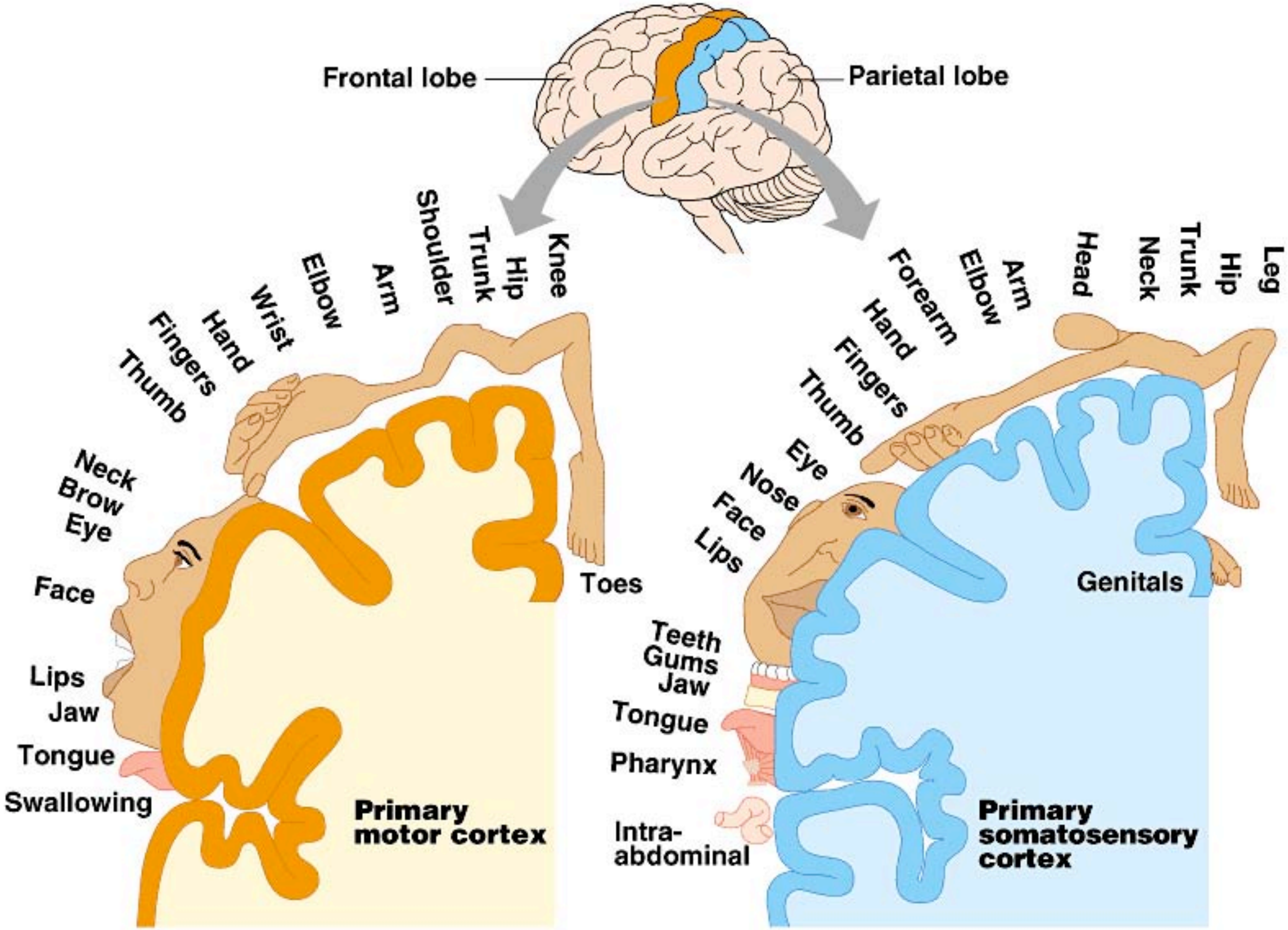
(a) Back of brain

Cerebrum specialization

- Regions of the cerebrum are specialized for different functions
- Lobes
  - frontal
  - temporal
  - occipital
  - parietal

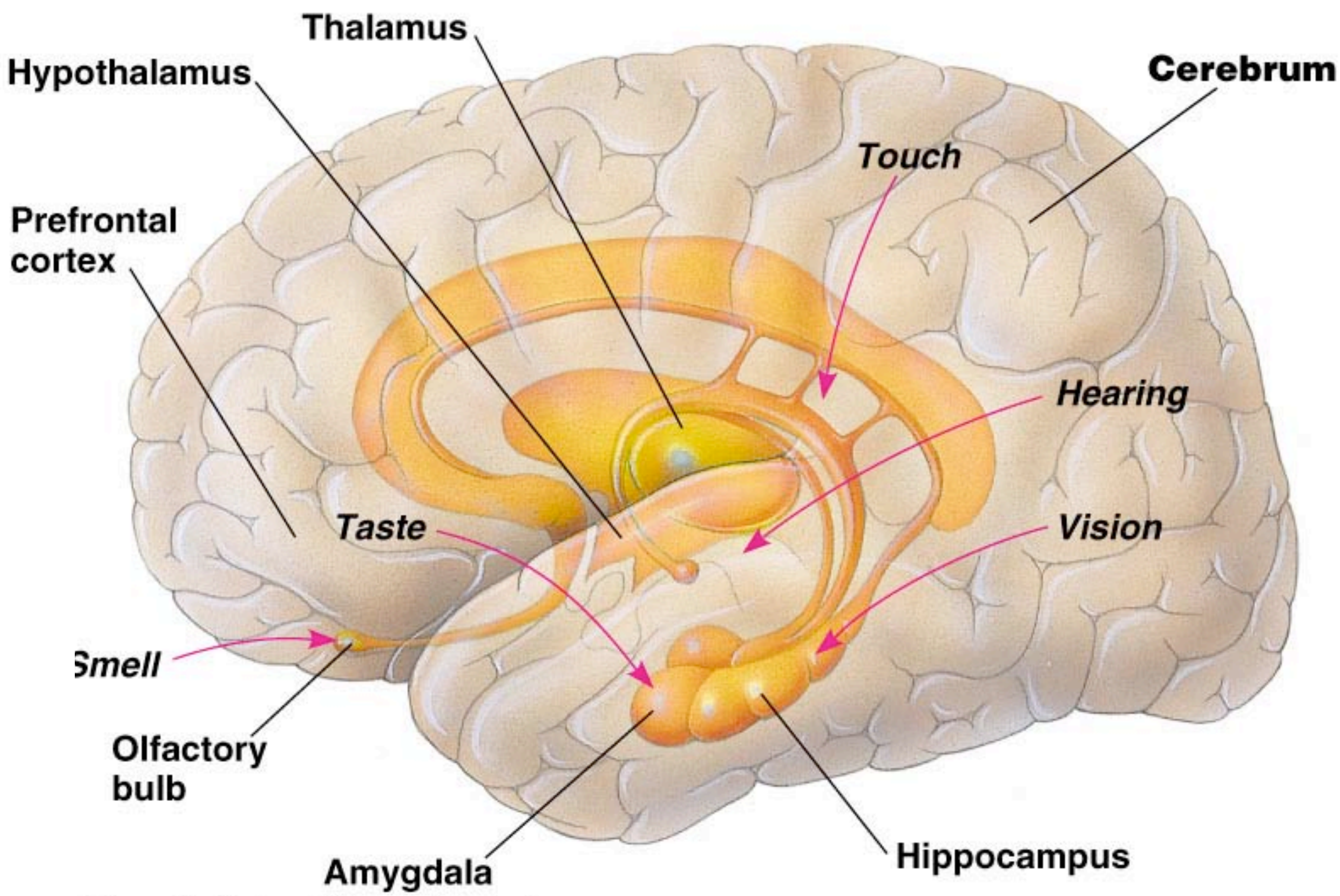


(b) Left side of brain


Frontal lobe
Parietal lobe
Toes
Knee
Hip
Trunk
Shoulder
Arm
Elbow
Wrist
Hand
Fingers
Thumb
Neck
Brow
Eye
Face
Lips
Jaw
Tongue
Swallowing
Primary motor cortex
Leg
Hip
Trunk
Neck
Head
Arm
Elbow
Forearm
Hand
Fingers
Thumb
Eye
Nose
Face
Lips
Teeth
Gums
Jaw
Tongue
Pharynx
Intra-abdominal
Genitals
Primary somatosensory cortex

Limbic system

Mediates basic emotions (fear, anger), involved in emotional bonding, establishes emotional memory



Amygdala involved in recognizing emotional content of facial expression

Any Questions??