Warm-up

- Objective:
  - Explain how membrane potentials arise from differences in ion concentrations between cells' content and the extracellular fluid.
- Warm-up:

Cells from this structure migrate to other parts of the embryo and eventually form the teeth and pigment cells in skin

1. Balstula
2. Gastrula
3. Morula
4. Neural tube
5. Notochord

Warm-up

- Objective:
  - Explain how membrane potentials arise from differences in ion concentrations between cells' content and the extracellular fluid.
- Warm-up:

How do action potentials relay different intensities of information?

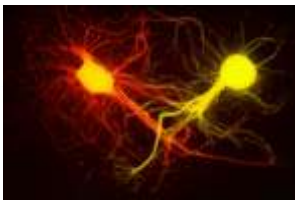
1. By changing the amplitude of the action potential
2. By changing the speed with which the impulse passes
3. By changing the frequency of the action potential
4. By changing he duration of the action potential
5. By reversing the direction of the action potential

Warm-up

- Objective:
  - Explain how membrane potentials arise from differences in ion concentrations between cells' content and the extracellular fluid.
- Warm-up:

The threshold potential of a particular membrane measures - 70mV at time zero. After 10 minutes, it measures -90mV. What is the best explanations for what happened to the membrane?

1. It became depolarized
2. The concentrations of Na+ and K+ became ballanced
3. The membrane hyperpolarized
4. The membrane hypopolarized
5. The membrane is more likely to pass an impulse at 90mV.



Chapter 48

Nervous System

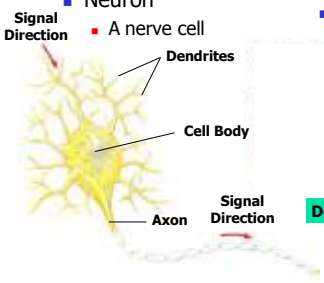
Why do animals need a nervous system?

What characteristics do animals need in a nervous system?

- Fast
- Accurate
- Reset quickly

Nervous System Cells

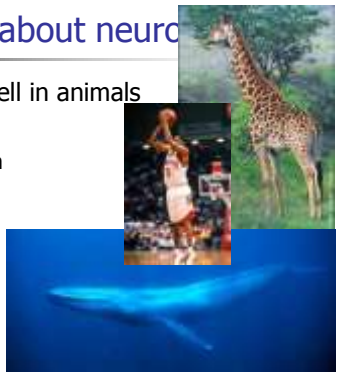
- Neuron
  - A nerve cell



- Structure fits function
  - Many entry points for signal
  - One path out
  - Transmits signal

Dendrite → cell body → axon

Fun facts about neuro



- Most specialized cell in animals
- Longest cell
  - Blue whale neuron
    - 10-30 meters
  - Giraffe axon
    - 5 meters
  - Human neuron
    - 1-2 meters

Transmission of a signal

- How is a signal transmitted down neuron?

Think Dominoes!

Transmission of a signal

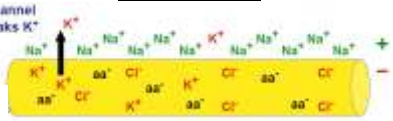
- Dominoes
  - Start the signal
    - Knock down line of dominoes by tapping 1st one
      - Send message
  - Propagate the signal
    - Do dominoes move down the line?
      - No, just a wave through them
  - Reset the system
    - Before you can do it again, have to set up dominoes again
      - Reset the axon

Transmission of a nerve signal

- Neuron has a 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 reset channels so neuron can react again

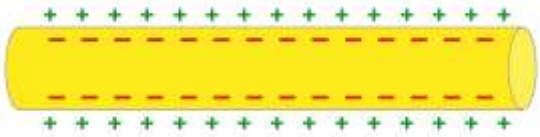
Cells: Surrounded by charged ions

- Cells live in a sea of charges ions
  - Anions (negative ions)
    - More concentrated within the cell
    - Cl-, charged amino acids
  - Cations (positive ions)
    - More concentrated in the extracellular fluid
    - K+, Na+

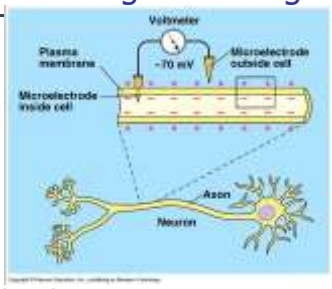


Cells have voltage

- Opposite charges on opposite sides of cell memebrane
  - Membrane is polarized
    - Negative inside; positive outside
    - Charge gradient



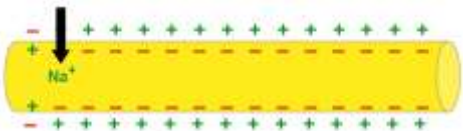
Measuring cell voltage



Unstimulated neuron= resting potential of -70mV

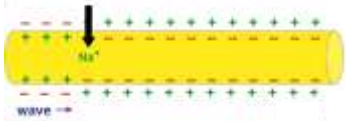
How does a nerve impulse travel?

- **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
    - Cells become depolarized



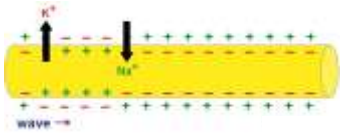
How does a nerve impulse travel?

- **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 the cell
    - "Wave" moved down neuron = "action potential"



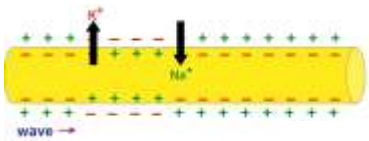
How does nerve impulse travel?

- **Reset**: 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



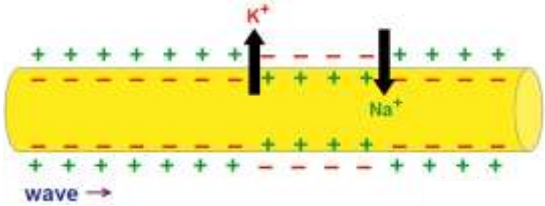
How does a nerve impulse travel?

- Combined waves travel down neuron
  - Wave of opening ion channels move down neuron
  - Signal moves in one direction →→→
    - Flow of K+ out of cell stops activation of Na+ channels in wrong direction



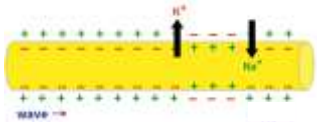
How does nerve impulse travel?

- Action potential propagates
  - Wave = nerve impulse, or action potential
  - Brain → fingertips in milliseconds!



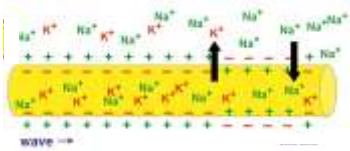
Voltage-gated channels

- 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



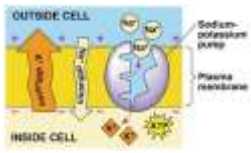
How does the nerve reset itself?

- After firing a neuron has to reset itself
  - Na+ needs to move back out
  - K+ needs to move back in
  - Both are moving against concentration gradients
    - Need a pump!

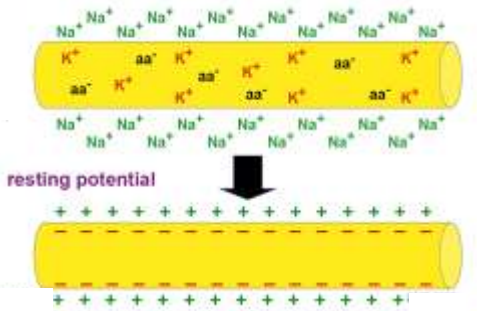


How does the nerve reset itself?

- Na+/K+ pump
  - Active transport in membrane
    - Requires ATP
  - 3 Na+ pumped out
  - 2 K+ pumped in
  - Resets charges across membrane

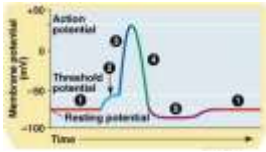


Neuron is ready to fire again

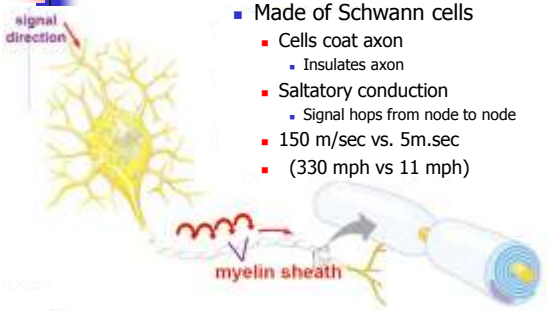


Action potential graph

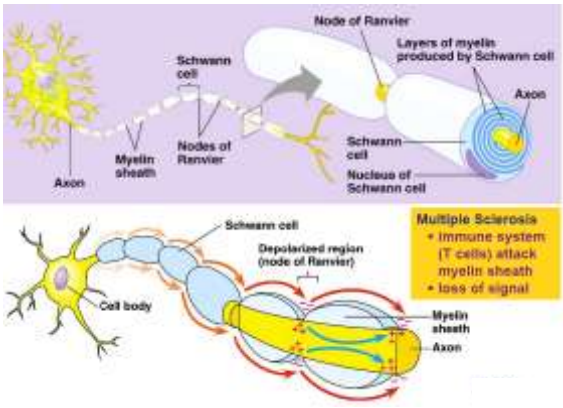
1. Resting potential
2. Stimulus reaches threshold potential
3. Na+ channels open; K+ channels closed
4. Na+ channels close; K+ channels open
5. Undershoot: K+ channels close slowly



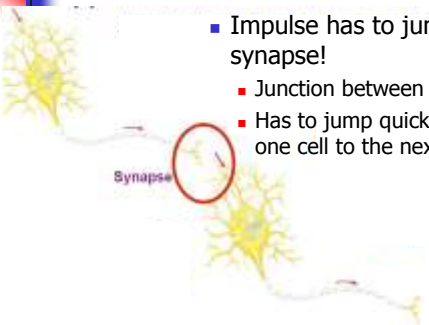
Myelin Sheath



- Made of Schwann cells
  - Cells coat axon
    - Insulates axon
  - Saltatory conduction
    - Signal hops from node to node
  - 150 m/sec vs. 5m.sec
  - (330 mph vs 11 mph)



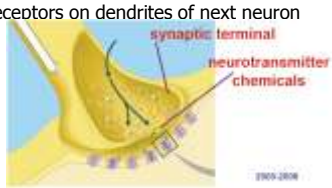
What happens at the end of the axon?

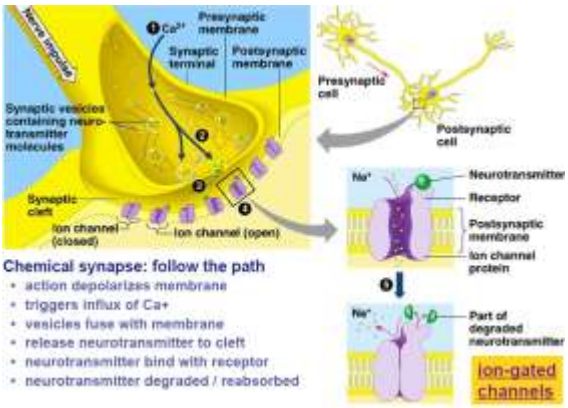


- Impulse has to jump the synapse!
  - Junction between neurons
  - Has to jump quickly from one cell to the next

Synaptic terminal

- Chemicals stored in vesicles
  - Release neurotransmitters
    - Diffusion of chemicals across synapse conducts the signal – chemical signal – across synapse
    - Stimulus for receptors on dendrites of next neuron



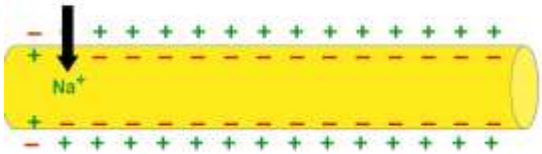


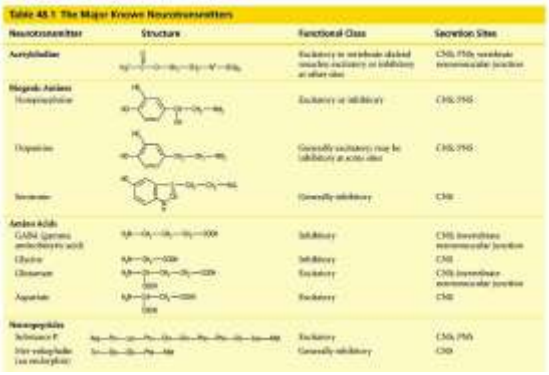
Chemical synapse: follow the path

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

Nerve impulse in next neuron

- Post-synaptic neuron
  - Triggers nerve impulses in next nerve cell
    - Chemical signal opens "ion-gated" channels
    - Na+ diffuses into a cell
    - K+ diffuses out of cell





Neurotransmitters

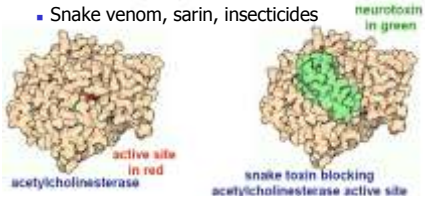
- Acetylcholine
  - Transmit signal to skeletal muscle
- Epinephrine (adrenaline) & norepinephrine
  - Fight or flight response
- Dopamine
  - Widespread in brain
  - Affects sleep, mood, attention & learning
  - Lack of dopamine in brain associated with Parkinson's disease
  - Excessive dopamine linked to schozophrenia
- Serotonin
  - Widespread in brain
  - Affects sleep, mood, attention & learning

Neurotransmitters

- Weak point of nerve systems
  - Any substances that affects the 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
  - Inhibitor = neurotoxins
    - Snake venom, sarin, insecticides



Simplest Nerve Circuit

- **Reflex, or automatic response**

- Rapid response
  - Automatic
- 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?

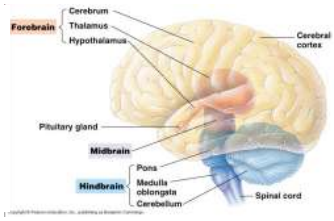
Human Brain

Evolutionary older structures

- Evolutionary older structures of the brain regulate essential autonomic & integrative functions
  - Brainstem
    - Pons
    - Medulla oblongata
    - Midbrain
  - Cerebellum
  - Thalamus, hypothalamus, epithalamus

Brain stem

- The "lower brain"
  - Medulla oblongata
  - Pons
  - Midbrain
- Functions
  - Homeostasis
  - Coordination of movement
  - Conduction of impulses to higher brain centers

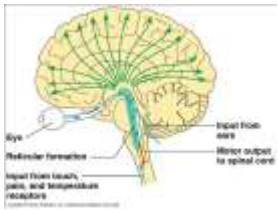


Medulla oblongata & pons

- Controls autonomic homeostasis
  - Breathing
  - Heart & blood vessels activity
  - Swallowing
  - Vomiting
  - Digestion
- Relays information to & from higher brain centers

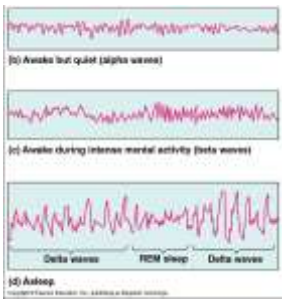
Midbrain

- 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 brain
  - Recorded as an electroencephalogram (EEG)
  - Most dreaming during REM (rapid eye movement)



Cerebrum

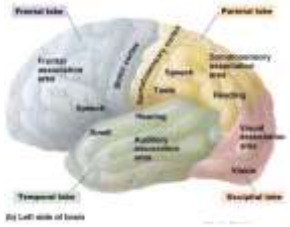
- Most highly evolved structure of mammalian brain
- Cerebrum divided
  - Hemispheres
  - Left = right side of body
  - Right = left side of body
- Corpus callosum
  - Major connection between 2 hemispheres

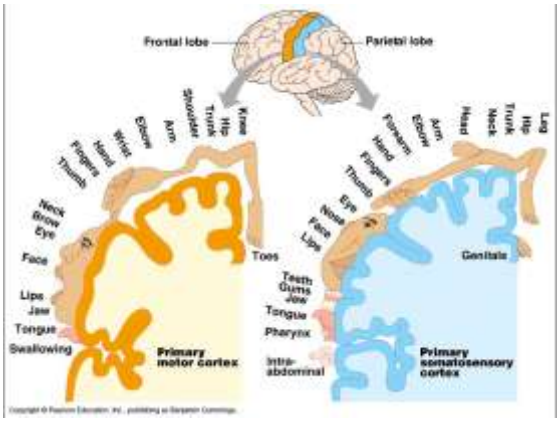
Lateralization of Brain Function

- Left hemisphere
  - Language, math, body operation, processing of serial sequences of information, visual & auditory details
  - Detailed activities required for motor control
- Right hemisphere
  - Patterns of recognition, spatial relationships, non-verbal ideation, emotional processing, parallel processing of information

Cerebrum specialization

- Regions of the cerebrum are specialized for different functions
- Lobes
  - Frontal
  - Temporal
  - Occipital
  - Parietal





Limbic system

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

Amygdala: Involved in redognizing emotional content in facial expression