COGS 17

Week 3

Structure + Function of Cells in Nervous System

Reminders!

Homework Problem Sets

- Homework #2 is due this WED 11:59 PM!
- No late homeworks accepted

Midterm

- Midterm 1 is Tues, April 22 from 3-30:4:50 PM (8 days!)
- Can be taken online or in class
- Will be proctored in class

Extra Credit

- SONA
- Mnemonics
- Do all HWs → 4 extra credit points

For Slides + Problem Sets

Link:

https://drive.google.com/drive/folders/1DlvXFvEKxhF3ykEaK2_jBsNUgGOb8fS3?usp=drive_link

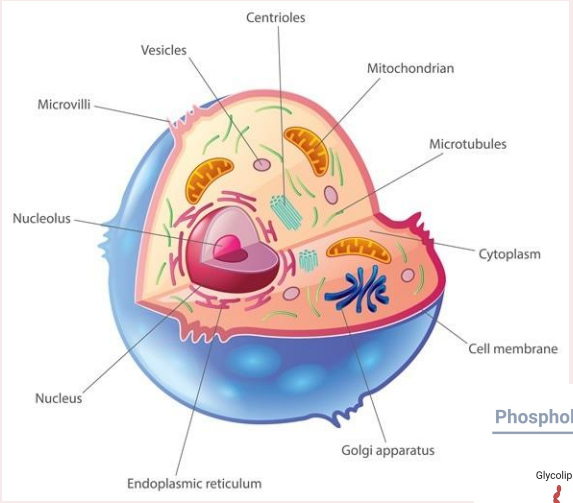
Common Features of Cells

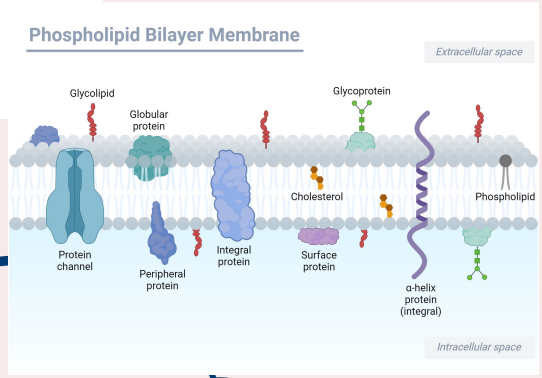
Soma
- Cell body

Cytoplasm
- Fluid within a cell
- Maintains structure

Extracellular Fluid
- Fluid outside of a cell

Cell Membrane
- Semi-permeable bilayer composed of lipids and proteins





Important Organelles

Nucleus

- Site for DNA storage
- “Control center”

Ribosomes

- Site of protein synthesis
- Receives mRNA from nucleus

Mitochondria

- Powerhouse of the cell!!
- Produces ATP that supplies energy for cell processes

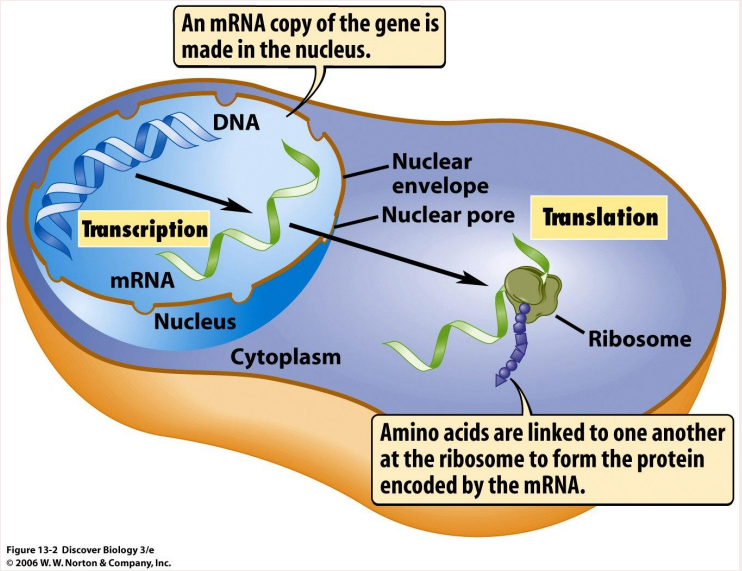


Figure 13-2 Discover Biology 3/e

Cells of the Nervous System

Neurons

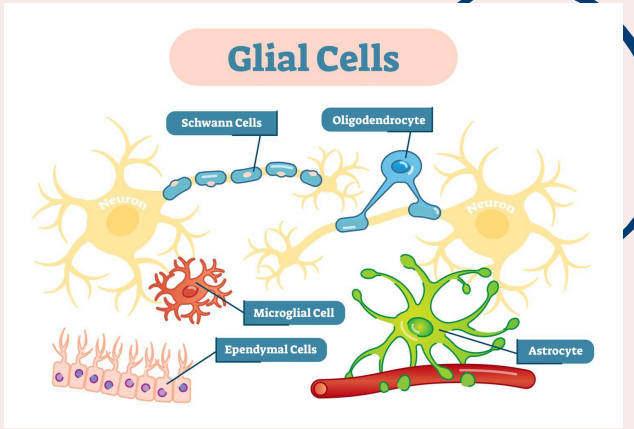
- Responsible for information transfer via modified processes and the membrane

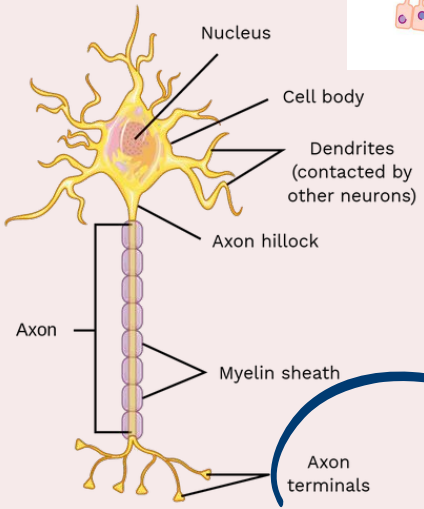
Glia Cells

- Non-neural cells of the Nervous System
- Do NOT participate in info transfer

- “Glia” = “glue”, holding the Nervous System together both chemically and physically

- Can regenerate unlike most neurons
- Make up 50% of the brain by weight





Types of Glial Cells

Astrocytes

- Provides nutrients, recycles NTs, maintains the BBB, and numerous other functions

Microglia

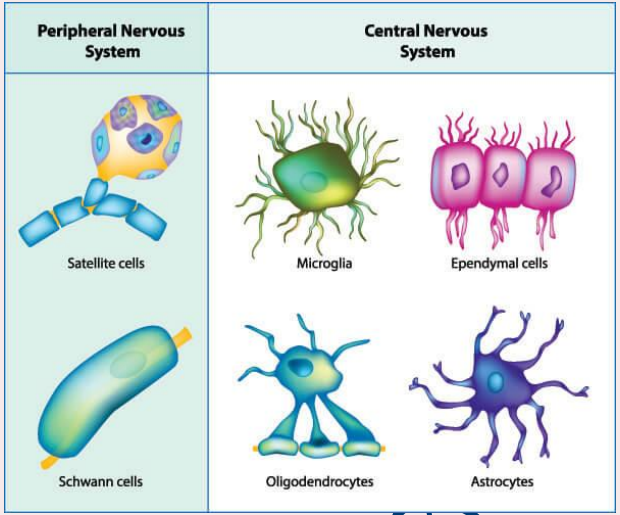
- White blood cells of the nervous system
- Removes toxins from the brain, repairs damaged neurons

Ependymal Cells

- Lines ventricles and acts as a layer between the ventricular cavities and the parenchyma
- Secretes CSF into the ventricles

Oligodendrocytes

- Surrounds axons in a process called myelination in the CNS
- Schwann Cells: specialized Oligos which myelinate neurons of the PNS



Neurons

Specialized cells for information transfer

Dendrites

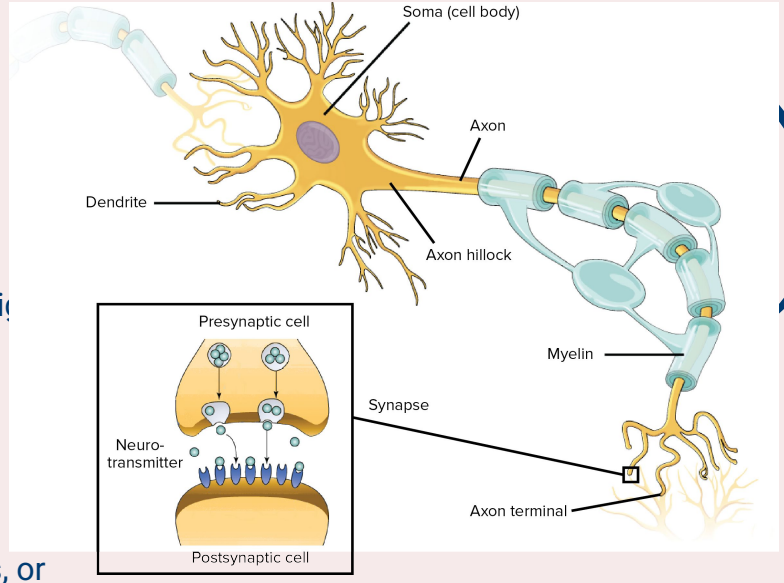
- Spiny protrusions from the Soma which receive incoming si
- Site of postsynaptic membranes

Axons

- Long fibers which reach out to other neurons
- Carries outgoing signals
- Terminates in Presynaptic Terminals (AKA terminal buttons, or end bulbs) which releases NTs into Synaptic Cleft

Receptor Sites

- Specialized areas which interact with NTs from other neurons



The Nerve Impulse

Nature seeks a balance, or equilibrium

Concentration Gradient

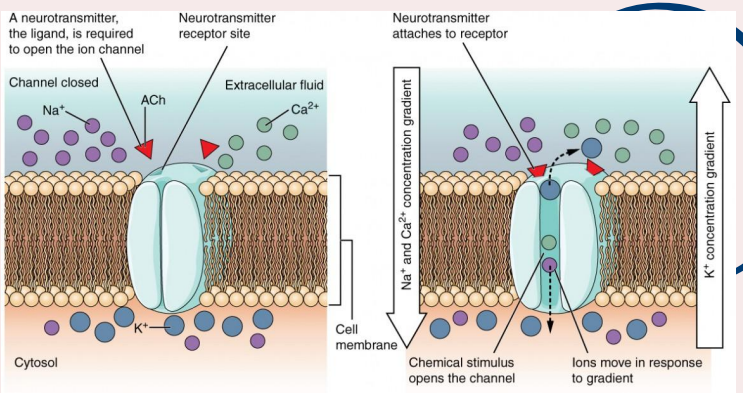
- Molecules in areas of greater concentration will diffuse to areas of lesser concentration (high → low)

Electrical Gradient

- Like a magnet, the same charges repel whereas opposite charges attract
  = Electrostatic Pressure

<u>Selective Permeability</u>

- Bilayers are typically impermeable to charged ions and large molecules (i.e. glucose)
- REMEMBER: Na+, K+, Ca++, Cl-



Resting Potential

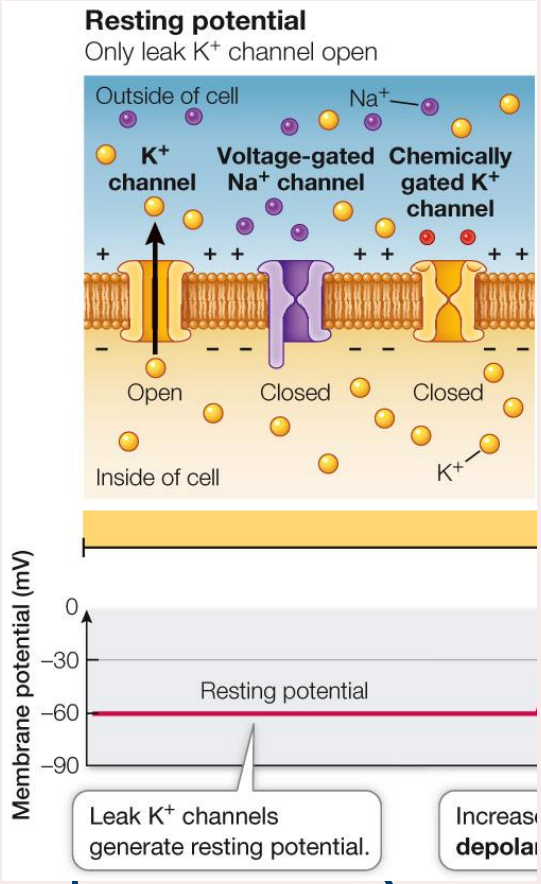
Highly polarized – ready to "fire"

Membrane Potential

- Diff in charge between the inside and outside of the cell, measured in millivolts (mV)

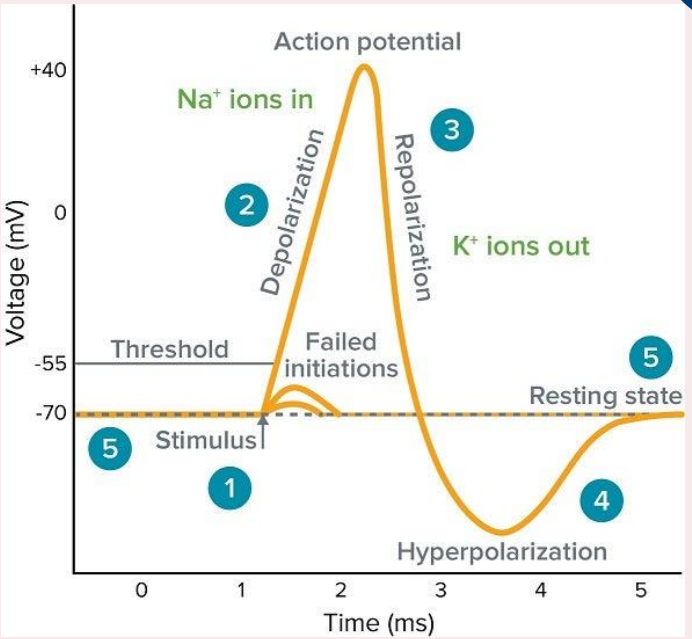
Resting Potential

- Most neurons have a RP of -70 mV

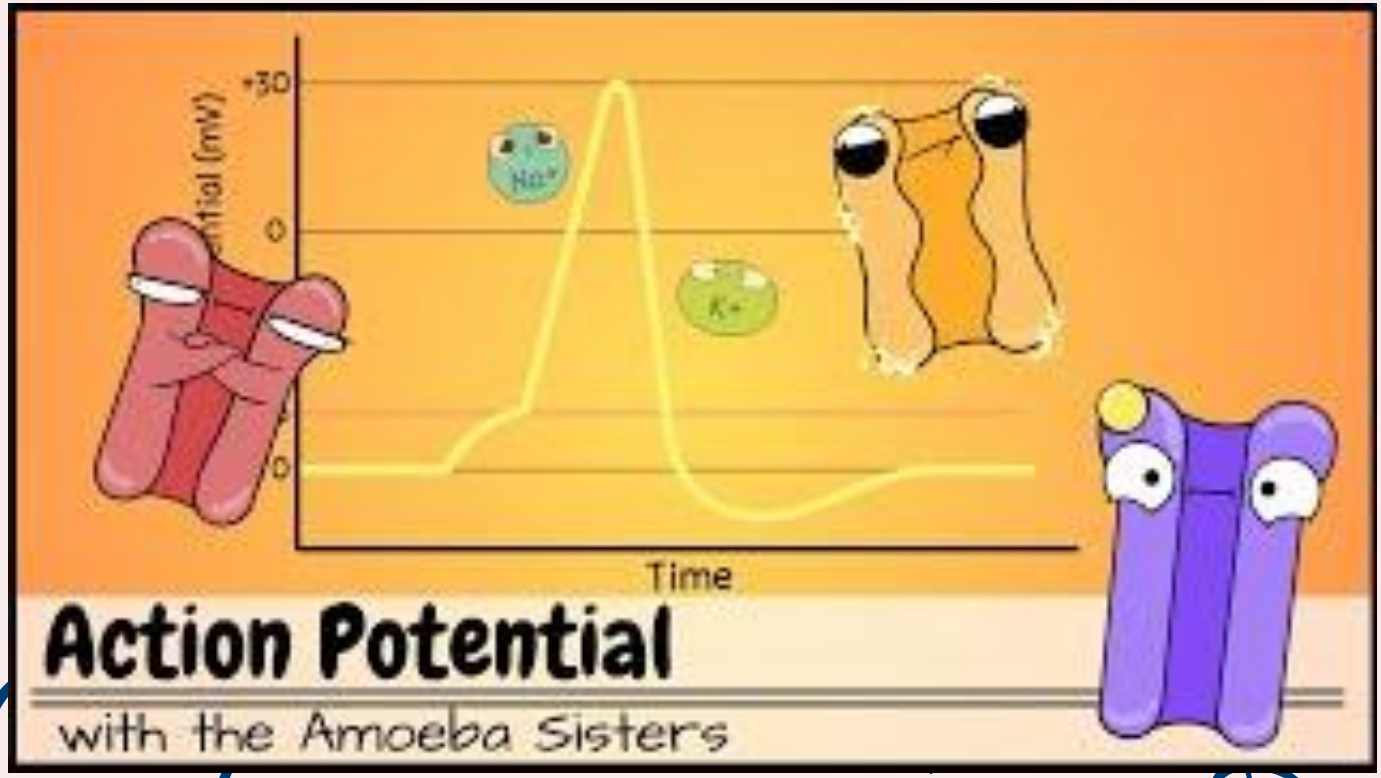


Action Potential (AP)

1. Na+ Gates at the Axon Hillock open
2. Na+ enters the cell, resulting in a local Depolarization (+50 mV)
    a. More positive inside the cell
3. Local polarity change causes the next Na gates to open and Na+ enters cell, previous Na+ gates close
4. The K+ Gates at Hillock open, K+ exits cell as a result of the intracellular positive charge, resulting in a local Re-Polarization (-50 mV)
5. Same repeated process occurs along the axon
6. When “Spike” of Depolarization reaches the terminal, Ca++ enters cell & NT is released



Action Potential (AP)



Restoring the Resting Potential

Sodium/Potassium Pump

- Requires ATP
- Establishes resting potential by transporting 3 Na+ out and 2 K+ in

Calcium Pump

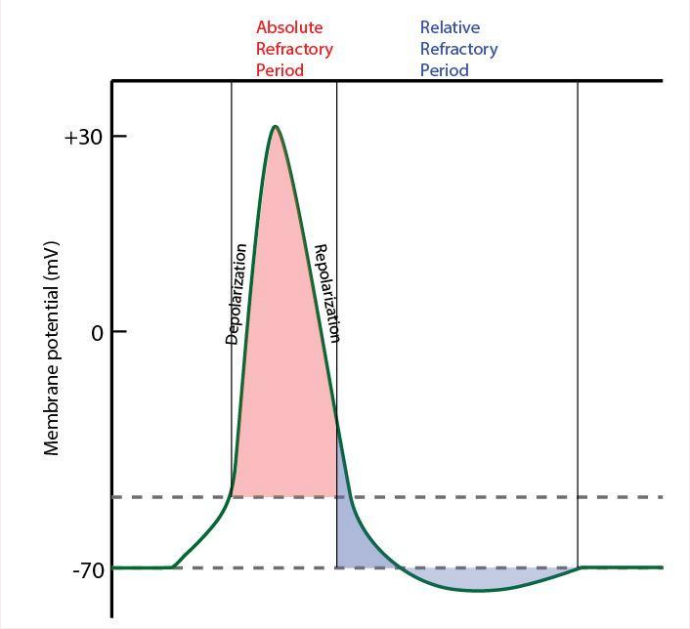
- Requires ATP
- Ejects Ca++ from Terminal

Refractory Period

- Cell cannot fire while re-polarizing

All-or-None Law

- AP has same amplitude and velocity, amount of NT released is fixed



Myelination

Glia Cells

- Oligodendrocytes are wrapped around the axon, with gaps in between called the “Nodes of Ranvier”

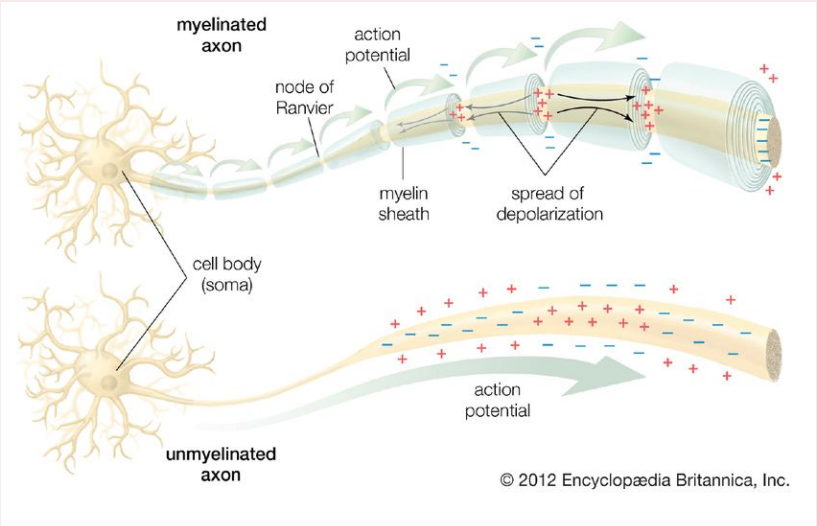
Ionic Conduction

- Ions flow across membrane
- Slow, but stays strong

Electrical Conduction

- Electricity flows through axon under “insulation”
- VERY fast, but decays over distance

Overall, myelinated axons show Saltatory (“Jumping”) Conduction

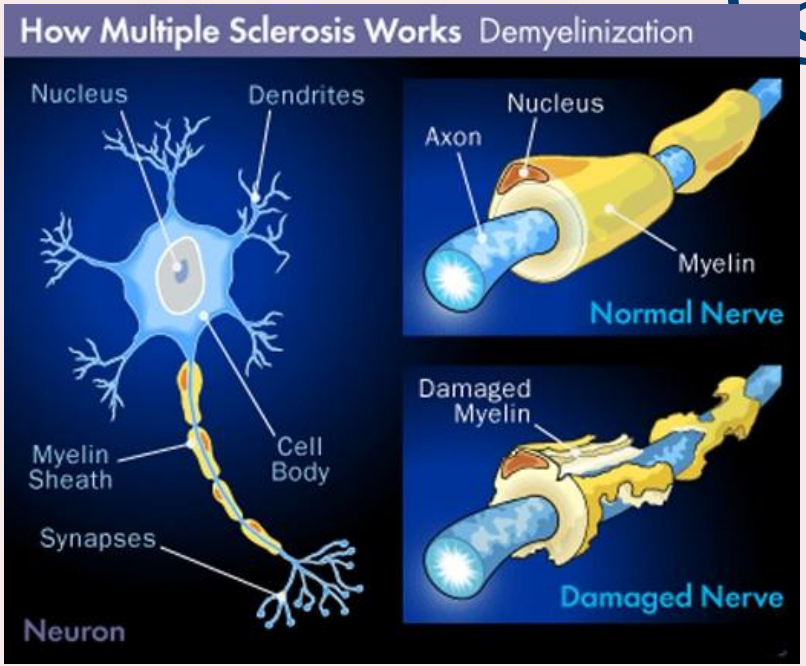


Multiple Sclerosis

Has to do with myelin, not the neuron itself

Characterized by damaged myelin that degenerates gradually

Damaged nerves cannot carry messages



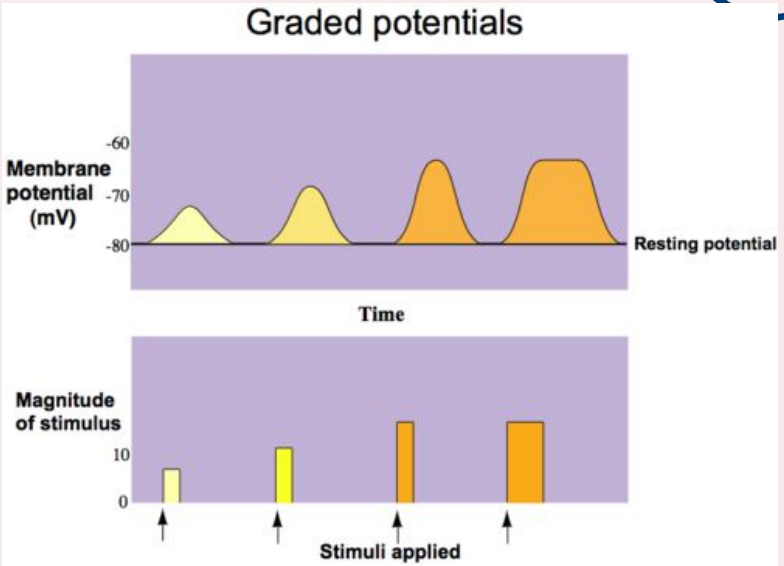
Graded Potentials

Not all neurons show APs

Cells that fire "Graded Potentials" may release MORE or LESS NTs

Ex. Hair Cells that contain auditory receptors

- Soft sound, cilia move a little → a little NT is released
- Loud sound, cilia move a lot → a lot of NTs are released



The Synapse

Presynaptic cell + Synaptic Cleft + Postsynaptic cell = The Synapse

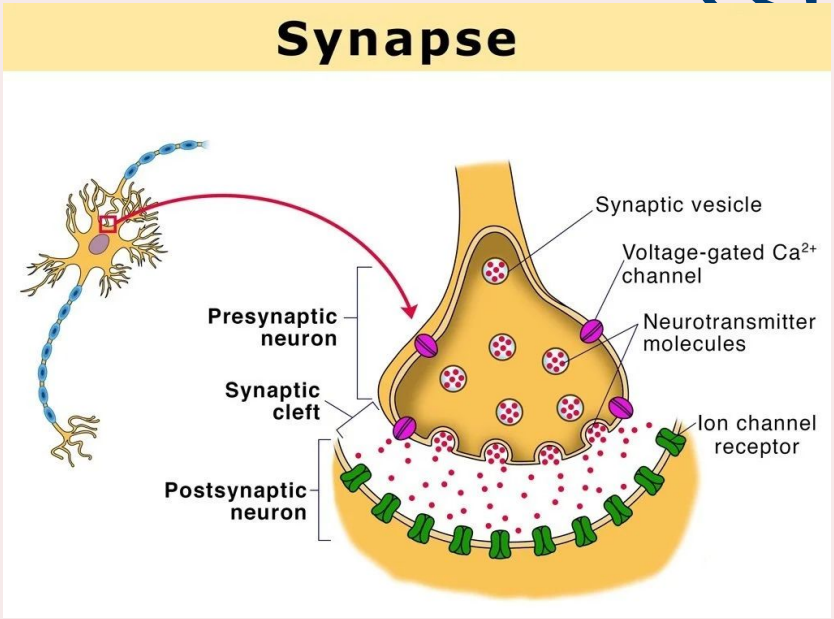
Presynaptic cells release NTs into the cleft via Exocytosis

- NTs are packaged into vesicles

Influx of Ca initiates exocytosis

- Ca opens the Fusion Pore, which binds vesicles to the presynaptic cellular membrane

Following exocytosis, NTs passively diffuse across the synaptic cleft and binds to NT-specific receptor sites on postsynaptic neurons



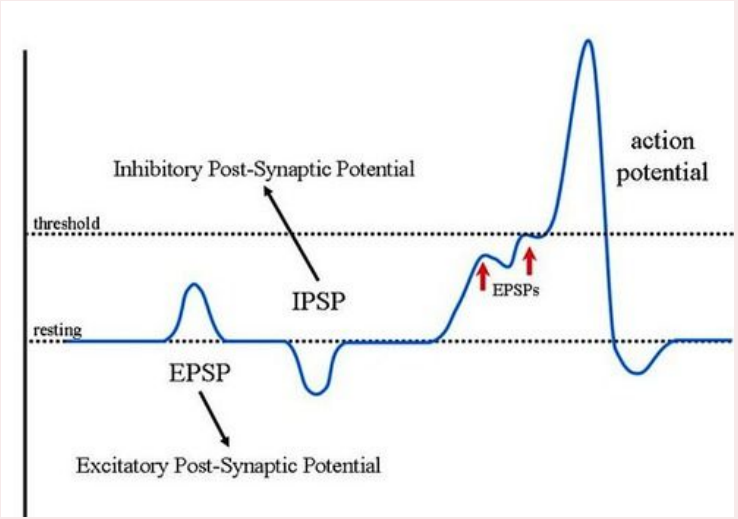
Postsynaptic Polarity

EPSP

- Cell becomes HYPO-polarized (more positive)
- Membrane potential also rises, increasing likelihood of initiating an AP

IPSP

- Cell becomes HYPER-polarized (less positive)
- Membrane potential decreases, further away from threshold makes it less likely to fire an AP



Summation

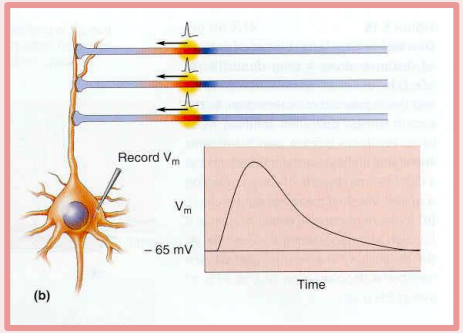
Multiple excitatory and inhibitory inputs converge on each cell

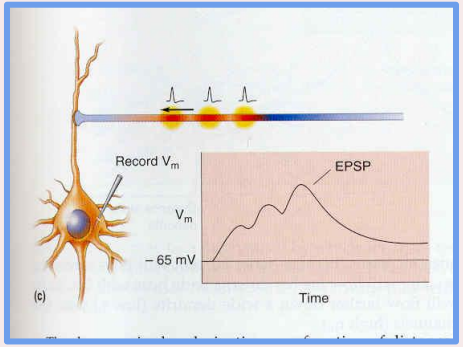
Temporal

- When one (or more) cells repeatedly stimulate another in rapid succession

Spatial

- When multiple cells converge on a single cell at the same time





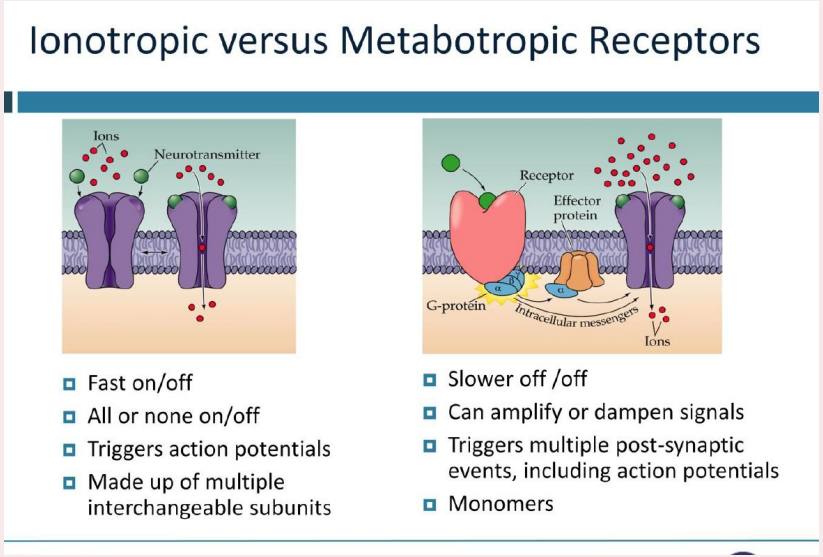
Postsynaptic Mechanisms

Ionotropic

- Directly affects ion gates
- Rapid and Short-lived responses
- Best for sending info about changing inputs

Metabotropic

- Causes metabolic changes in Postsynaptic cell
- Activation of G-protein and second messenger
- Slower but long-lasting responses



Neurotransmitter Examples w/ Functions

Neurotransmitter	Functions
Acetycholine (Ach)	• All neuro-muscular junctions • Cortical arousal
GABA	• Most common inhibitory NT • Regulate anxiety
Glutamate	• Most common excitatory NT • Learning • Perception • Schizophrenia
Serotonin (5HT)	• Often acts as a neuromodulator • Mood regulation, sleep, perception
Dopamine	• Reinforcement • Attention • Motor control
Norepinephrine	• Arousal • Attention
Epinephrine (adrenalin)	• Arousal • Attention
Substance P	• Pain (damage, itch, extreme temperatures, etc)
Endorphins	• Counter effects of Substance P
Hormones	• Testosterone, estrogen, cortisol, oxytocin, endorphins, etc

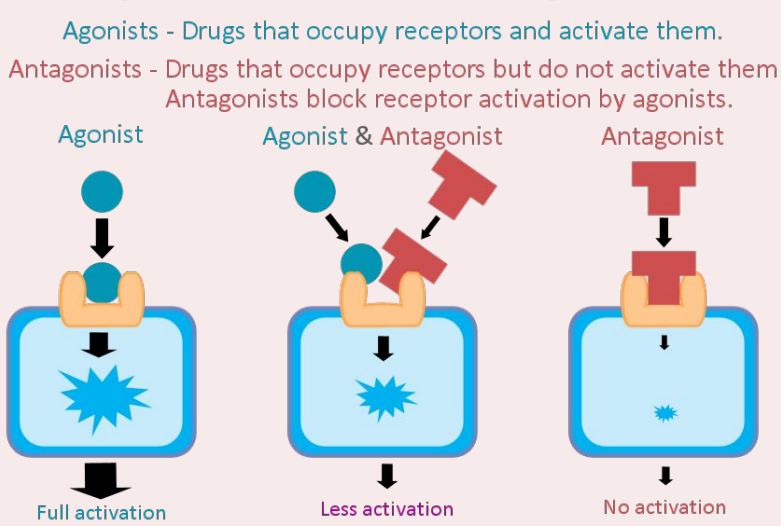
Agonists vs. Antagonists

Agonists → Increases effect of a NT

- Ex. Acetylcholinesterase
  - Enzyme which breaks down ACh in the cleft
- Ex. Black Widow Spider venom causes massive release of NT (ACh)
- Ex. Serotonin Reuptake
  - Prosac (antidepressant): serotonin reuptake inhibitor (SSRI), increasing NT's duration in the cleft

Antagonists → Decreases or inhibits effect of a NT

- Ex. Reserpine prevents NTs from being packaged into vesicles



Other Factors affecting Cell Function

1. Activation of DNA sequences initiated the production of proteins for structural and chemical changes within cell
2. Repeated activity leads to more dendritic spines and more receptor sites (# of receptor sites)
3. Receptor Sites can be blocked by NT mimics that do not readily detach
    a. Ex. LSD binds to Serotonin sites
4. Some NTs may require Hours/Days to replenish
    a. Carried by Kinesin molecules (walk along micro-tubules from soma to terminal)
5. Some NT precursors can pass the BBB and be used as medication (Ex. L-DOPA)

Exceptions: Receptor Sites on PRE-synaptic Terminal

- Auto-Receptors
    - Some axons have receptor sites for their own NT (usually inhibitory)
    - This acts as a negative feedback loop which prevents NT release if there is already a lot of the specific NT in the cleft
- Axoaxonic Synapses (Axon to Axon)