Section 2
Cells

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COGS 17 A05

04/14/25

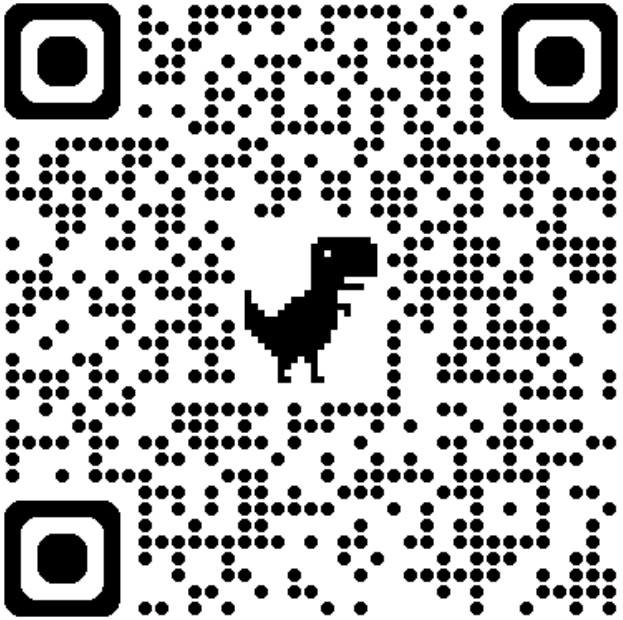
Notice

MIDTERM I (125 Points)– Next Tue!

3:30-4:50 pm (80 minute)

Exam Online

For section slides:



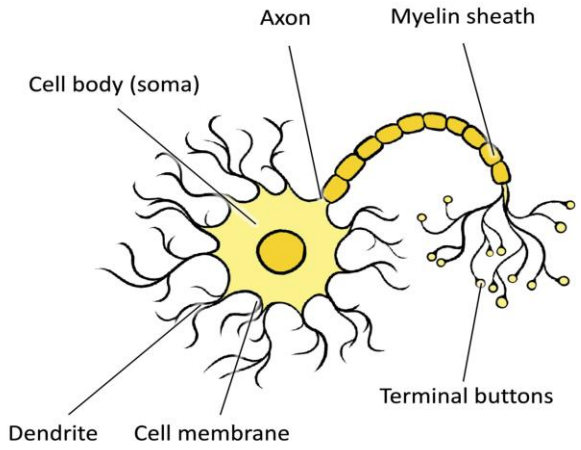
Common features of Cells

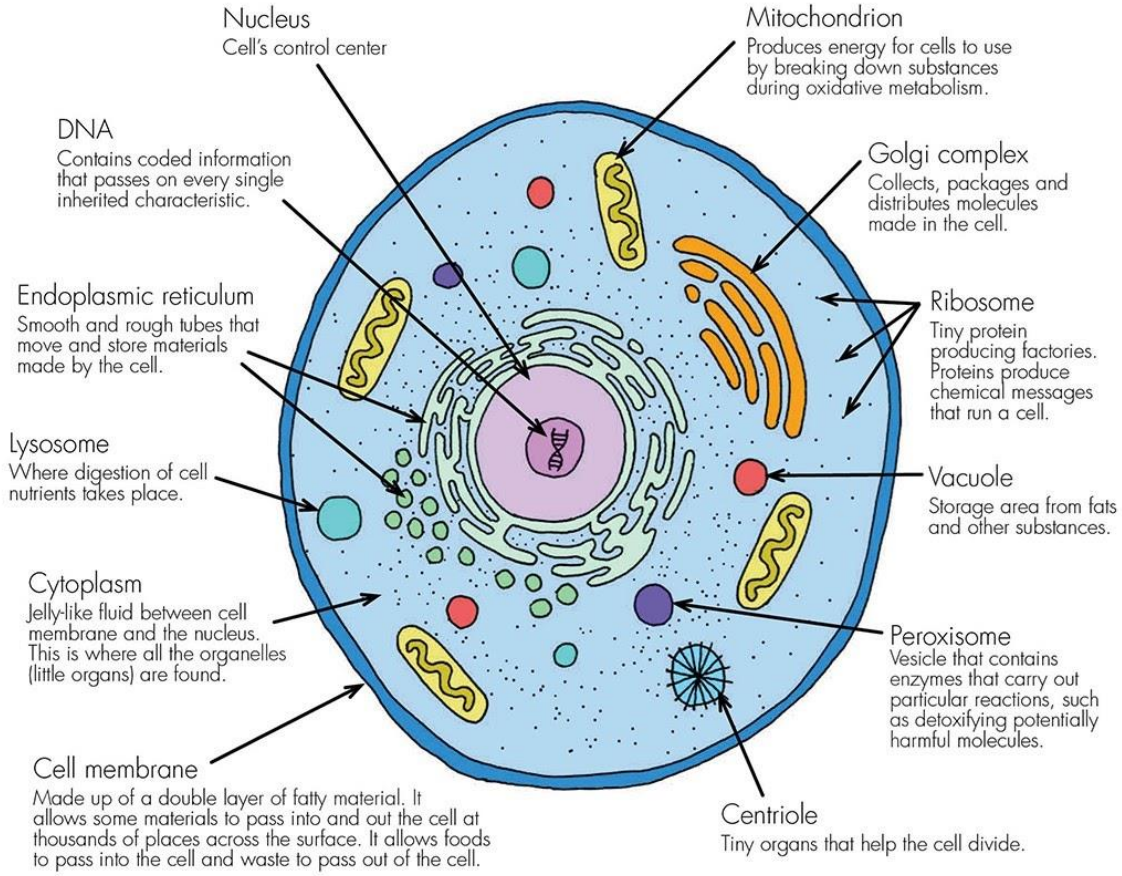
- Soma
  Fancy word meaning “cell body”

- Cytoplasm
  Fluid within a cell

- Extracellular Fluid
  Fluid outside of a cell

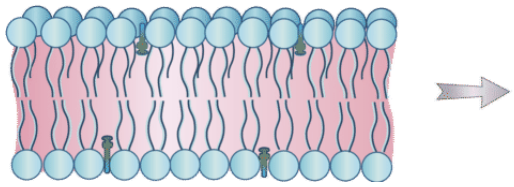
- Cell Membrane
  A double layered wall consisting of lipids (fat molecules)





Phospholipid bilayer **Phospholipid molecule**

Double Lipid membrane



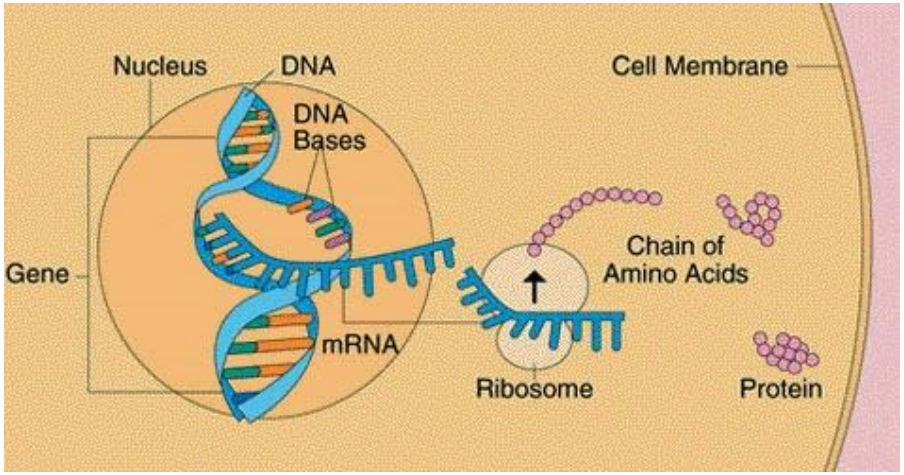
Stay away from water!

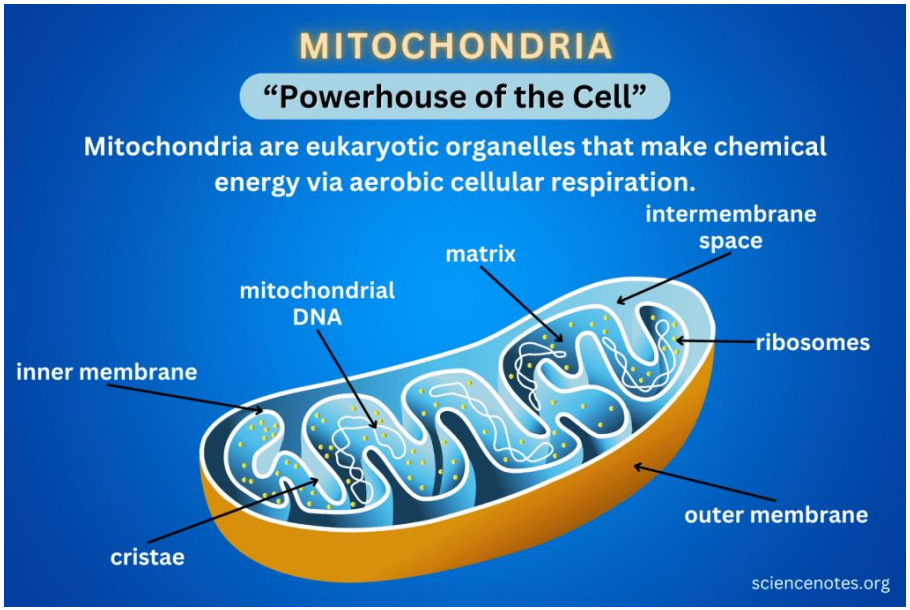
Important Organelles to Remember

- Nucleus
  An inner “control center” where **DNA** is stored

- Ribosomes
  Small protein producing factories

- Mitochondria
  The “powerhouse of the cell”





Specialized Cells of the Nervous System

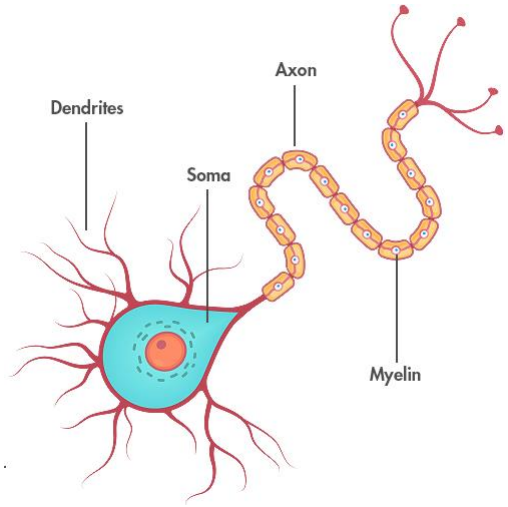
2 Types of Cells

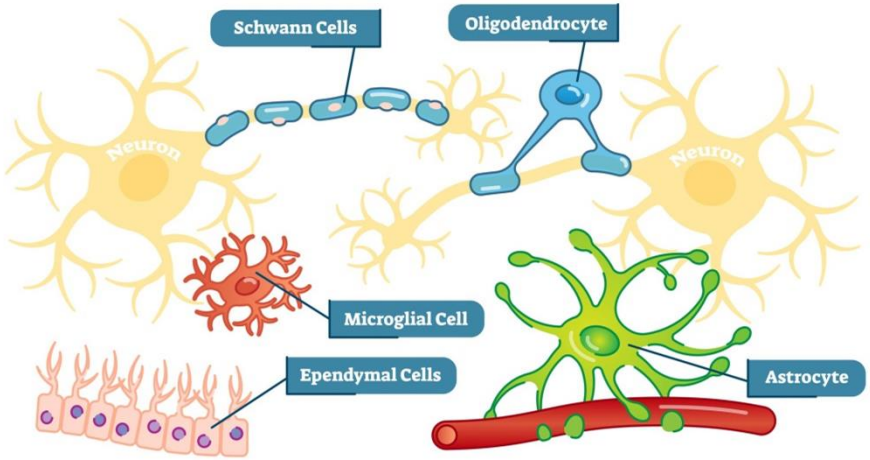
- Neurons
  Cells that are specialized for Information Transfer via **Processes** and **Membrane**

- Glia Cells
  Have many functions but do not participate in Information Transfer

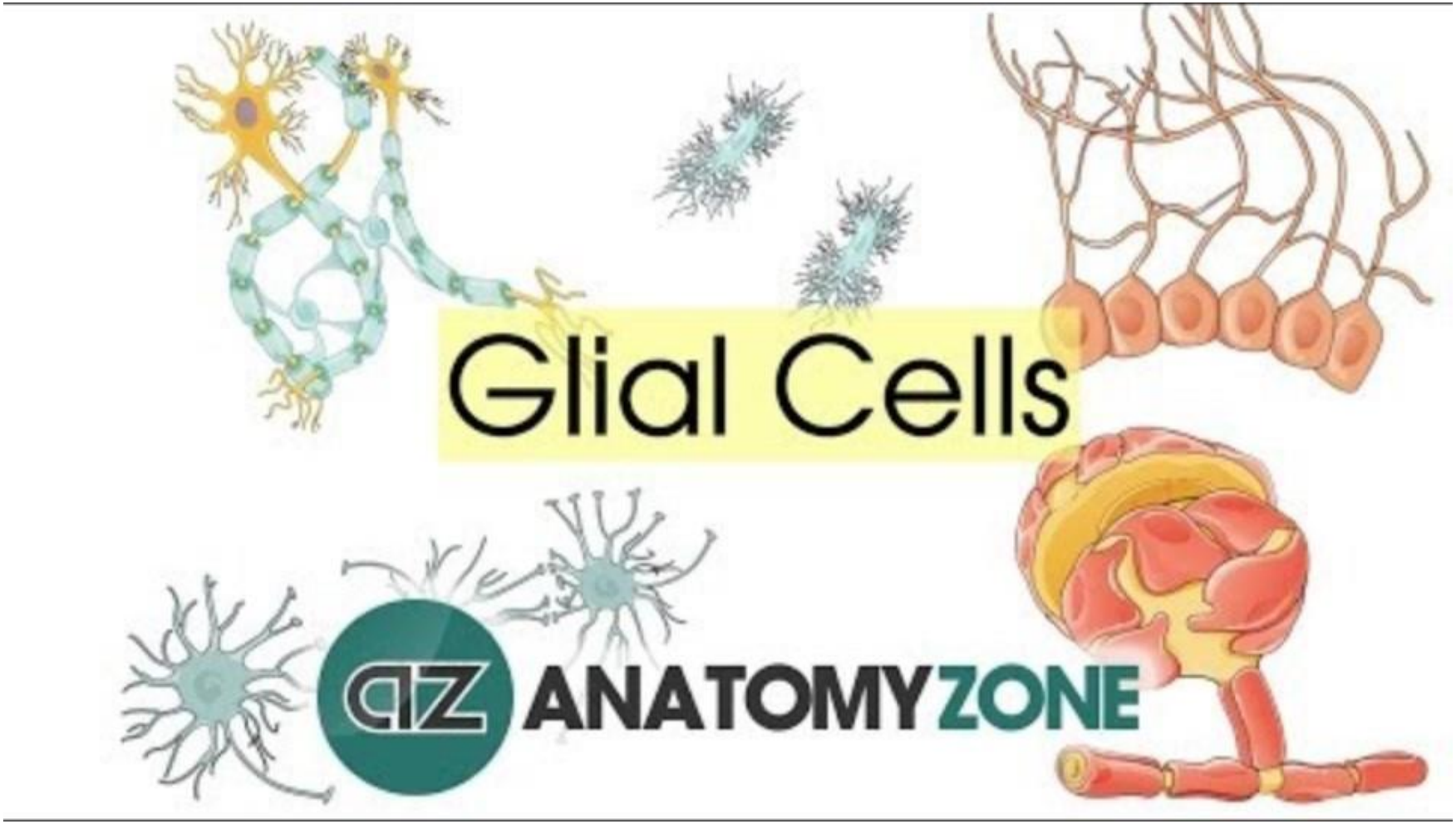
  "Glia" meaning "Glue" which holds the nervous system together, both physically and chemically, to support Neurons

  A lot smaller than neuron (1/10 size), but greater in amount (x10 times as many), takes up 50% of brain by weight





Different Glia Cells



Different Glia Cells

- **Radial Glia**

Guide the migration and growth of neurons during fetal development

- **Ependymal Cells:**

Lines ventricles and secretes CSF into the Ventricles

- **Oligodendrocytes**

Surrounds axons in a process called myelination in the CNS

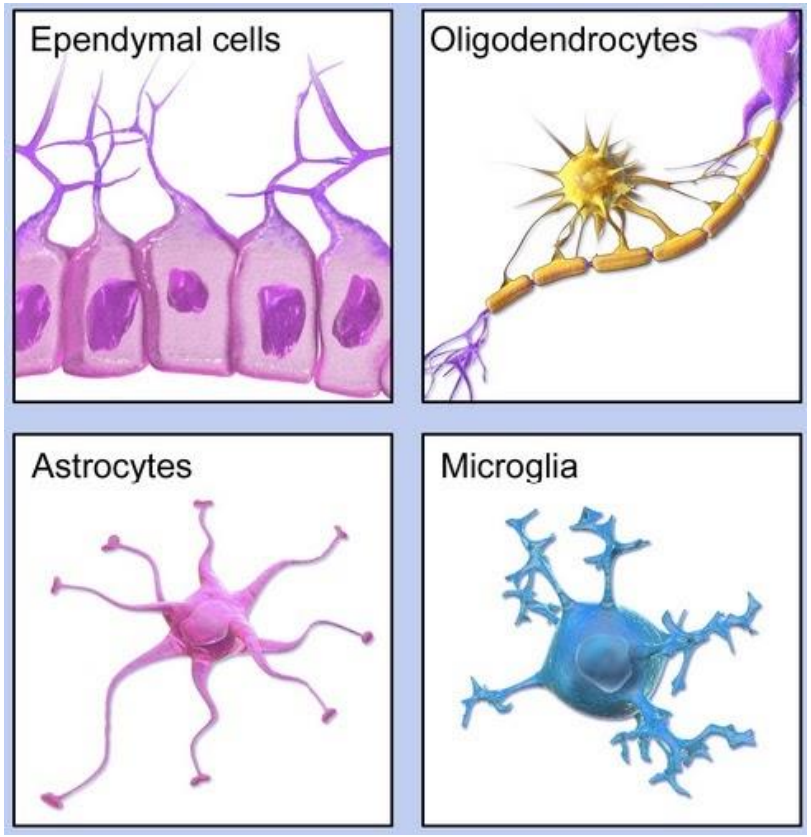
Schwann Cells: specialized Oligos which myelinate neurons of the PNS

- **Astrocytes**

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

- **Microglia**

Removes toxins from the brain, repairs damaged neurons



Neurons

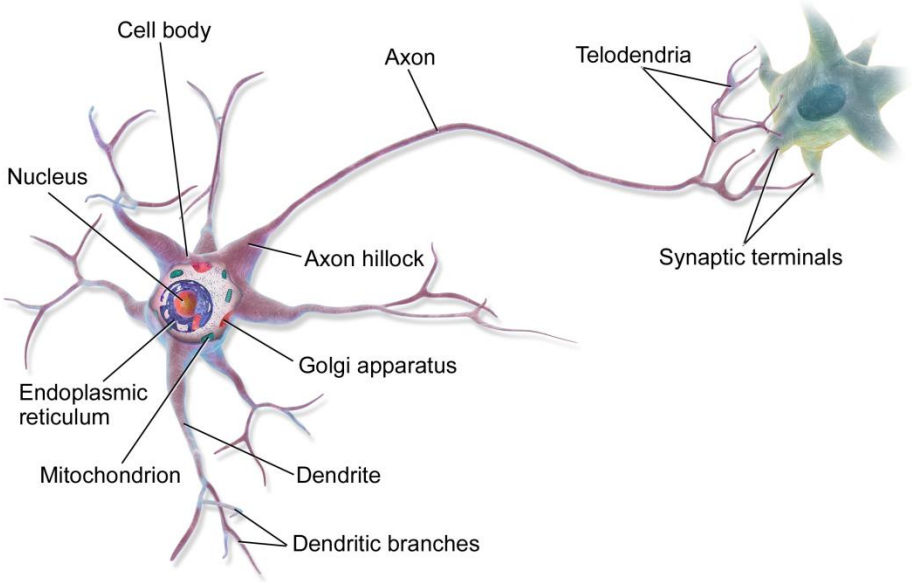
- Very small cell-body, but branches can be 2m long

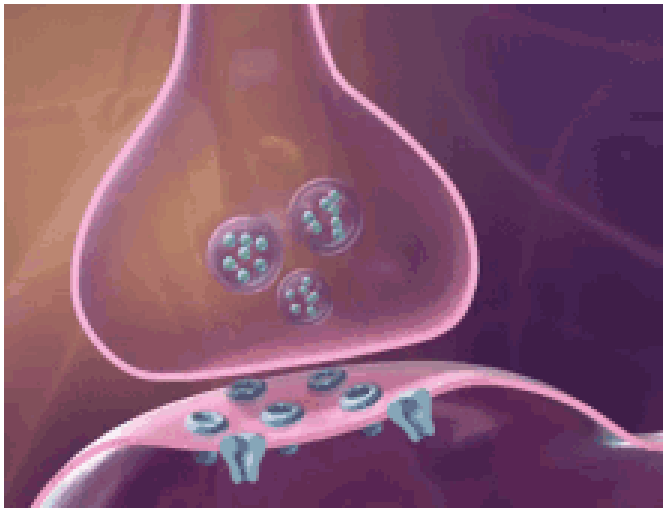
- Specialized cells for information transfer

- <u>Dendrites:</u>
  - Spiny protrusions from the Soma which receives **incoming** signals
  - Site of Postsynaptic Membranes
  - w/ receptor sites

- <u>Axons</u>
  - 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 the Synaptic Cleft

- <u>Receptor Sites:</u>
  Specialized areas which interact with NTs from other neurons

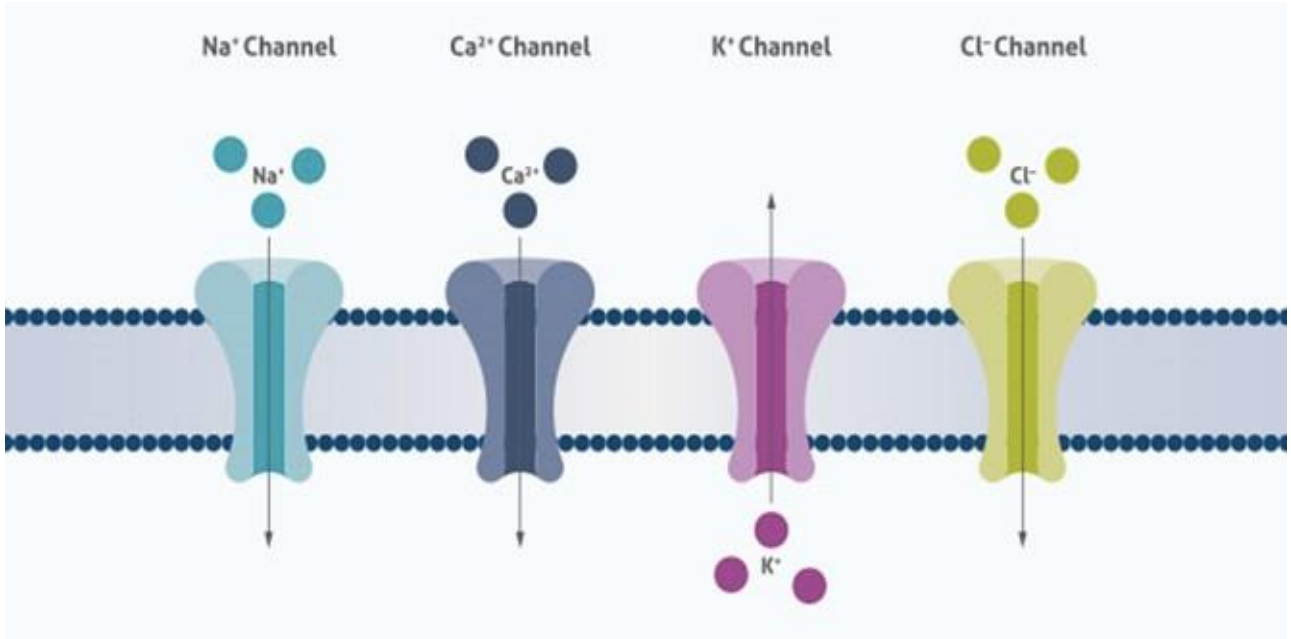




Important Ions to remember:

Na^+, K^+, Ca^{2+}, Cl^-

Sodium, Potassium, Calcium, Chloride



Important Concepts

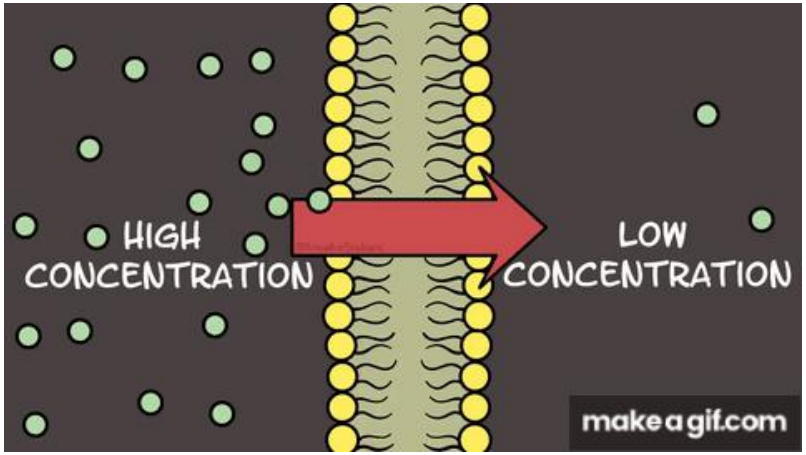
- Nature always seeks **Equilibrium**, so is neural communication

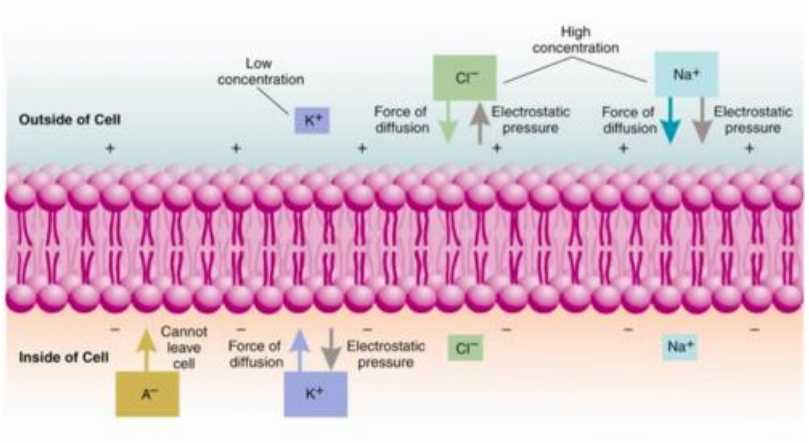
- How to achieve this stable state?

- Concentration Gradient:
  - Molecules in areas of **greater** concentration will *diffuse* to areas of **lesser** concentration

- Electrical Gradient:
  - Negative repels negative charges and positive repels positive charges, but negative & positive attracts each other
    = **Electrostatic Pressure**

- Selective Permeability of Membranes
  - Lipid bi-layers: typically impermeable to charged ions and larger molecules
  - Control which chemicals enter/leave the cell and this is done by gates that open or close to let ions pass through



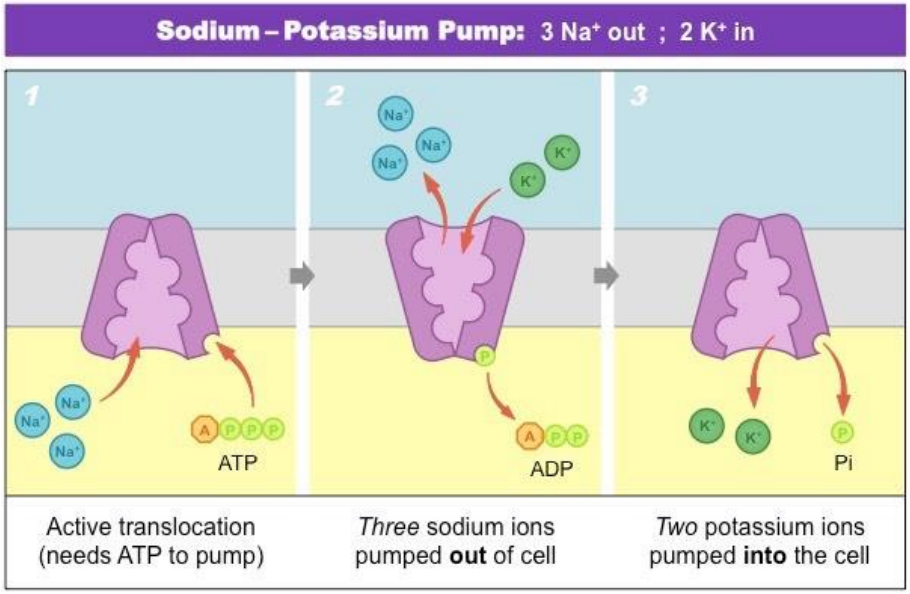


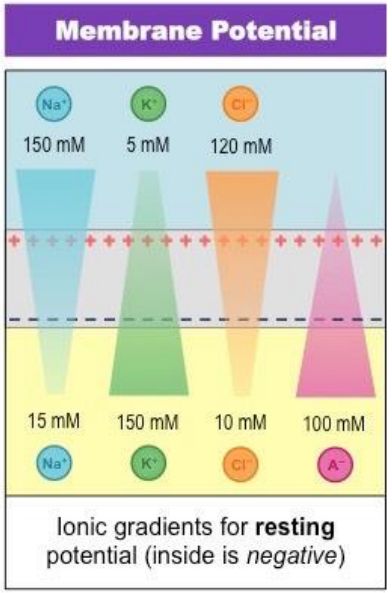
Resting Potential

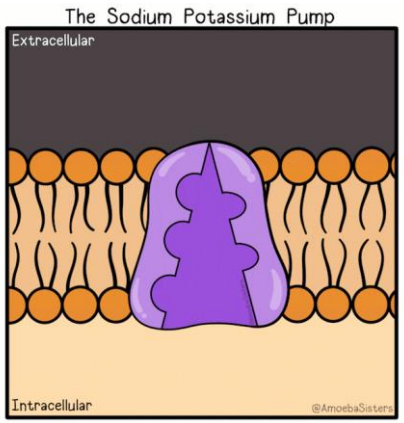
- Membrane Potential
  - The difference in charge between the inside and outside of the cell, in milli-volts (mV)

- Resting Potential:
  - All gates are locked (waiting for ion flows and is ready to fire)
  - Typically highly polarized, **-70 mV** for Neurons (fewer positive ions inside than outside cell)

- Sodium/Potassium Pump
  - Helps establish resting potential by transporting **3 Na^+ out** and **2 K^+** ions **in**

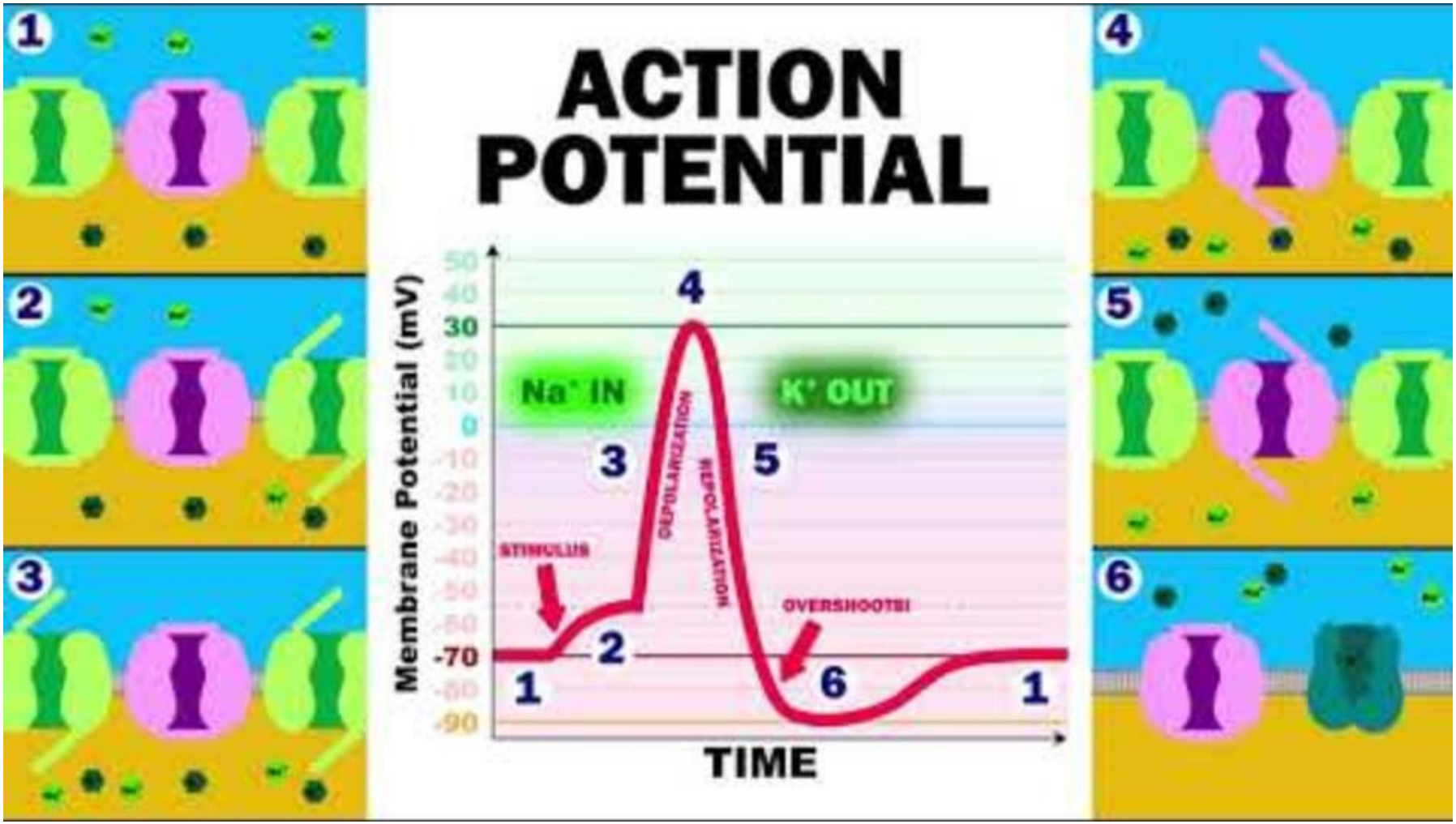






Resting Potential

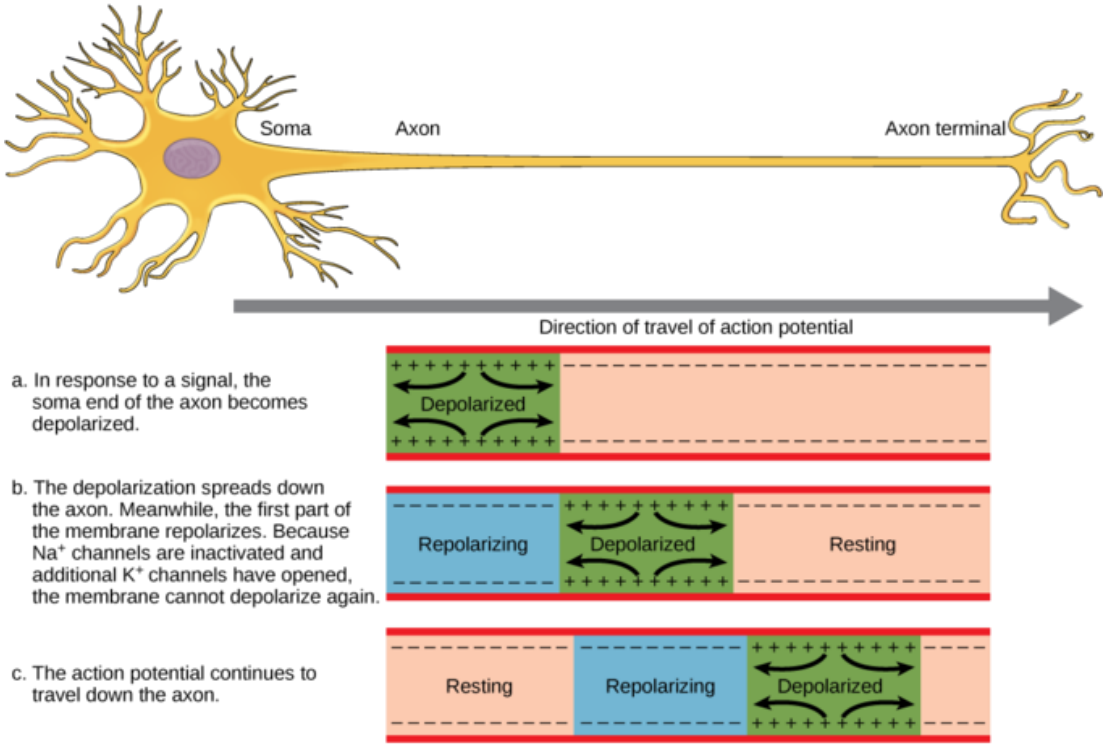
Action Potential (AP)



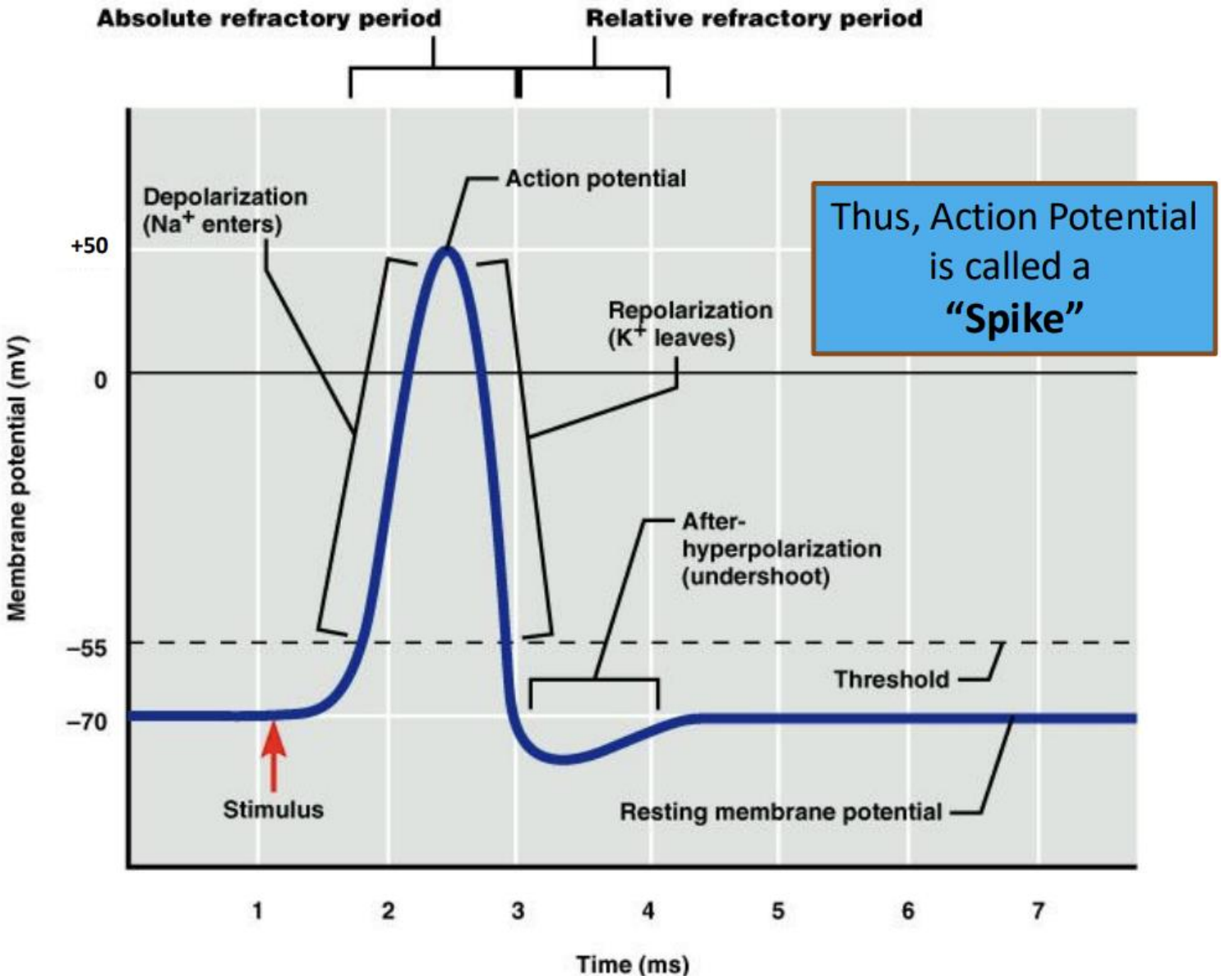
Action Potential (AP)

- Depolarization of the Neuron
  - If Resting Neurons are **Polarized**, then **Depolarized** neurons are not "resting" AKA neurons are "firing"

- Propagation process
  - Stimulation from Presynaptic neuron → release of NTs → binds to Postsynaptic neurons **>** triggers AP that starts at the Axon Hillock

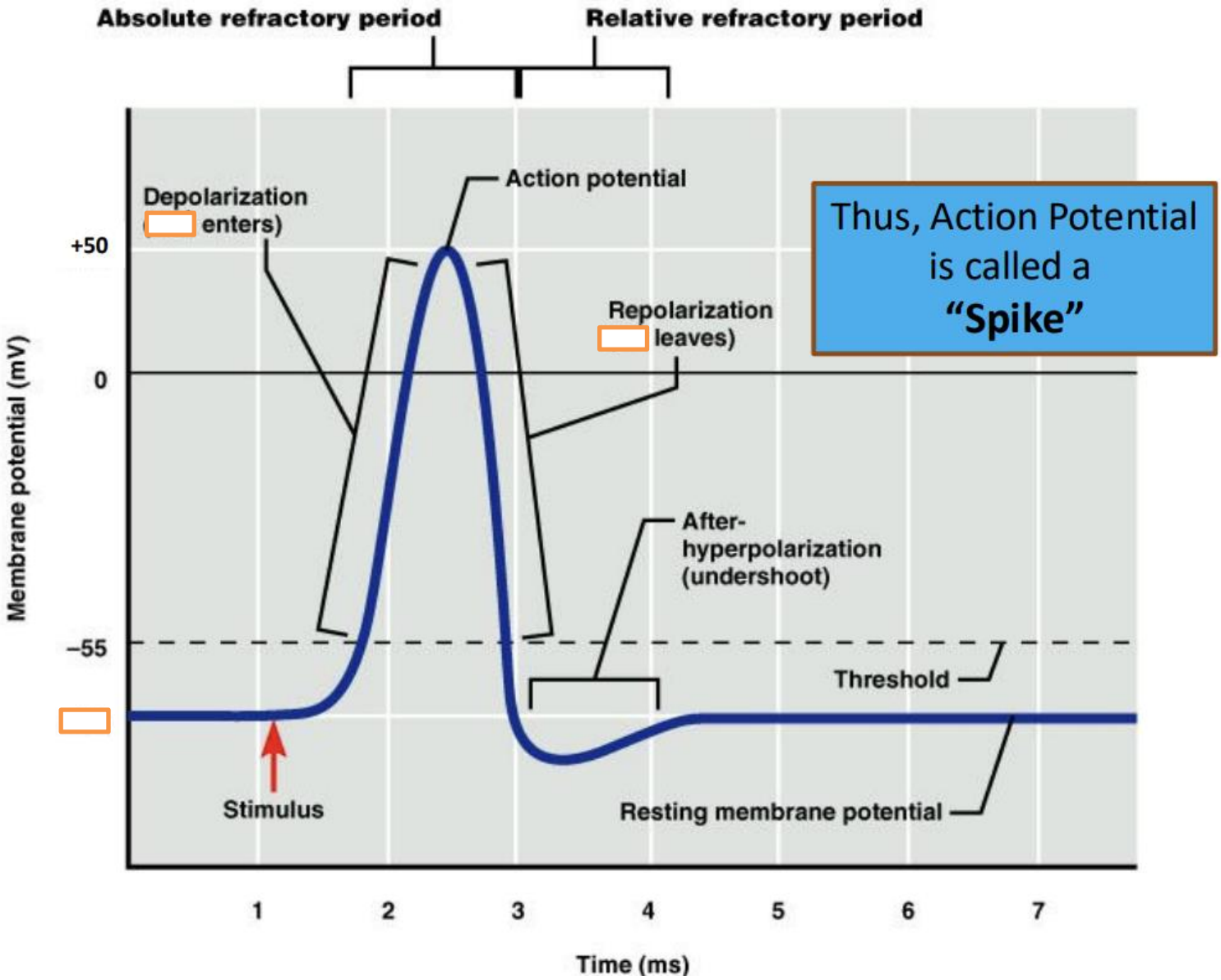


Action Potential (AP)



Thus, Action Potential is called a **"Spike"**

Action Potential (AP)



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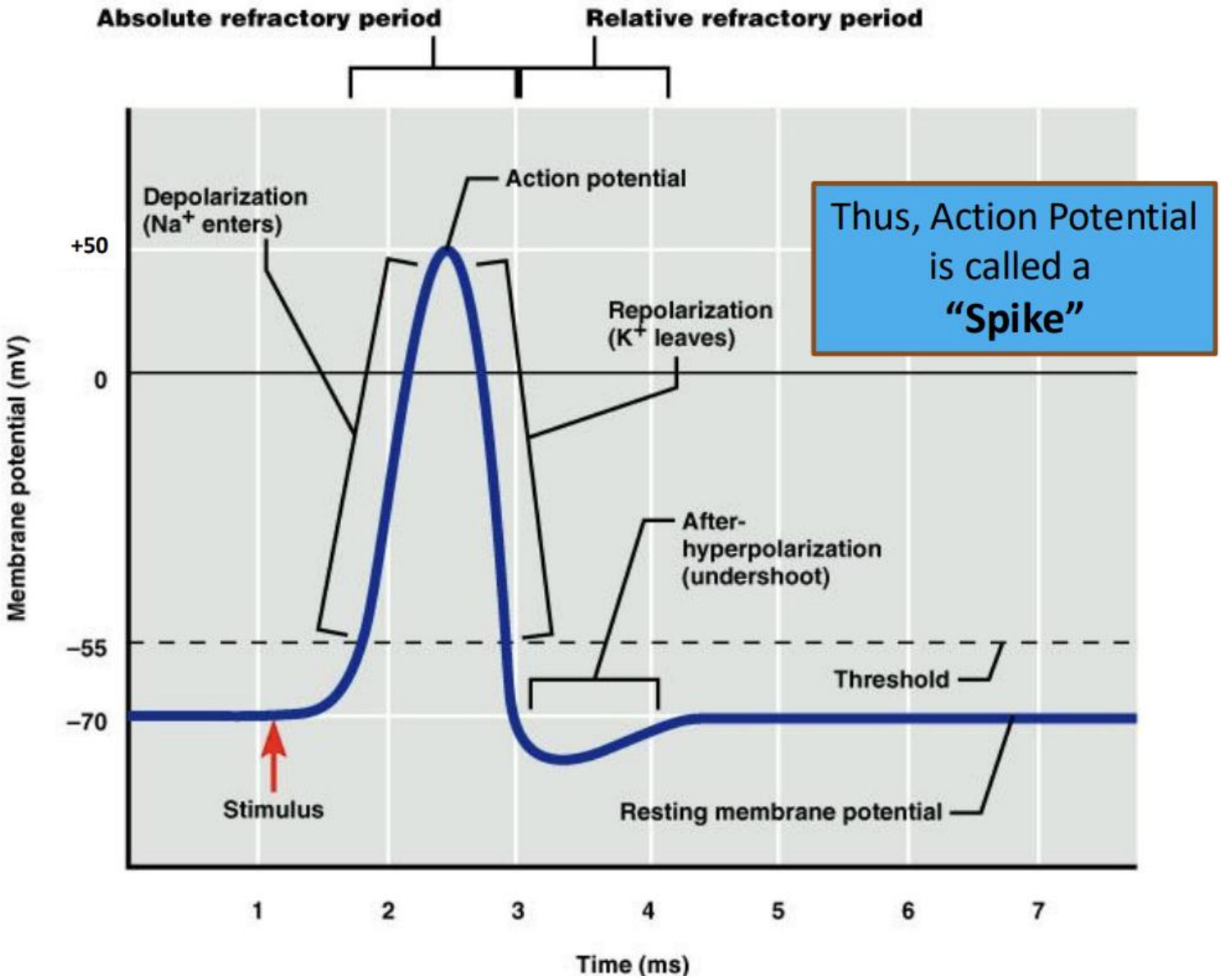


Thus, Action Potential is called a **"Spike"**

Action Potential (AP)

- Mechanism of Action
  - Na channels at axon hillock open, allowing an **influx** of **Na** ions, drastically shifting the membrane potential towards a peak of **( )** mV
  - Next Na gates open and more influx of Na ions
  - At the peak, Na channels close while K channels open, allowing an **efflux** of **K** ions, shifting the membrane potential **(positively/negatively)** to a point where it overshoots (hyperpolarizes)

  - K channels close and **Na/K pumps** start re-establishing resting potential (via **( )** Na out, **( )** K in) until membrane potential returns to -70 mV, This time period is called **Refractory Period**, during which the neuron cannot fire
  - Calcium pumps at the Axon Terminal actively transports Ca out to reset the NT release mechanism

- All or None Law
  - In a given cell, AP will always have the same amplitude and velocity regardless of the intensity of the stimulus that triggered it

Action Potential (AP)

- Mechanism of Action
  - Na channels at axon hillock open, allowing an **influx** of **Na** ions, drastically shifting the membrane potential towards a peak of +50 mV
  - Next Na gates open and more influx of Na ions
  - At the peak, Na channels close while K channels open, allowing an **efflux** of **K** ions, shifting the membrane potential negatively to a point where it overshoots (hyperpolarizes)

  - K channels close and **Na/K pumps** start re-establishing resting potential (via 3 Na out, 2 K in) until membrane potential returns to -70 mV, This time period is called **Refractory Period**, during which the neuron cannot fire
  - Calcium pumps at the Axon Terminal actively transports Ca out to reset the NT release mechanism

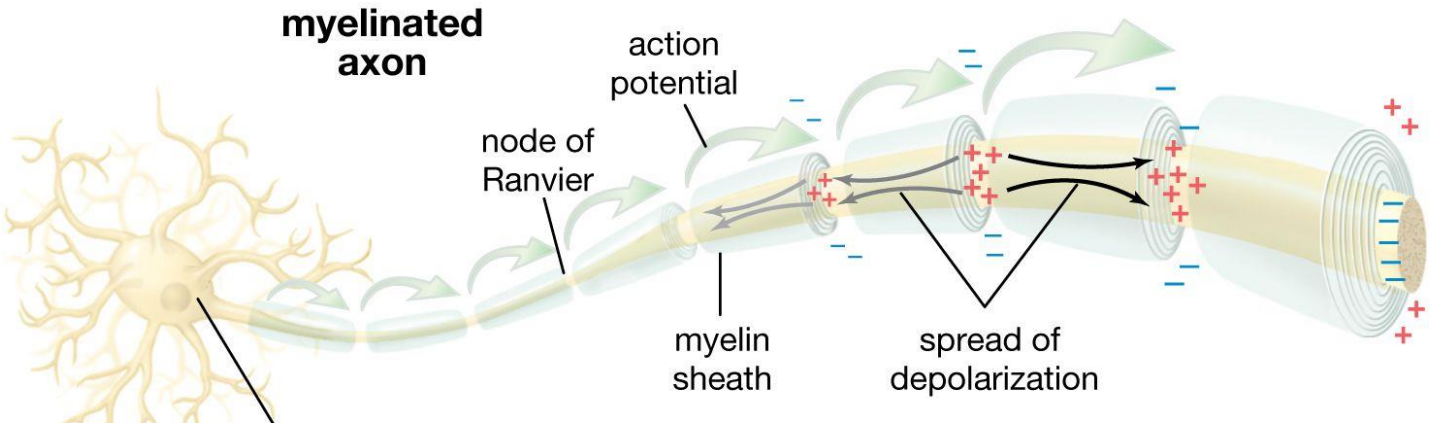
- All or None Law
  - In a given cell, AP will always have the same amplitude and velocity regardless of the intensity of the stimulus that triggered it

Myelination

- **Speed up** AP

- Glia cells wrapped around the axon, w/ gaps between called “Nodes of Ranvier”, act as an insulator
- **Electrical conduction** (electricity flows thru axon insulation) in myelinated portions: very fast but decays over time → Reboost to original strength occurs at…

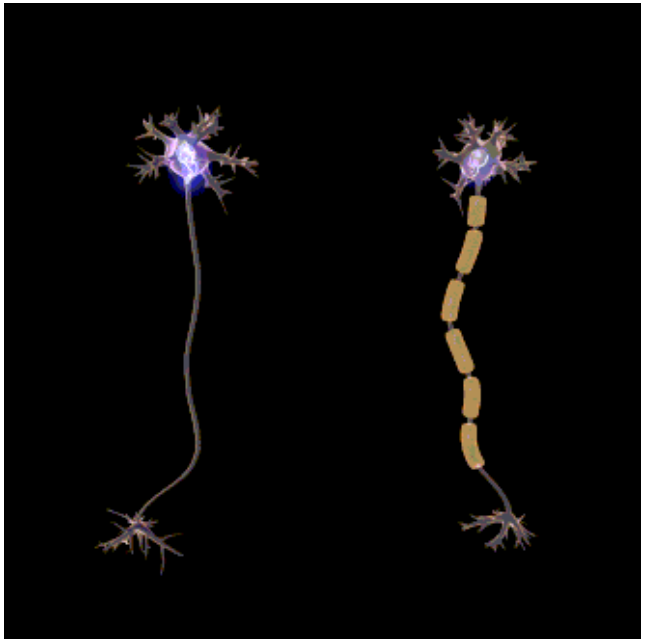
- <u>Nodes of Ranvier:</u>
  - The small gaps between myelin sheaths
  - sustain **Ionic Conduction** (when charged atoms flow through pores in the cell membrane, slower but stronger signal transmission) boosts the electrical signal

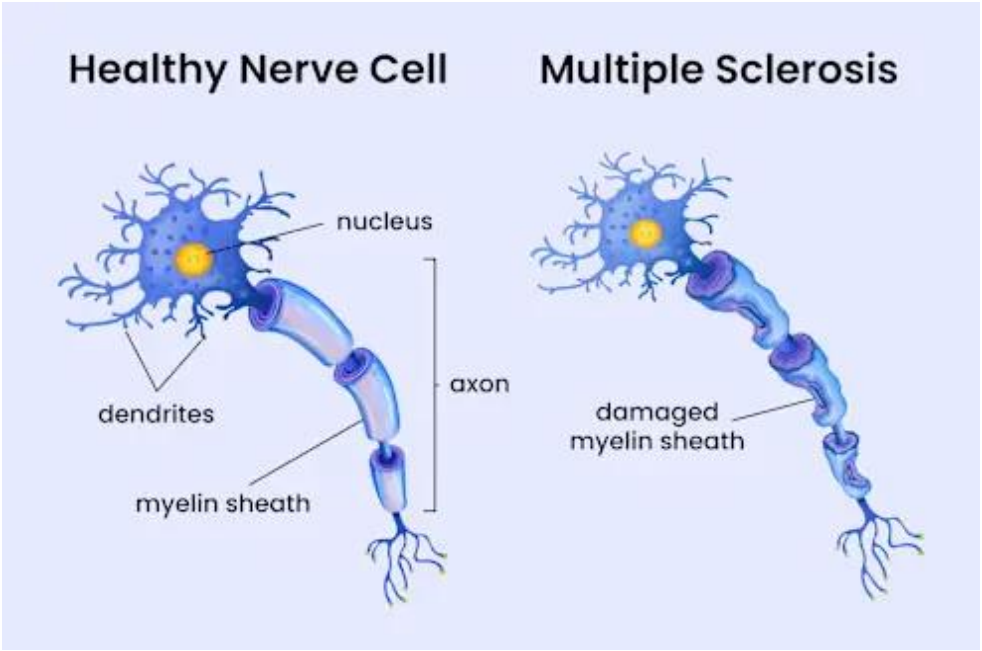


Myelination

- <u>Saltatory Conduction:</u>
  - Nerve impulse “jumps” from one node to another in a myelinated cell
  - Increases overall speed of impulse

- <u>Multiple Sclerosis (MS):</u>
  - A neurodegenerative disease where myelin degrades over time
  - Electrical signals decay quickly and AP fail





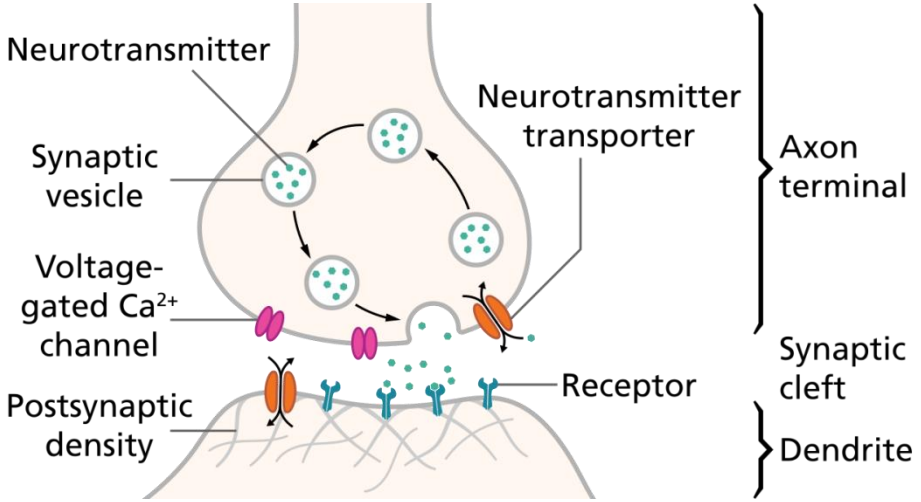
The Synapse

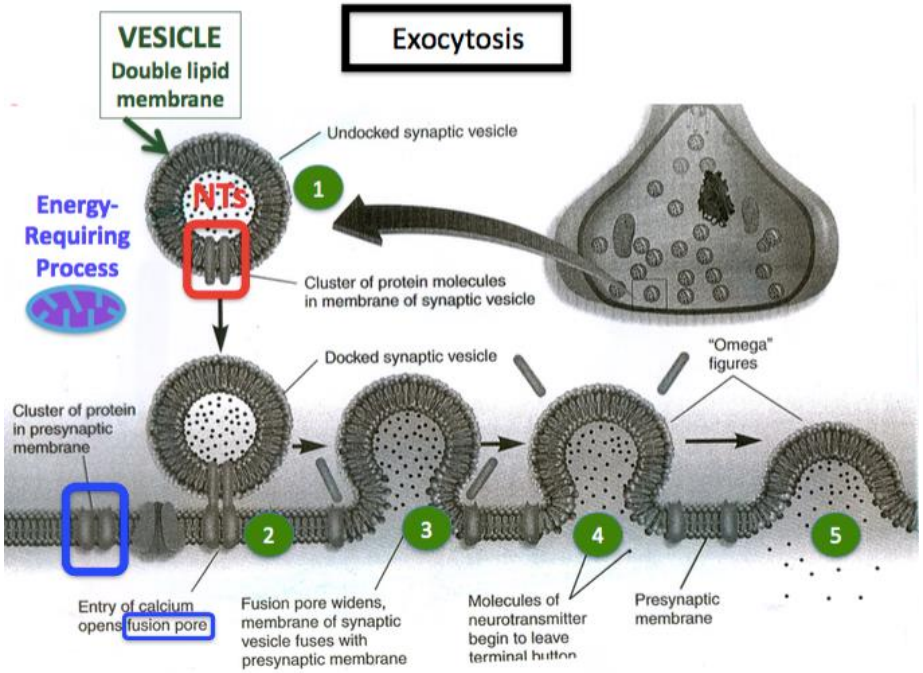
- Presynaptic cell + Synaptic Cleft + Postsynaptic cell = The Synapse

- Presynaptic cells release NTs into the cleft via **Exocytosis (releasing the NTs)**
  - NTs are packaged into vesicles

- **Influx of Ca** initiates the exocytosis
  - Ca opens the Fusion Pore which **binds vesicles** to the presynaptic cellular membrane

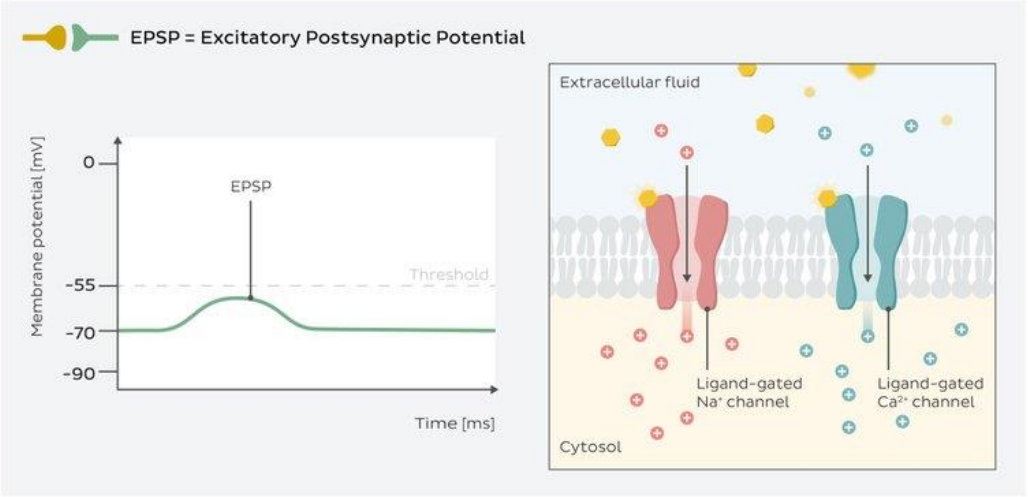
- Following exocytosis, **NTs** passively **diffuse** across the synaptic cleft and binds to NT-specific receptor sites on postsynaptic neurons

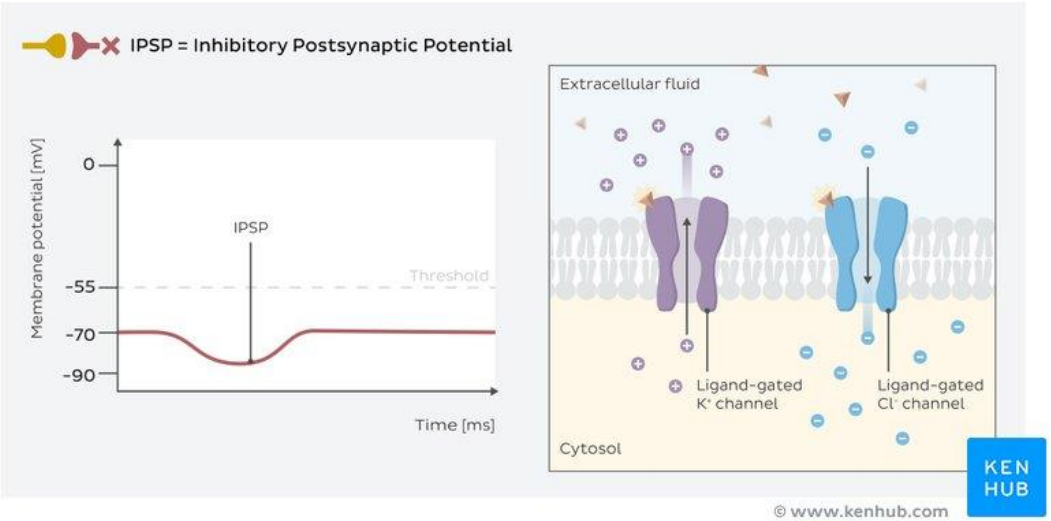




Polarity of Postsynaptic Cells

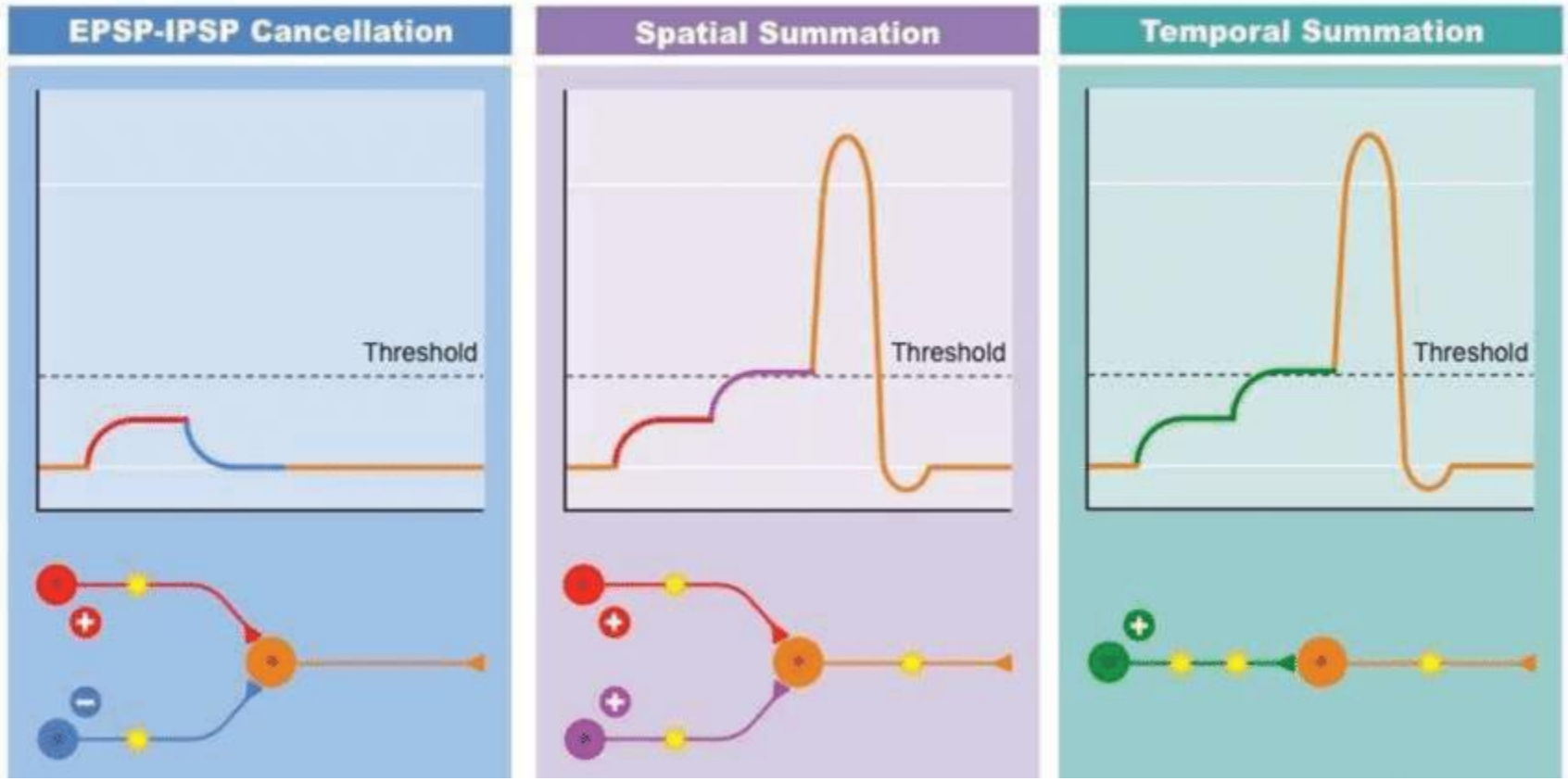
- **EPSP**
  - Increases a cell's likelihood of releasing NTs, **more** likely to "fire"
  - Usually due to Na+ entering the cell
- **IPSP**
  - Decreases a cell's likelihood of releasing NTs, **less** likely to "fire"
  - Usually due to K+ entering or Cl- exiting



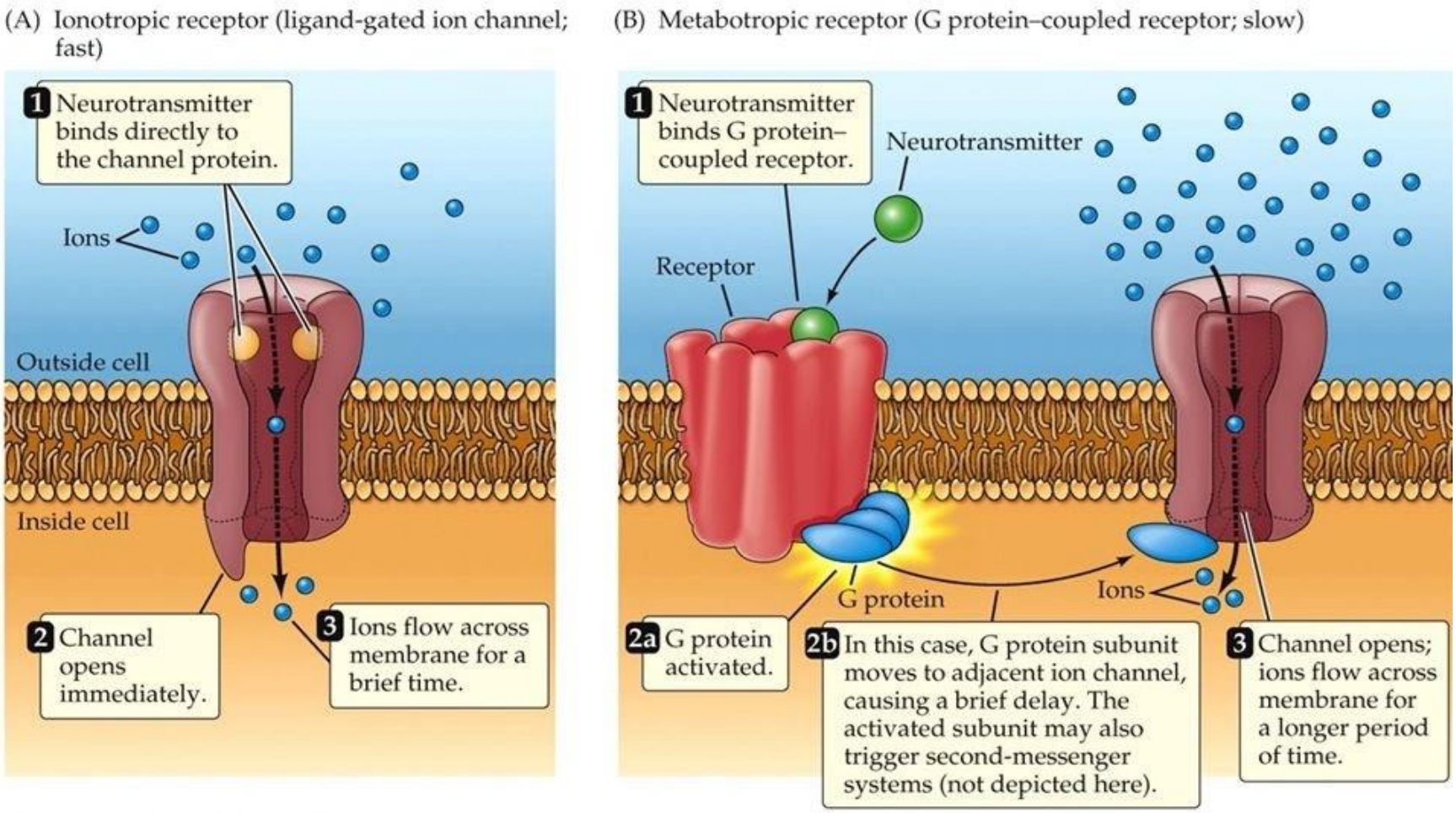


Polarity of Postsynaptic Cells

- Summation
  - A neuron's response = sum of EPSPs and IPSPs
  - **Temporal Summation:** one or more cells **repeatedly** stimulate another in rapid succession
  - **Spatial Summation:** multiple cells converge on a single **location** on a cell at the same time



Mechanisms of Neurotransmitters



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

Some Neurotransmitters and their Functions

Chemicals are called NTs if they impact nearby neurons

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

Agonist vs Antagonist

- **Agonists**: chemical that **increases** likelihood of NT
- **Antagonist**: chemical that **decreases** likelihood of NT

- What works as an Agonist vs. Antagonist often depends on how NT is typically processed in the cleft

Some examples:

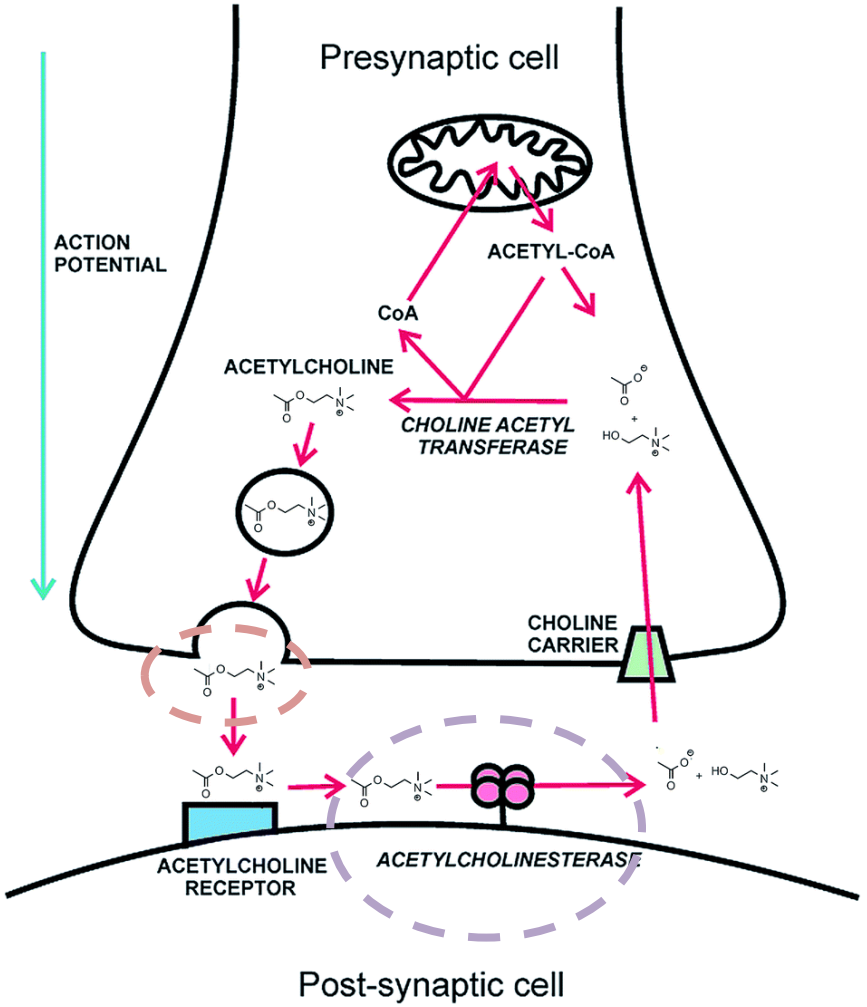
1. Acetylcholinesterase (AChE)

    - Enzyme which breaks down ACh in the cleft (NT is often deactivated by enzymes or Glia in the cleft)

      e.g., ACh deficit

    → Given AChE-Blocker, it will bind to the esterase, preventing the break down of ACh and freed ACh to re-stimulate the post synaptic cell and stays in the cleft longer

    → AChE-Blocker = act as an ACh agonist (increase the effect)



Agonist vs Antagonist

Some examples:

2. <u>Serotonin Reuptake</u>

- Usually, serotonin (5-HT) remains intact, and is reabsorbed back into the presynaptic cell after it's used (=**Reuptake**)

- 5-HT Agonist (e.g., Prozac, antidepressant): block this reuptake → prolonging its effects on postsynaptic cell

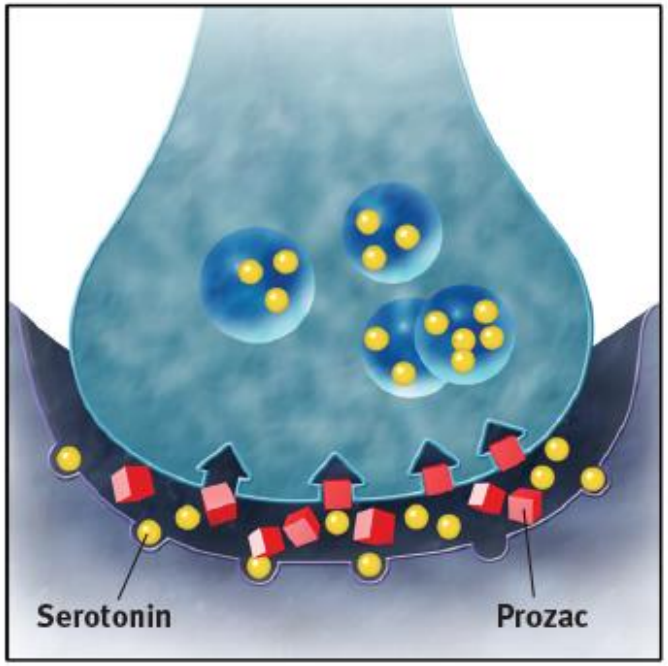
- 5-HT Antagonist (e.g., enzyme MAO): converts 5-HT into inactive form that won't affect Postsynaptic Cell

- Agonists and Antagonists can also act **inside** the **presynaptic** cell to affect NT release:

- Some antagonistic drugs (e.g. Reserpine) prevent NTs (Monoamines) from being packaged into vesicles

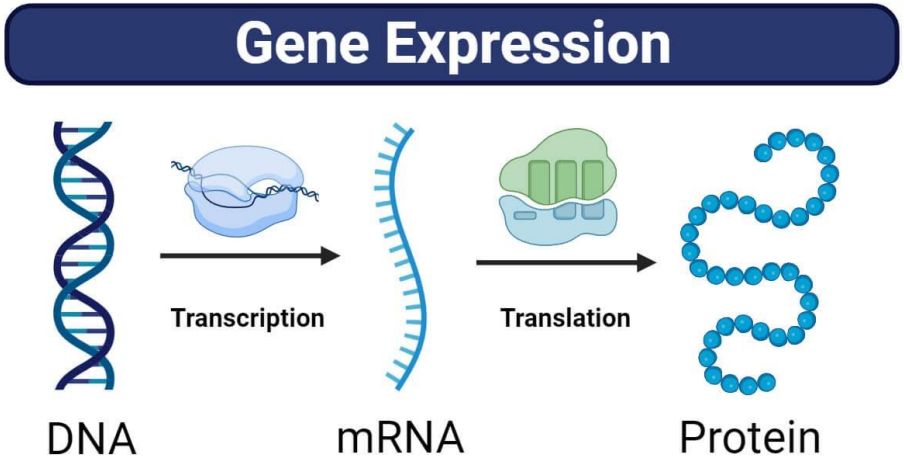
- Some agonists (e.g., Black Widow Spider venom) cause massive release of NT (ACh)

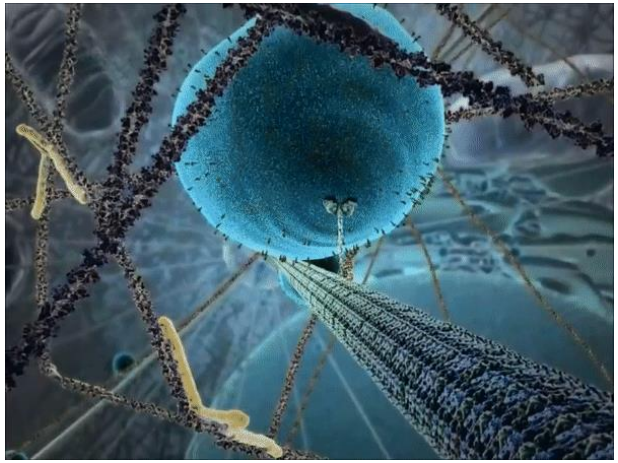
Prozac partially blocks normal reuptake of the neurotransmitter serotonin; excess serotonin in synapse enhances its mood-lifting effect.



Other Factors affecting Function

1. Gene Transcription: Activation of DNA sequences initiated the production of proteins for structural and chemical changes within cell
2. Receptor Sites can increase/decrease in #: repeated activity → more dendritic spines, more receptor sites
3. Receptor Sites can be blocked by NT mimics that do not readily detach (e.g., LSD, a potent psychedelic, binds primarily to serotonin receptors in the brain and act as agonist)
4. Some NTs, like Substance P (Pain), are produced in soma and carried by motor protein, Kinesin (transport NT to terminal by walking along micro-tubules) → may require hours/days to replenish
5. A few NT precursors can pass the BBB → used as medication (e.g., L-DOPA for dopamine)



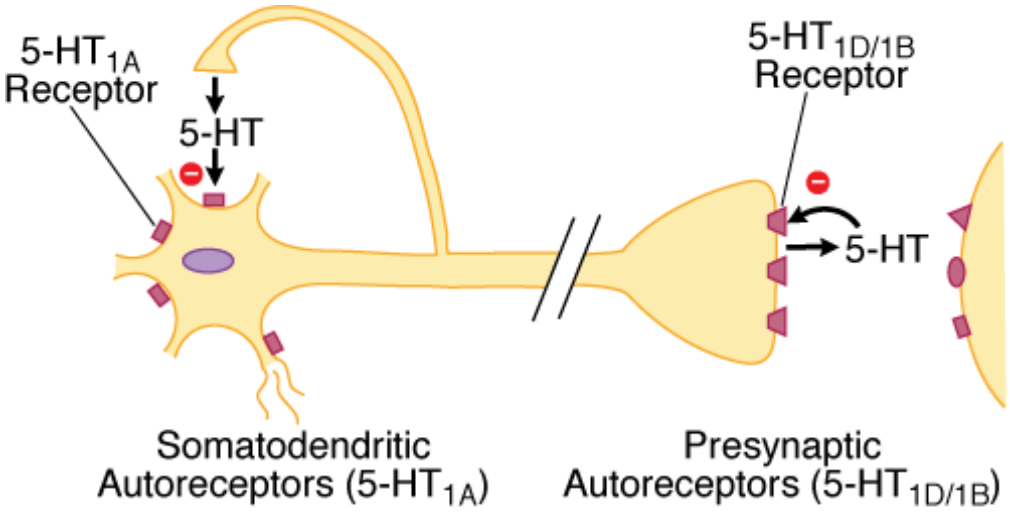


Other Factors affecting Function

Exceptions: Receptor Sites on **PRE-synaptic** Terminal

- Auto-Receptors (a class of NT receptor)
  - Some axons have receptor sites for their own NT
  - Usually inhibitory, and act in a negative feedback role by becoming active when the amount of neurotransmitter release is too high

- Axo-axonic Synapses (Axon to Axon)
  - Presynaptic Terminal may have Receptor Sites for Inhibitory or Excitatory NT from another cell



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