

# COGS 17 WEEK 3

## WINTER 2024, A04

# ANNOUNCEMENT

- Midterm On Jan 25, 2024 (Tomorrow) 3:30 – 4:50 pm
- 24 Questions, most of them require multiple responses
- 80 Minutes to complete
- One attempt
- You can revisit and change answers

# PROBLEM SET FOR REVIEW

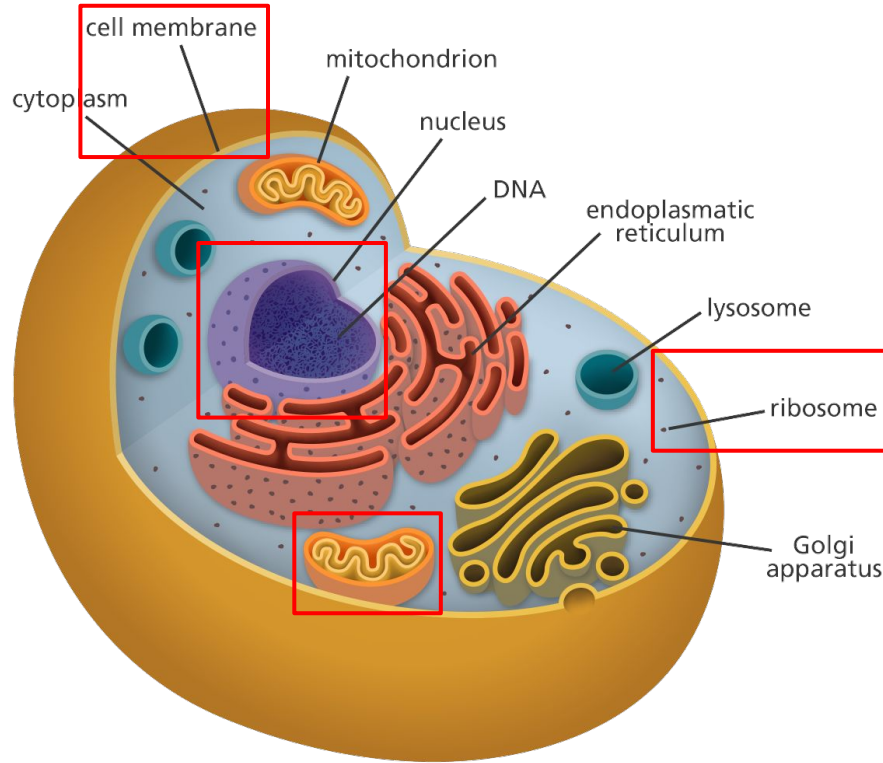
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SCAN ME

CELLS

# CELLS



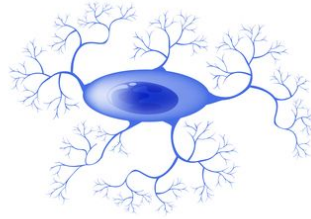
- Nucleus -- where DNA stored
- Ribosome -- where protein synthesis occurs
- Mitochondria -- Produce ATP, the “powerhouse” of the cell
- Cell membrane -- lipid, **BILAYER**, semi permeable membrane

# GLIAL CELLS

*Oligodendrocytes*



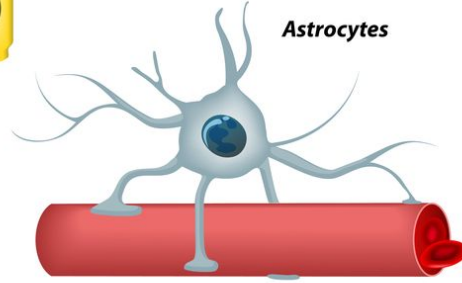
*Microglia*



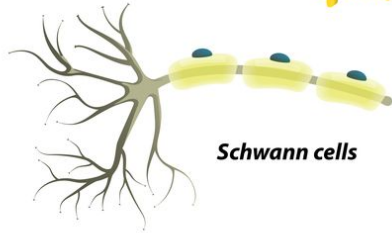
*Ependymal cells*



*Astrocytes*



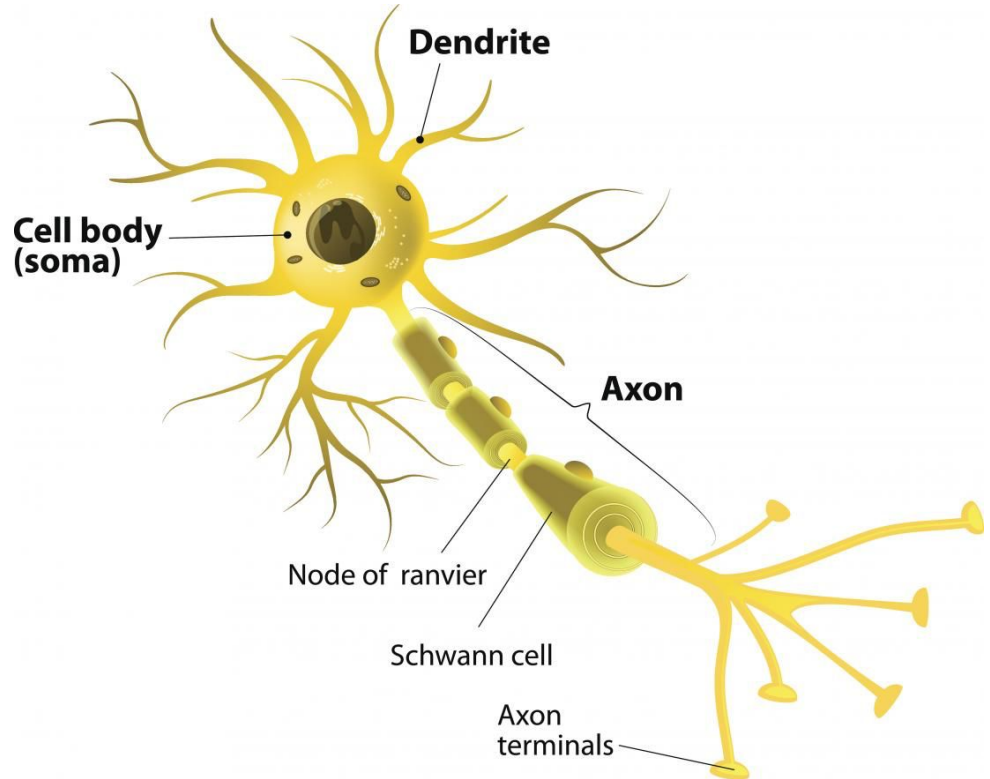
*Schwann cells*



- Non-neural cells of the nervous system with multiple functions
- Do **NOT** participate in information transfer
- Much smaller than neurons, but much more numerous
- ~50% of brain by weight

# NEURONS

- Cells that are specialized for **INFORMATION TRANSFER**
- Modified processes (i.e. dendrites & axon)
- Dendrites -- reception of **INCOMING** message via receptors
- Axon -- Site of release of **OUTGOING** message
- Modified membrane -- ion channels

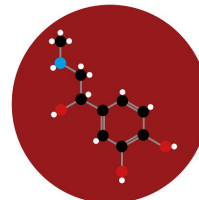


# NEUROTRANSMITTERS (NT)

- endogenous chemicals that allow neurons to communicate with each other throughout the body
- E.g. Acetylcholine (ACh), GABA, Glutamate, Serotonin (5-HT), Norepinephrine, etc.
- May have different effects in different parts of body

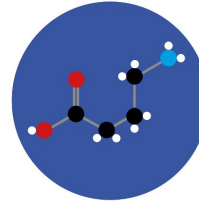
## CHEMICAL STRUCTURES OF NEUROTRANSMITTERS

**ADRENALINE**  $C_9H_{13}NO_3$   
THE FIGHT OR FLIGHT NEUROTRANSMITTER



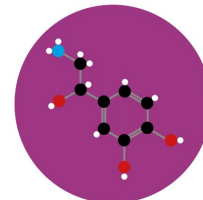
Adrenaline, also known as epinephrine, is a hormone produced in high stress or exciting situations. It stimulates increased heart rate, contracts blood vessels, and dilates bronchi, mobilising energy for the muscles to respond to the fight. This leads to an increase in blood and oxygenated oxygen levels. Epinephrine is used to treat allergic reactions, work by relaxing bronchi.

**γ-AMINOBUTYRIC ACID**  $C_4H_9NO_2$   
THE CALMING NEUROTRANSMITTER



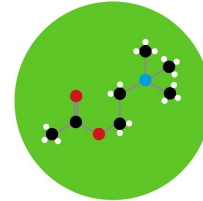
Gamma-aminobutyric acid (GABA) is the major inhibitory neurotransmitter of the brain. It acts as a calm, bring tension in the central nervous system. It is also involved in the regulation of the heart rate and blood pressure. GABA also contributes to the regulation of the immune system and the regulation of the immune system.

**NORADRENALINE**  $C_8H_{11}NO_3$   
THE CONCENTRATION NEUROTRANSMITTER



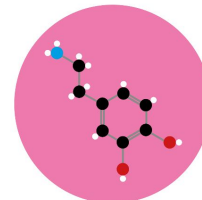
Noradrenaline, also known as norepinephrine, is a neurotransmitter that affects emotional, physiological, and psychological functions. The body of it is used to regulate the heart rate, blood pressure, and the body's response to stress. It is also involved in the regulation of the immune system and the regulation of the immune system.

**ACETYLCHOLINE**  $C_7H_{15}NO_2^+$   
THE LEARNING NEUROTRANSMITTER



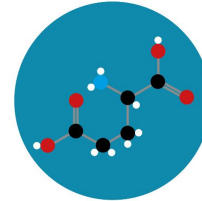
Acetylcholine, often shortened to ACh, is the principle neurotransmitter involved in learning, memory, and attention. In the brain, it is involved in the regulation of the heart rate, blood pressure, and the body's response to stress. It is also involved in the regulation of the immune system and the regulation of the immune system.

**DOPAMINE**  $C_8H_{11}NO_2$   
THE PLEASURE NEUROTRANSMITTER



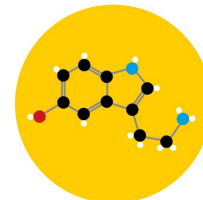
Dopamine is associated with feelings of pleasure & satisfaction. It is also associated with addiction, movement, and motivation. The body of it is used to regulate the heart rate, blood pressure, and the body's response to stress. It is also involved in the regulation of the immune system and the regulation of the immune system.

**GLUTAMATE**  $C_5H_9NO_4$   
THE MEMORY NEUROTRANSMITTER



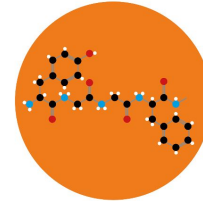
Glutamate is the most common neurotransmitter in the brain and is involved in a variety of functions, such as learning and memory. It also regulates the body's response to stress. It is also involved in the regulation of the immune system and the regulation of the immune system.

**SEROTONIN**  $C_{10}H_{12}N_2O$   
THE MOOD NEUROTRANSMITTER



Serotonin is thought to be a contributor to feelings of well-being and happiness. It regulates the sleep cycle along with melatonin, and also regulates mood, movement, and attention. The body of it is used to regulate the heart rate, blood pressure, and the body's response to stress. It is also involved in the regulation of the immune system and the regulation of the immune system.

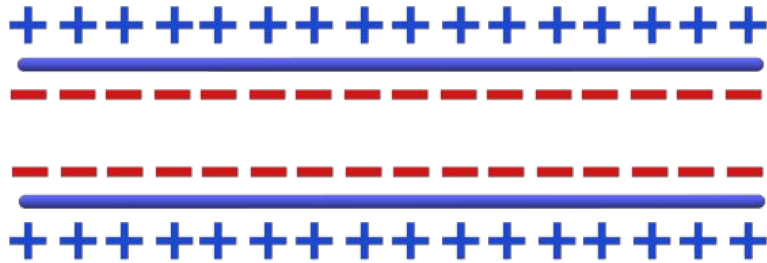
**ENDORPHINS** 20+ TYPES IN THE HUMAN BODY  
THE EUPHORIA NEUROTRANSMITTERS



Endorphins are a range of compounds. The biologically active section of which is about 30-40 amino acids long. These are released from the brain and the body's response to stress. It is also involved in the regulation of the immune system and the regulation of the immune system.



# RESTING POTENTIAL

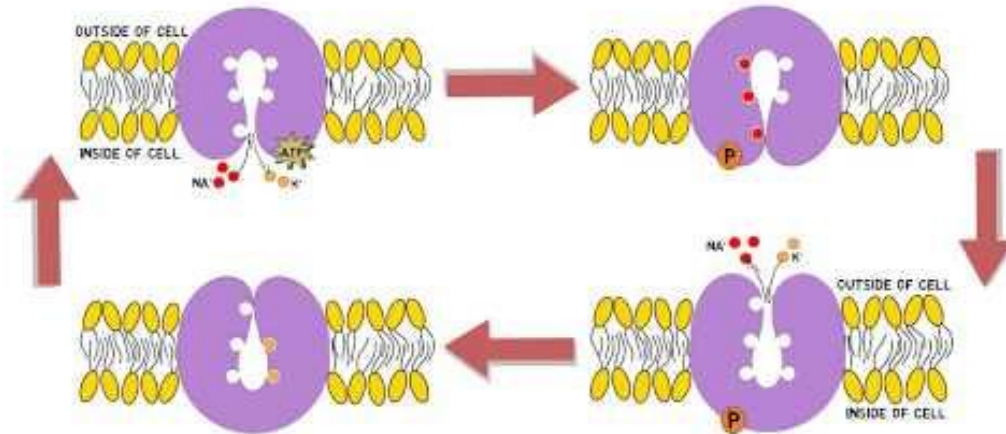


- Generally -70 mV
- More negative inside & more positive outside
- Established in part by Na-K pump, which actively transport 3 Na<sup>+</sup> out and 2 K<sup>+</sup> in
- Highly **POLARIZED** -- ready to "fire"

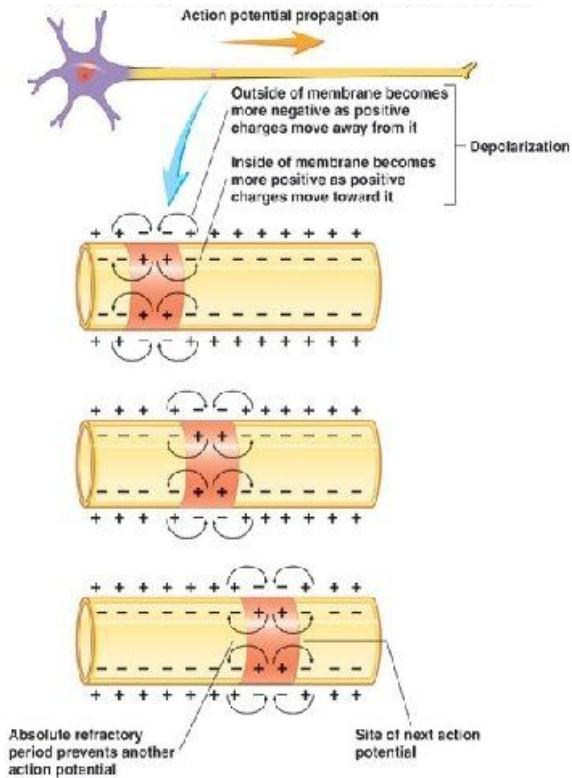
# SODIUM-POTASSIUM PUMP

## SODIUM-POTASSIUM PUMP CYCLE

-USES ATP TO TRANSPORT SODIUM AND POTASSIUM IONS ACROSS THE CELL MEMBRANE

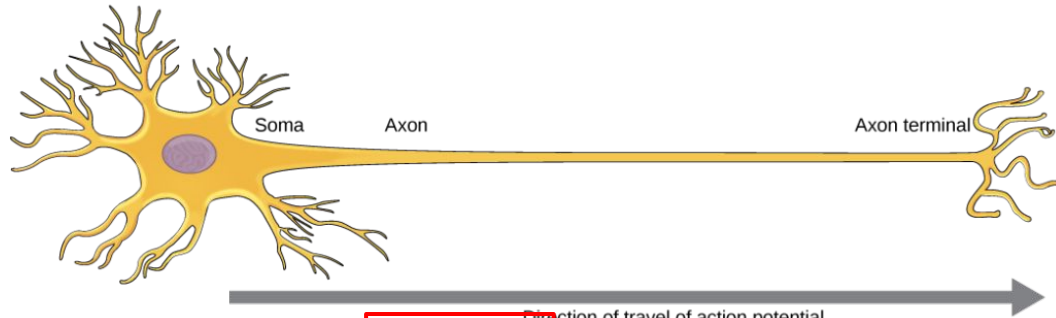


# ACTION POTENTIAL

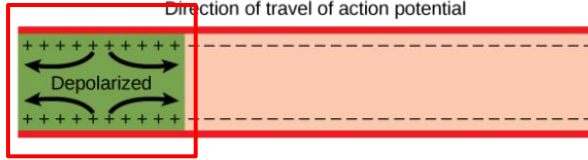


- **DEPOLARIZATION** of neuron
- Triggered by neurotransmitters from other neuron, electrical stimulation, or other stimuli
- Starting at Axon Hillock

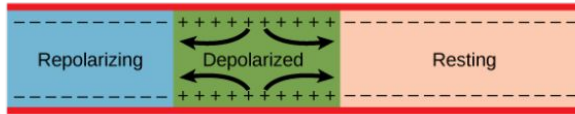
# ACTION POTENTIAL



a. In response to a signal, the soma end of the axon becomes depolarized.



b. The depolarization spreads down the axon. Meanwhile, the first part of the membrane repolarizes. Because  $\text{Na}^+$  channels are inactivated and additional  $\text{K}^+$  channels have opened, the membrane cannot depolarize again.

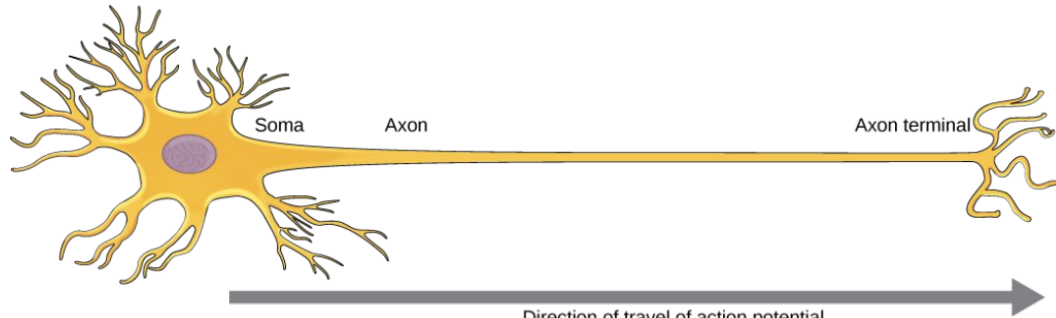


c. The action potential continues to travel down the axon.



- Voltage-activated  $\text{Na}^+$  gates open --  $\text{Na}^+$  in
- Reverse local polarization to  $\sim +50$  mV
- $\text{Na}^+$  influx causes adjacent  $\text{Na}^+$  voltage-activated gates to open & previously opened gates close
- Propagation of the action potential to the terminal

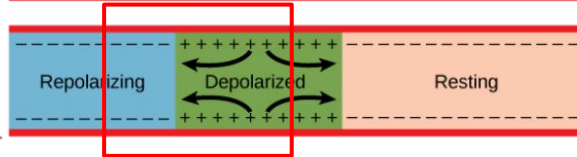
# ACTION POTENTIAL



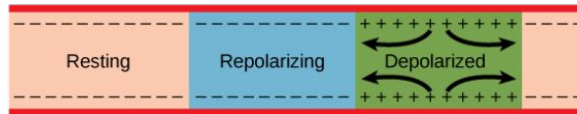
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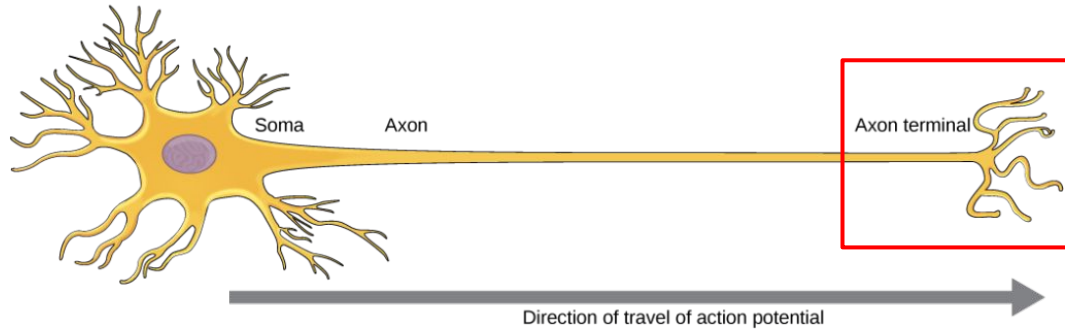


c. The action potential continues to travel down the axon.



- As previous  $\text{Na}^+$  gates close, local  $\text{K}^+$  gates open --  $\text{K}^+$  leaves the cell
- Because of opened  $\text{K}^+$  channels & closed  $\text{Na}^+$  channels, the membrane cannot depolarize again
- Refractory period -- prevents backflow of action potential

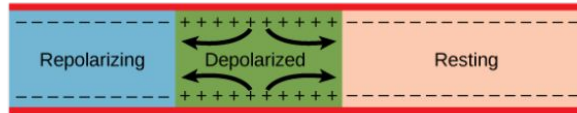
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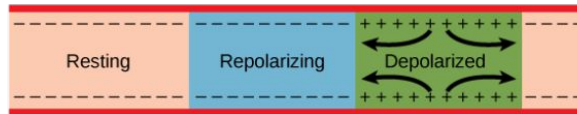
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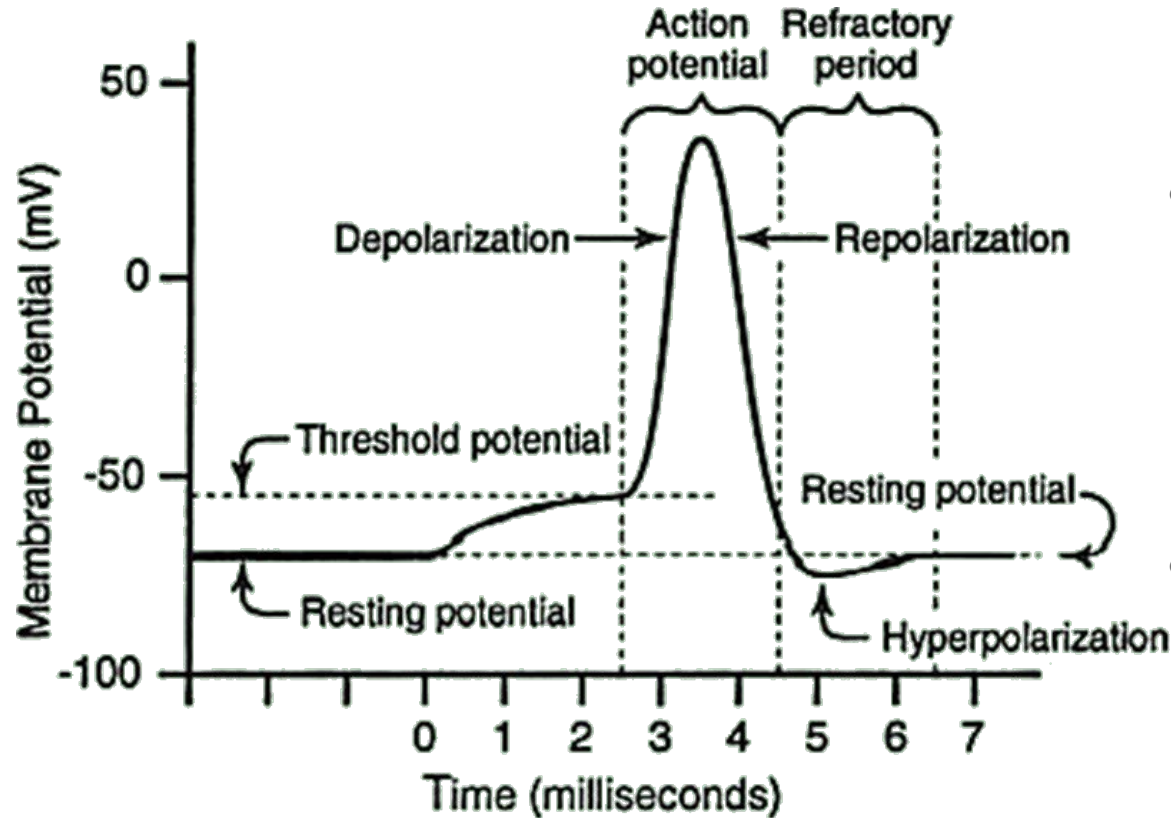


c. The action potential continues to travel down the axon.



- When reaches terminal,  $\text{Ca}^{2+}$  enters cell & Neurotransmitter released
- When outside becomes more positive again,  $\text{K}^+$  channels close
- Na-K pumps restore resting potential to  $-70 \text{ mV}$
- Ca pump reject  $\text{Ca}^{2+}$  from terminal
- Pumps require energy

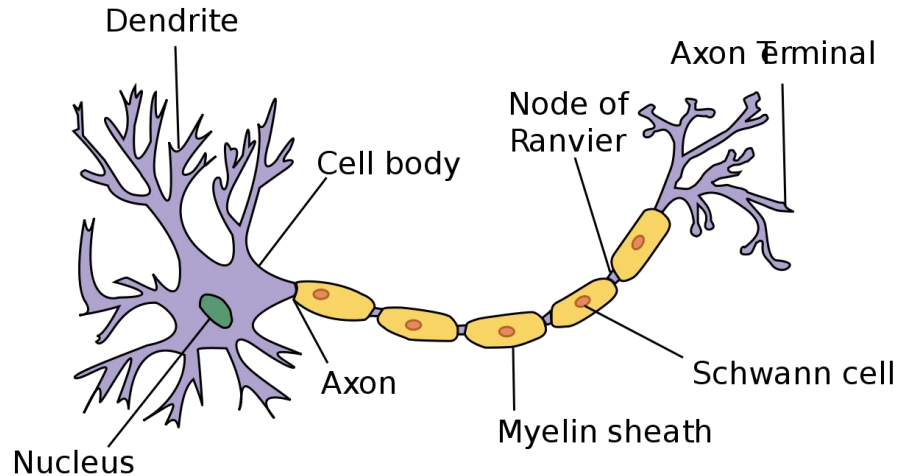
# ALL-OR-NONE LAW



- An Action Potential always has the same amplitude and velocity, regardless of the intensity of the stimulus that triggered it
- Either full response or no response at all

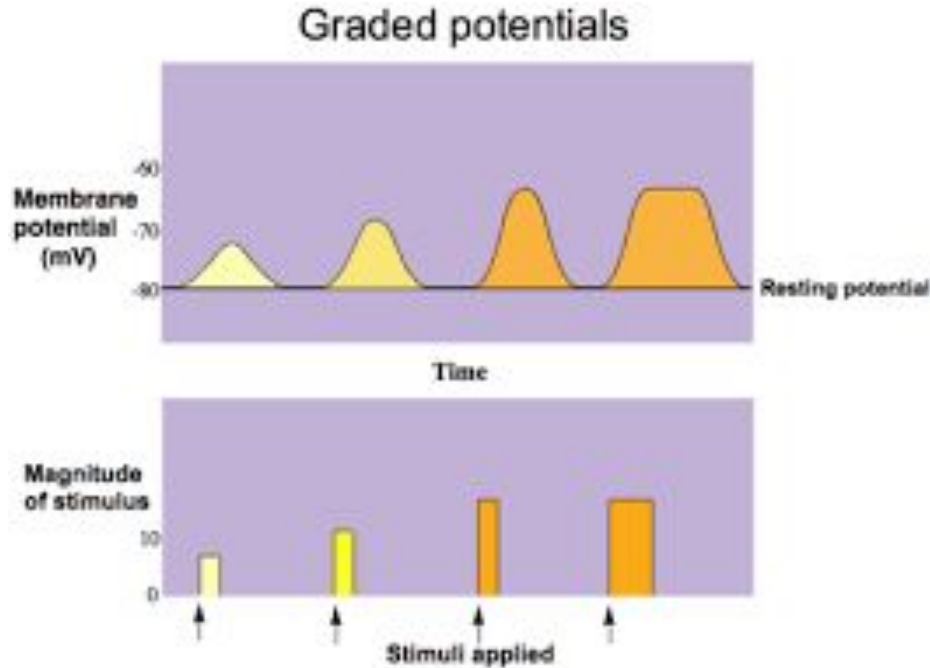
# MYELINATION AND SALTATORY CONDUCTION

- Increase the speed of propagation
- Glia cells form insulating sheaths around axons, with small gaps in between sheaths
- Electrical conduction -- fast, but degrades as it moves
- Node of Ranvier -- ionic conduction, re-boost the signal to original strength and pass it to next sheath
- Saltatory Conduction -- “Jumping” of the signal from node to node along axon



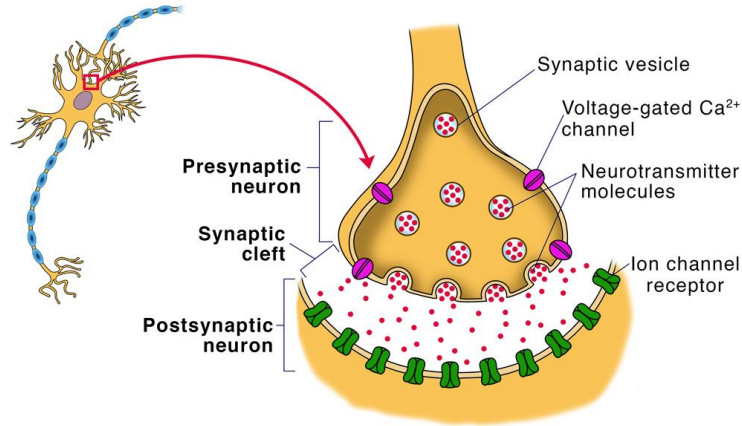


# GRADED POTENTIALS



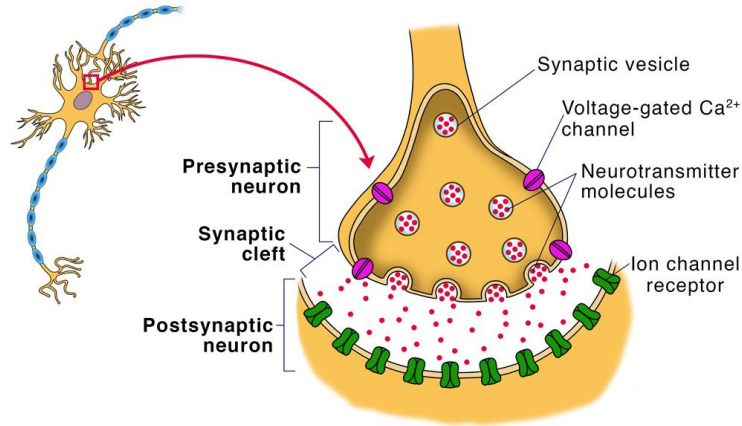
- Releasing NT from a Neuron does NOT always require an Action Potential
- Can vary in amplitude
- i.e. Strong response due to strong stimulus; weak response due to weak stimulus
- Examples: some receptor cells (e.g. retina), lateral inhibitors, local Neurons, etc.

# THE SYNAPSE



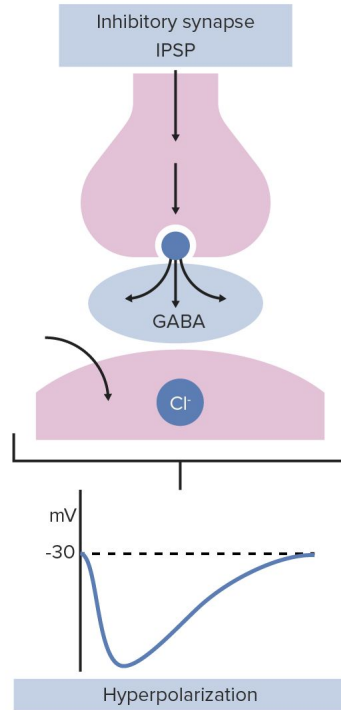
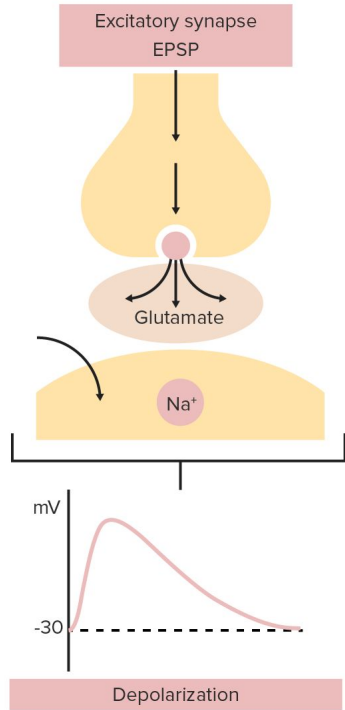
- Presynaptic cell releases NT into synaptic cleft, affects postsynaptic cell via Exocytosis (release of vesicles of NT).
- When membrane depolarization reaches the axon terminal, voltage-gated  $\text{Ca}^{++}$  channels open, causes influx of  $\text{Ca}^{++}$

# THE SYNAPSE



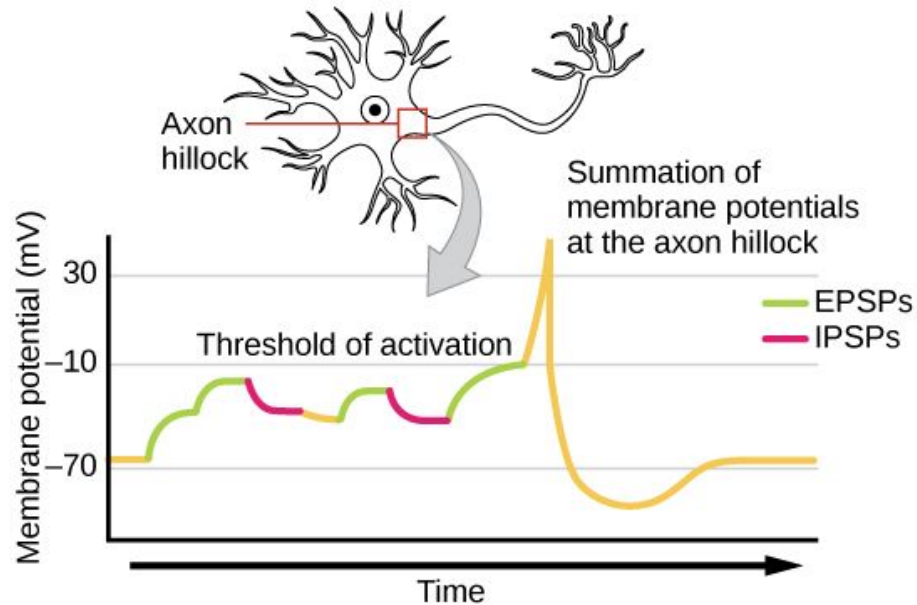
- NT passively diffuses across synaptic cleft
- NT binds to NT-specific receptor site on (usually) dendrites of postsynaptic cell
- Postsynaptic cell may fire its NT, etc.
- NT soon detaches from receptor
- NT is often then deactivated by enzymes or Glia

# EPSP Vs. IPSP



- EPSP: Excitatory Postsynaptic Potential – postsynaptic cells become hypo-polarized.
- IPSP: Inhibitory Postsynaptic Potential – postsynaptic cells become hyper-polarized.

# SUMMATION

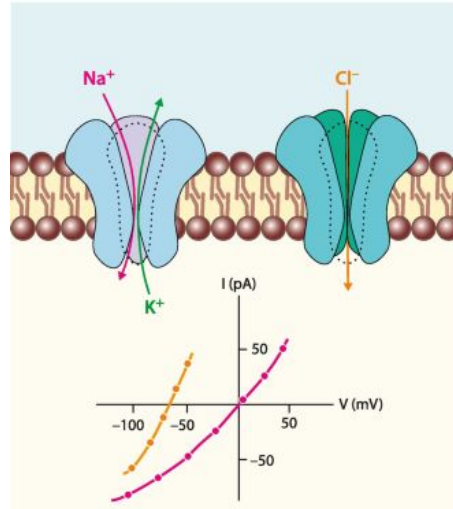


- The response of a given neuron is nearly always the product of a summation of EPSPs and/or IPSPs
- Two types of summation: Spatial summation and Temporal summation

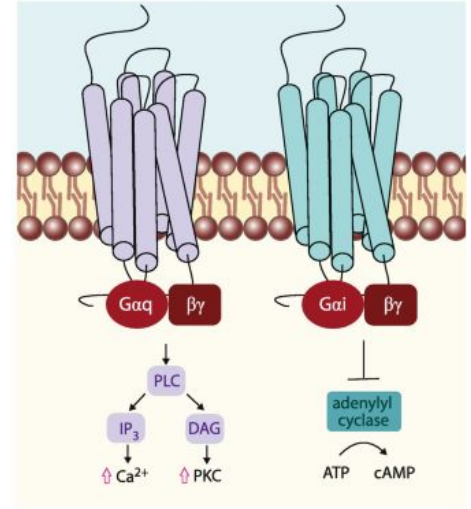
# IONOTROPIC VS. METABOTROPIC

- Iontropic: NT directly affects ion gates
  - Effects are rapid, short-lived
- Metabotropic: Triggers metabolic changes in Postsynaptic cell
  - Activates/triggers production of Secondary Messenger, which binds w/G-Protein to open separate ion gate, requires energy, slower and long-lasting

a ionotropic receptors

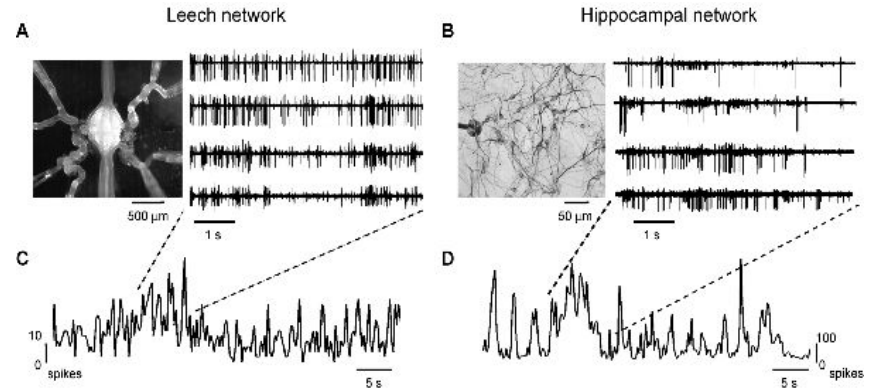


b metabotropic receptors



# SPONTANEOUS ACTIVITY

- Some Neurons show spontaneous Firing, in absence of incoming NT
- Usually graded potentials
- Converging NTs increase or decrease such cells' activity, modifying how much NT they will then release



# AGONISM VS. ANTAGONISM

- Agonist: chemicals that increase effect of a NT
- Antagonist: chemicals that decrease effect of a NT

## Agonists and Antagonists

Agonists - Drugs that occupy receptors and activate them.

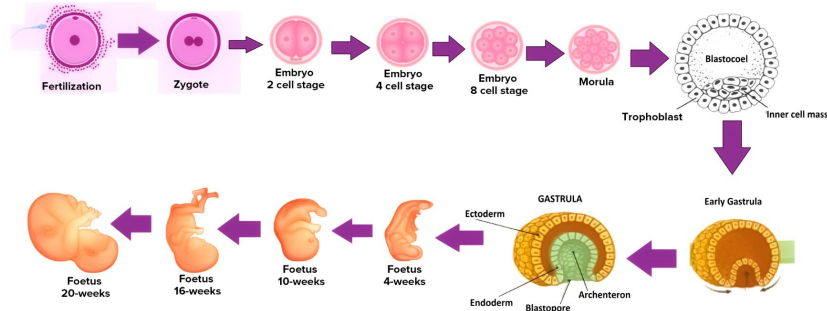
Antagonists - Drugs that occupy receptors but do not activate them.  
Antagonists block receptor activation by agonists.





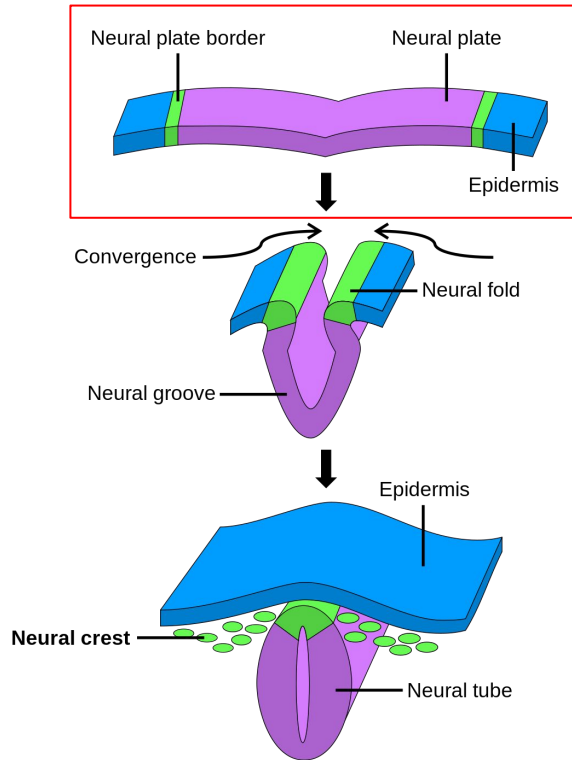
DEVELOPMENT

# EMBRYONIC DEVELOPMENT



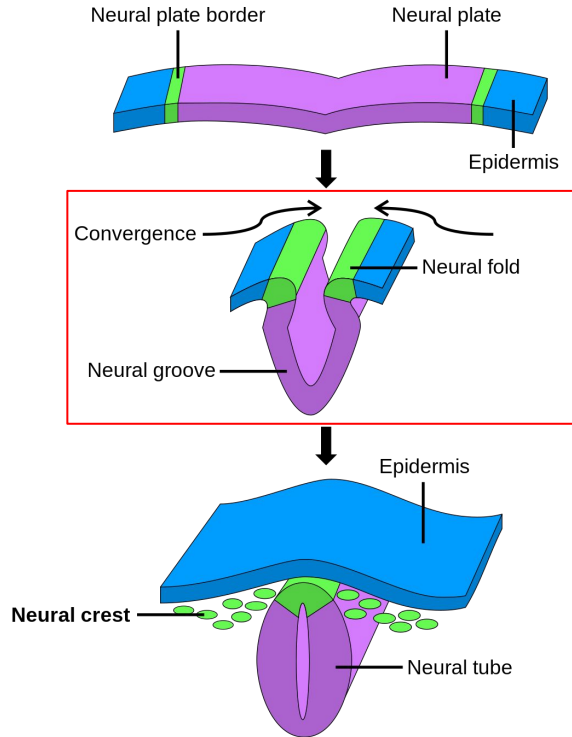
- A new embryo develops three cell layers: Ectoderm (outer layer, becomes nervous system & skin), Mesoderm (middle layer, becomes bones, muscles, blood vessels), endoderm (inner layer, becomes organs, glands)

# EMBRYONIC DEVELOPMENT



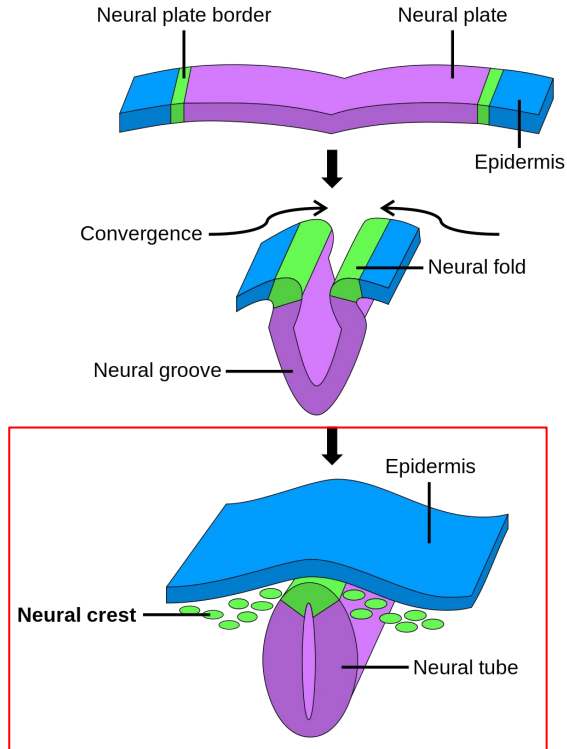
- Over first 2 weeks, embryo changes from a sphere of cells to an elongated “worm”, still 3 layered
- Then dorsal Ectoderm begins to thicken and forms hard Neural Plate

# EMBRYONIC DEVELOPMENT



- Edges of plate form ridges (Neural Folds) that curl toward each other along a longitudinal line

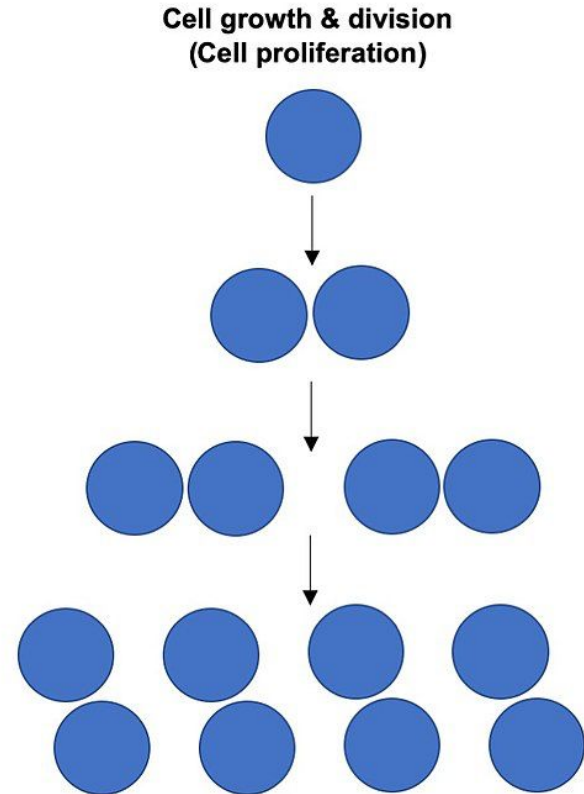
# EMBRYONIC DEVELOPMENT



- By week 4, edges of Neural Folds have fused, forming Neural Tube lined with Ectoderm, embedded in Mesoderm
- Spina Bifida - Neural fold failed to fuse
- Rostral end of Neural Tube >> Brain
- Caudal end >> Spinal Cord
- Surface of ridges (Neural Crest) >> Ganglia of ANS & Peripheral Neurons & Glia

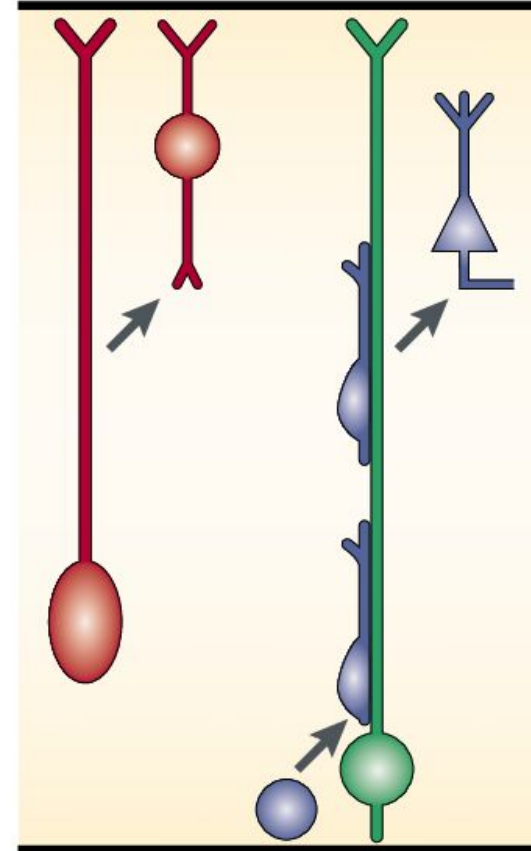
# PROLIFERATION

- Growth of new cells
- Stem Cells: Ectodermal cells that line the inside of the Neural Tube
  - give rise to neurons first through Symmetrical Division
  - ~Week 7, shift to Asymmetrical Division, producing one stem cell + one neuron
- Stem cells stay to divide, neurons start to migrate

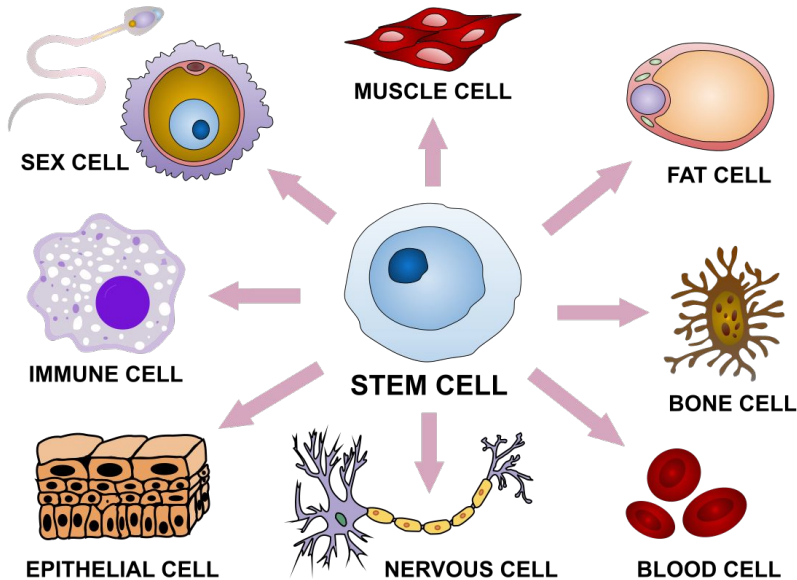


# MIGRATION

- Some Neurons migrate by “crawling” along Radial Glia fibers, often aided by Glycoproteins
- Other Neurons may migrate by following chemical trails laid down by Glia Cells or by other Neurons



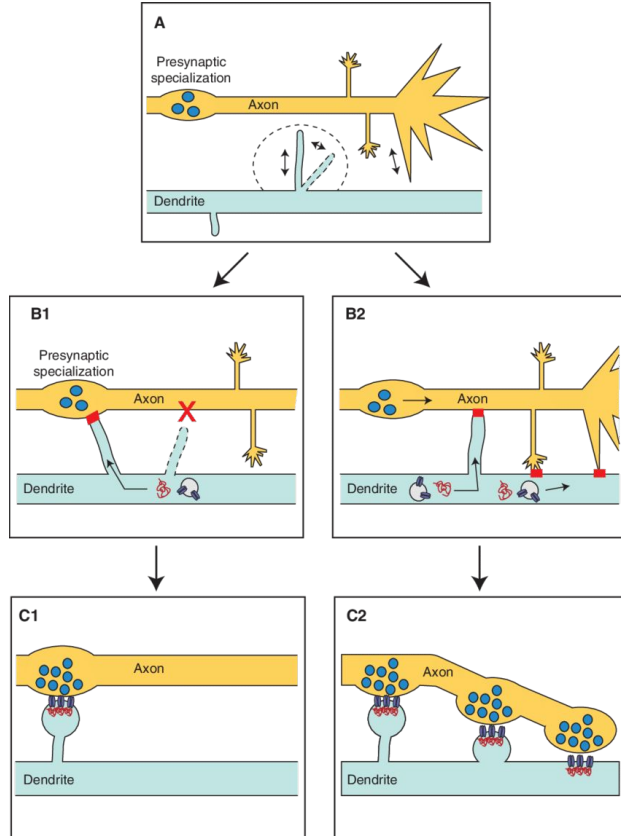
# DIFFERENTIATION



- Transition of a cell from one cell type to another
- Per Cell-Autonomous (genetic) and Induction (chemical influences from local environments) factors

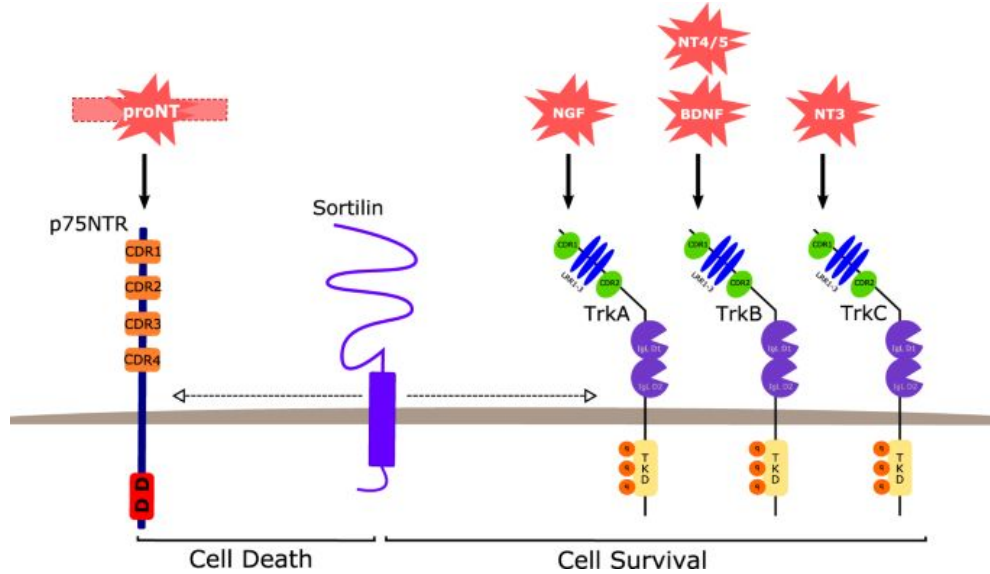


# SYNAPTOGENESIS



- Developing junctions (Synapses) between cells
- After migration, Neurons grow Axon first and Dendrites later
- Growth Cone at end of elongating Axon has many Filopodia that detect surrounding chemical gradients
- Some Axons are directed by Guidepost Cells
- Others depend on Chemical Trails produced by Glia cells or other migrating Neurons/Axons

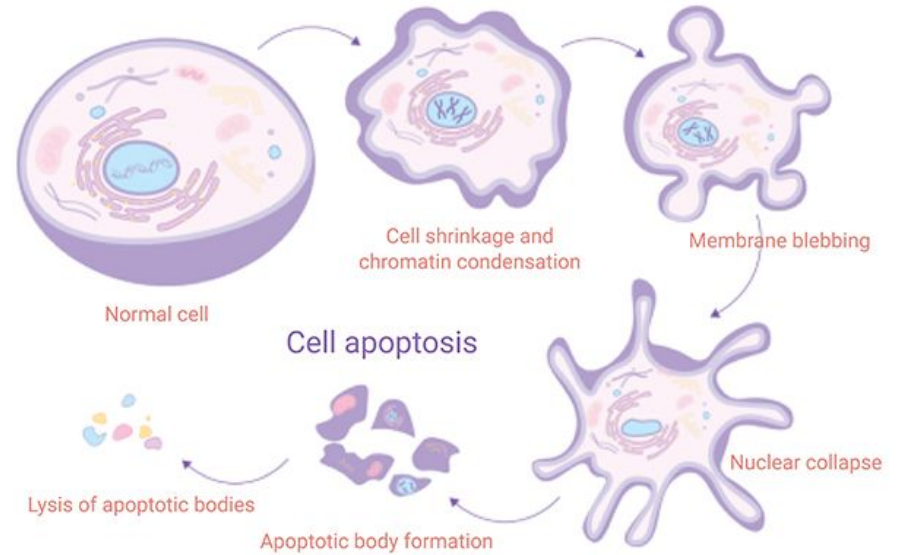
# NEUROTROPHINS



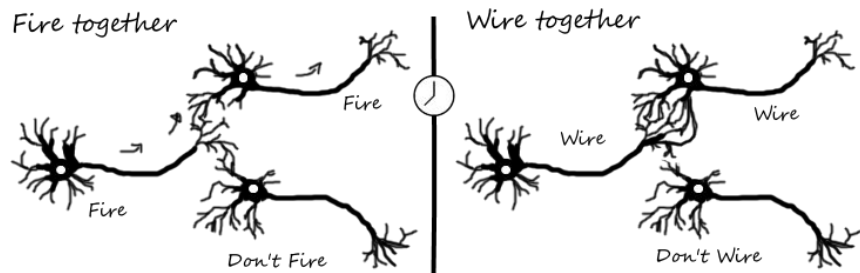
- chemicals that attract/repel and promote survival and activity of Neurons

# APOPTOSIS (PROGRAMMED CELL DEATH)

- Triggered by suicide genes
- As cells compete for connections, those who do not have connections die off
- Post-development, most remaining Stem Cells also die by the activation of their suicide genes

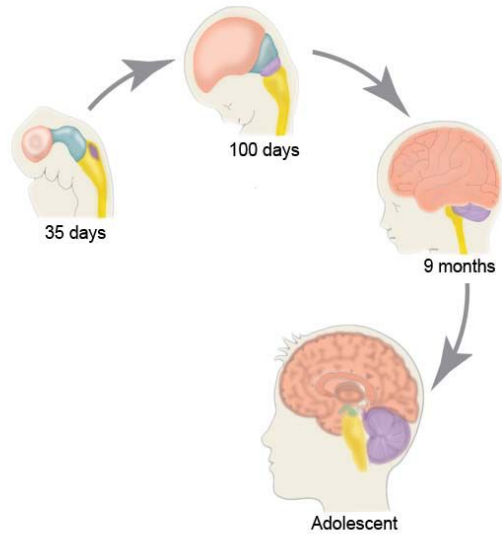


# CELLS THAT FIRE TOGETHER, WIRE TOGETHER

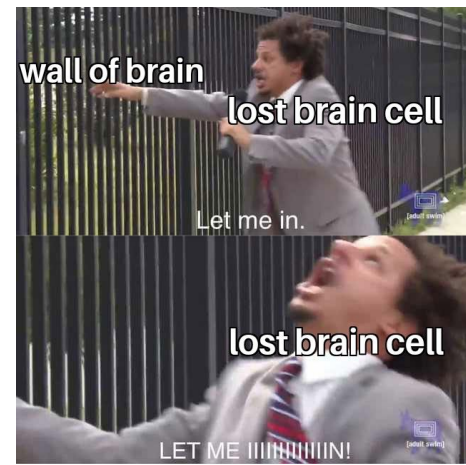


- Patterns of co-activity often determine outcome of competition
- Adjacent Presynaptic cells tend to correlate their bursts of activity, so tend to develop connections to adjacent Targets

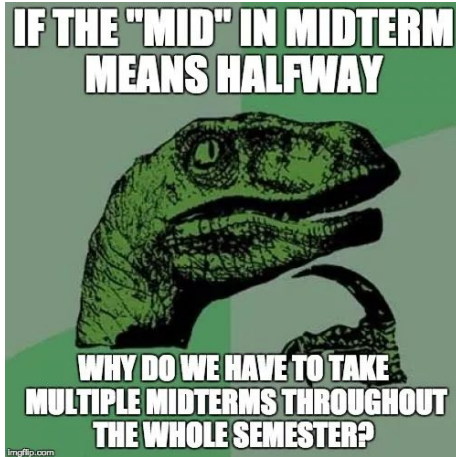
# FURTHER DEVELOPMENT



- Brain Growth
- Dendritic branching
- Further Synaptogenesis
- Myelination in neurons



GOOD LUCK ON YOUR MIDTERM!



# QUESTIONS?

Office Hours: Mon 5-6 pm

To get the section slides:

[https://github.com/JasonC1217/COGS17\\_A04\\_Wi24](https://github.com/JasonC1217/COGS17_A04_Wi24)

OR:

