COGS 17 Week 3

Winter 2024, A04

Slides Adapted From Previous Quarter

By: Jason Chen

Announcement

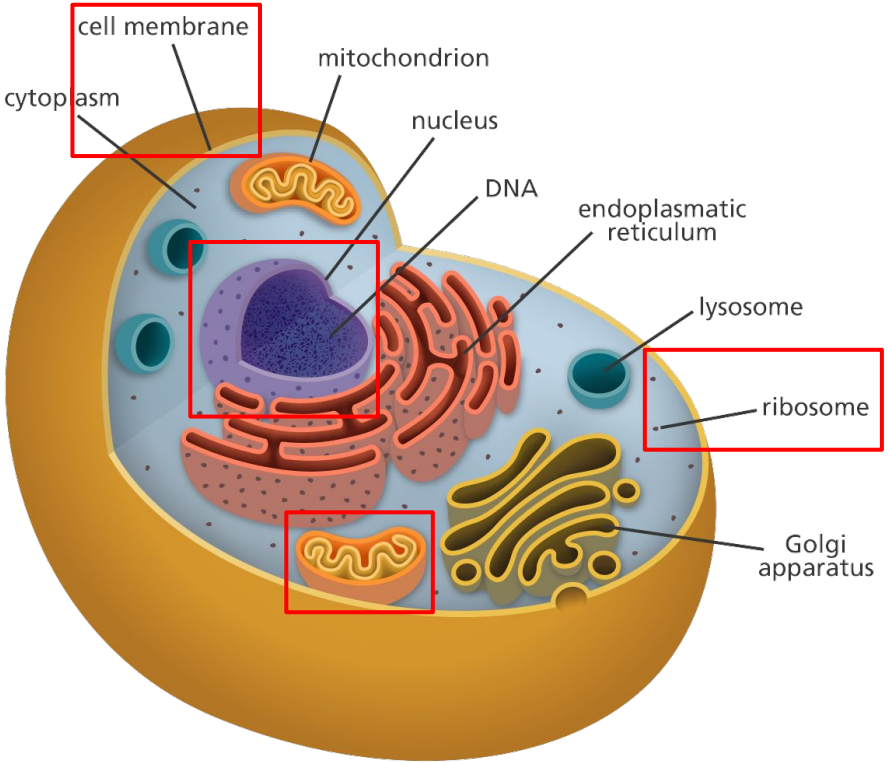
- Midterm On Jan 25, 2024 (Tomorrow) 3:30 - 4:50 pm
- 24 Questions, most of them require multiple responses
- 80 Minutes to complete
- One attempt
- You can revisit and change answers

Problem set for review

https://docs.google.com/document/d/1YWPDk2_ByvCgyB_ML0sywAihZWQYAjhzGUhepsGjQWM/edit?usp=sharing

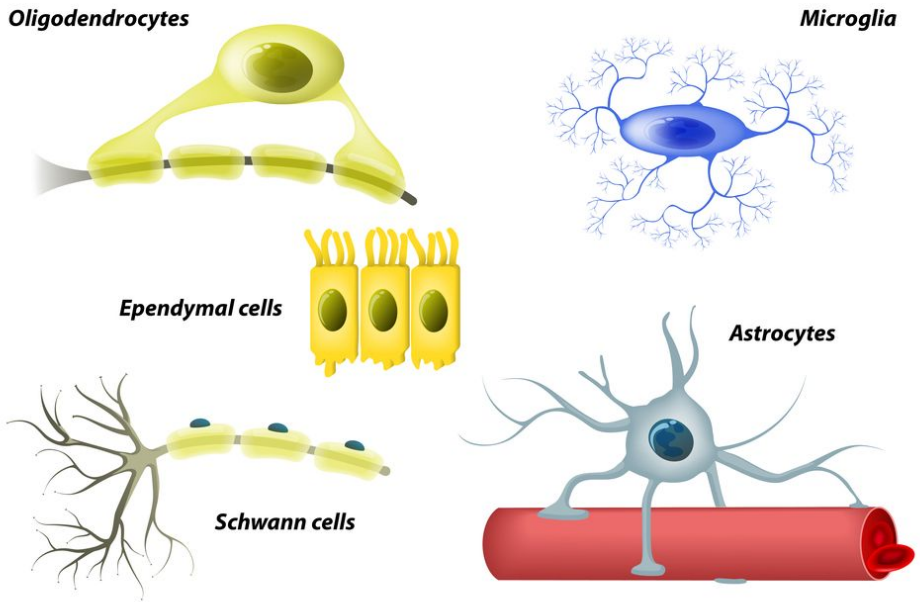
Cells

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

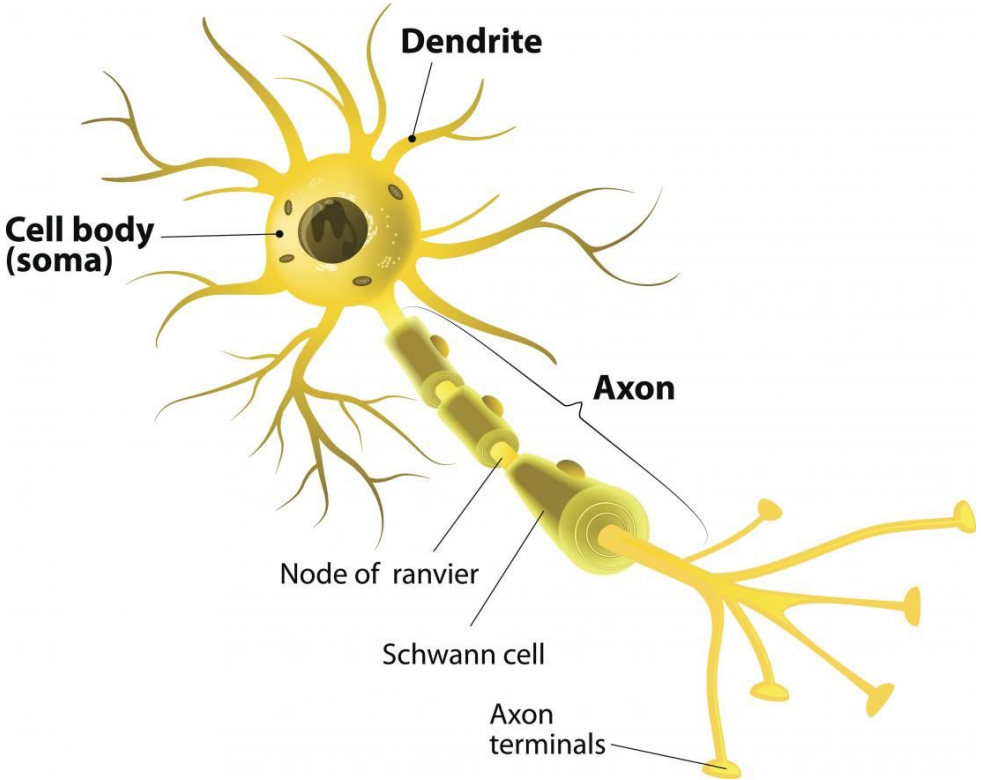
Glial Cells



- 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

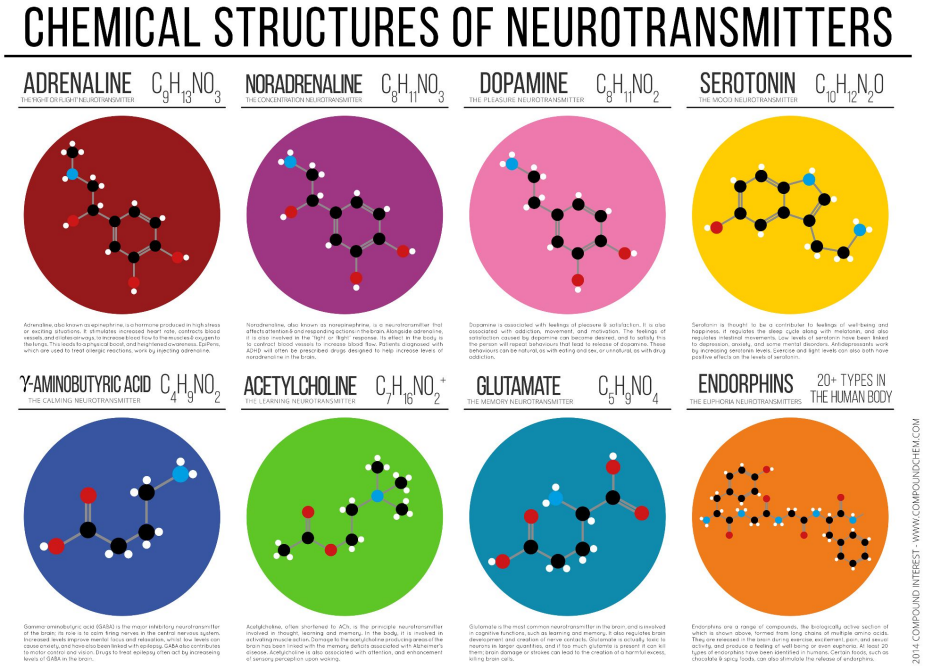
Neurons

- 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

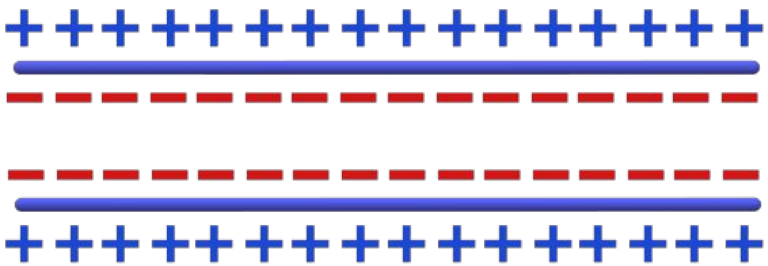


Neurotransmitters (NT)

- 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

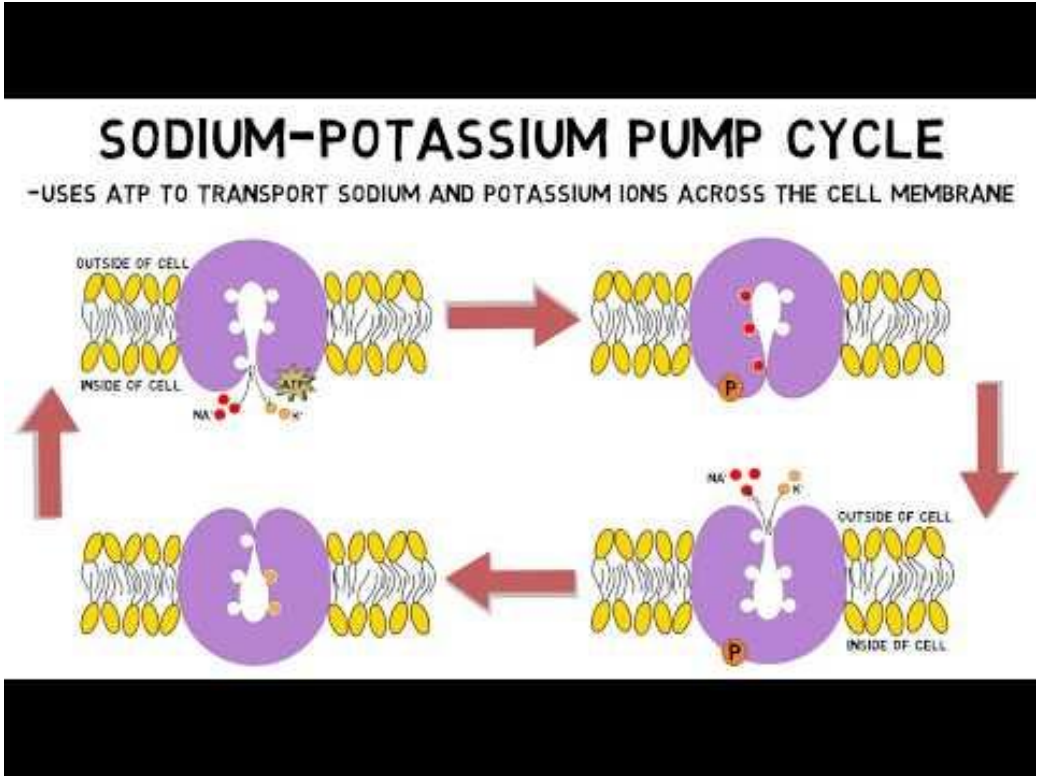


Resting Potential

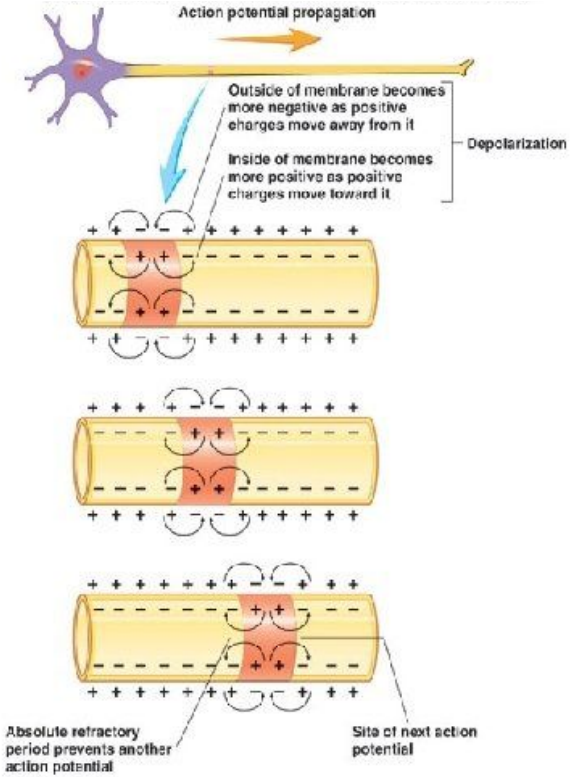


- Generally -70 mV
- More negative inside & more positive outside
- Established in part by Na-K pump, which actively transport 3 Na+ out and 2 K+ in
- Highly **POLARIZED** -- ready to “fire”

Sodium-Potassium Pump

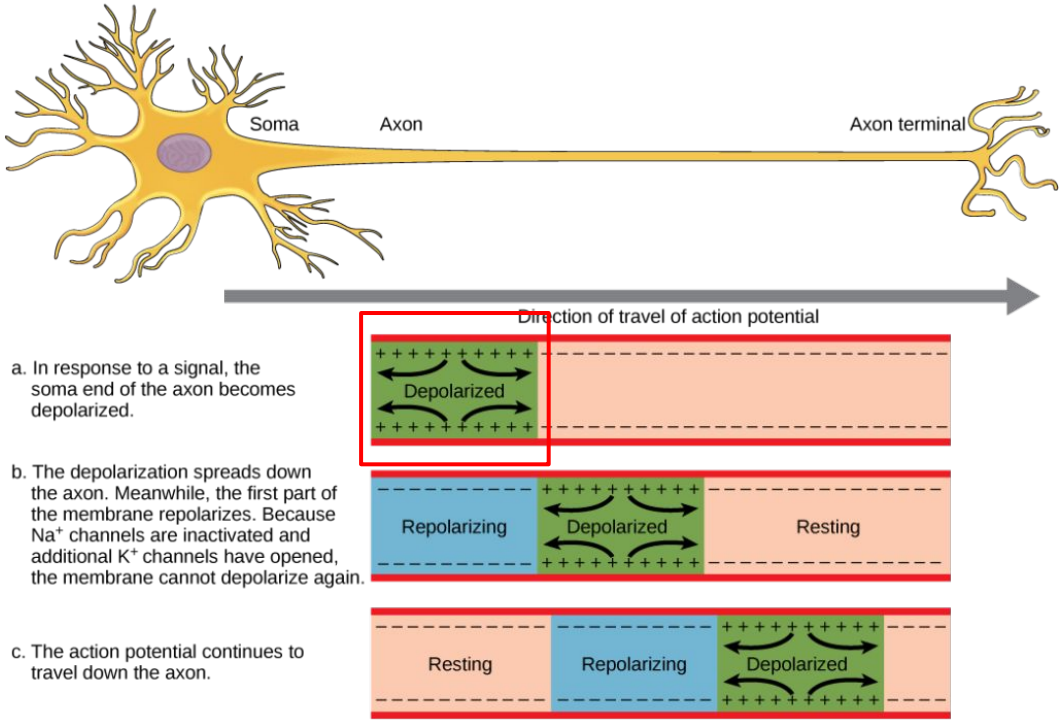


Action Potential



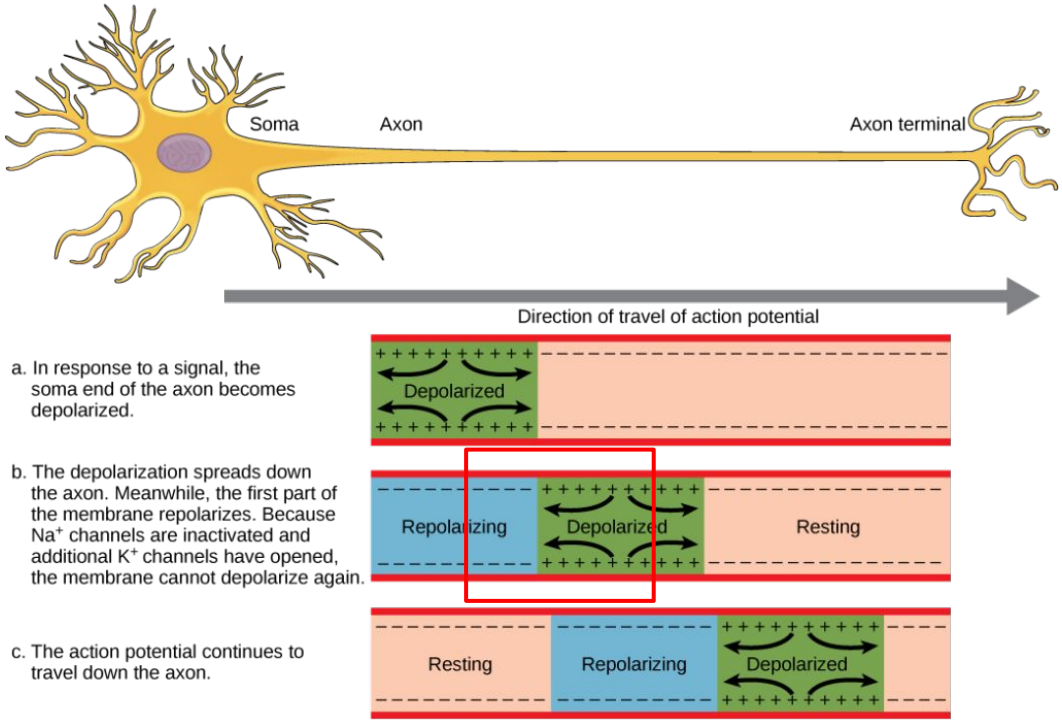
- **DEPOLARIZATION** of neuron
- Triggered by neurotransmitters from other neuron, electrical stimulation, or other stimuli
- Starting at Axon Hillock

Action Potential



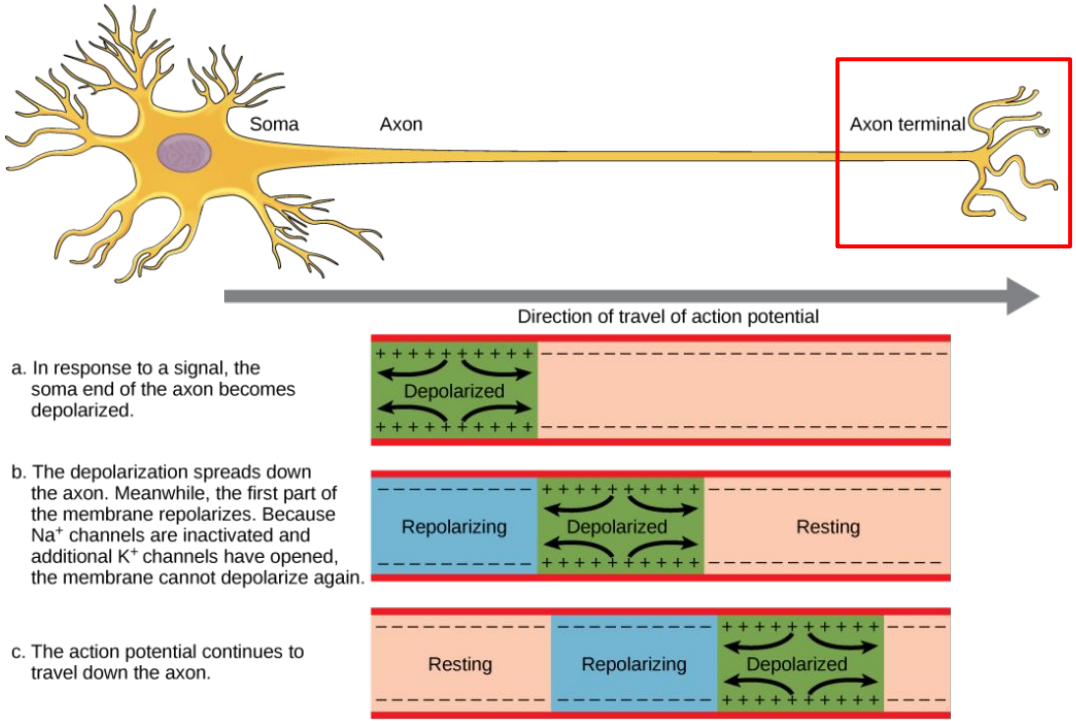
- Voltage-activated Na+ gates open -- Na+ in
- Reverse local polarization to ~ +50 mV
- Na+ influx causes adjacent Na+ voltage-activated gates to open & previously opened gates close
- Propagation of the action potential to the terminal

Action Potential



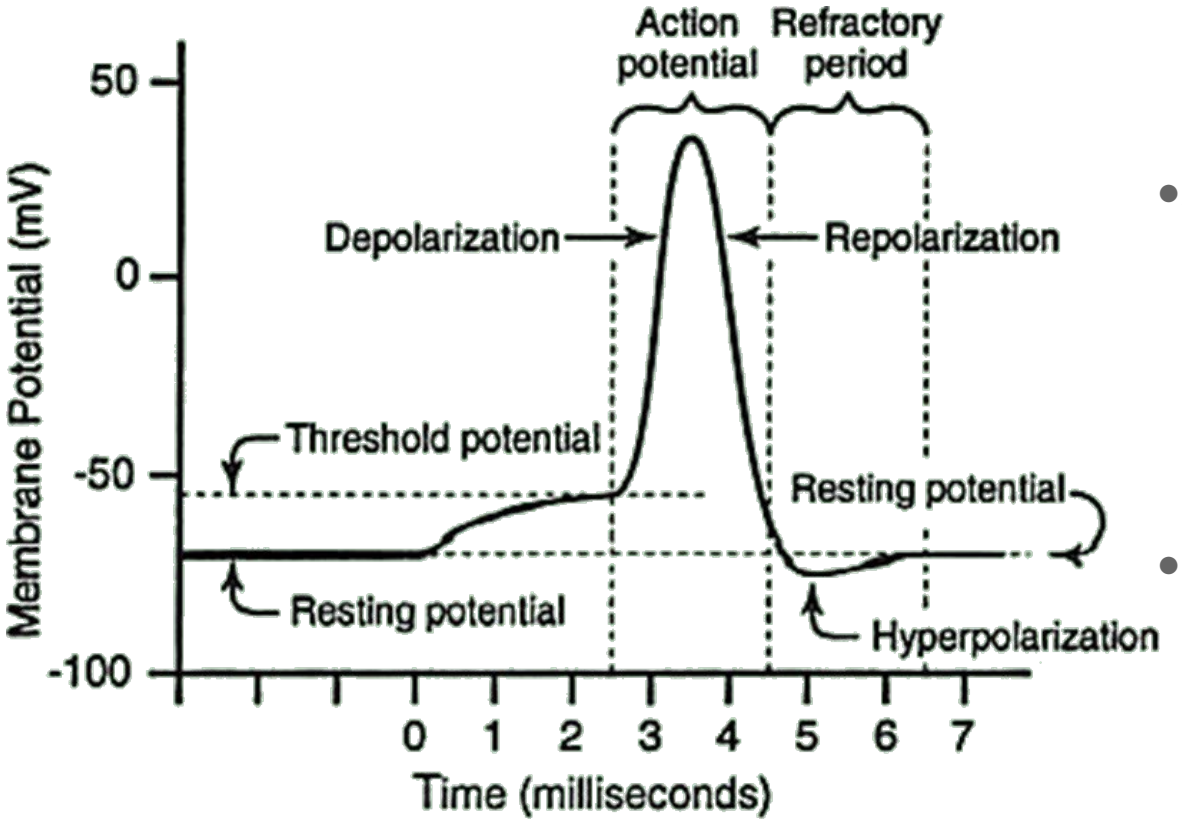
- As previous Na+ gates close,
  local K+ gates open -- K+
  leaves the cell
- Because of opened K+ channels & closed Na+ channels, the membrane cannot depolarize again
- Refractory period -- prevents backflow of action potential

Action Potential



- When reaches terminal, Ca2+ enters cell & Neurotransmitter released
- When outside becomes more positive again, K+ channels close
- Na-K pumps restore resting potential to -70 mV
- Ca pump reject Ca2+ from terminal
- Pumps require energy

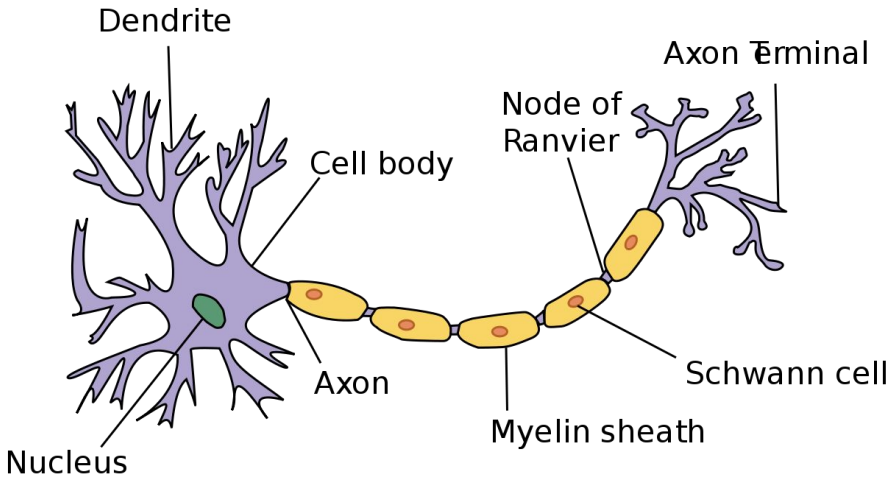
All-or-none Law



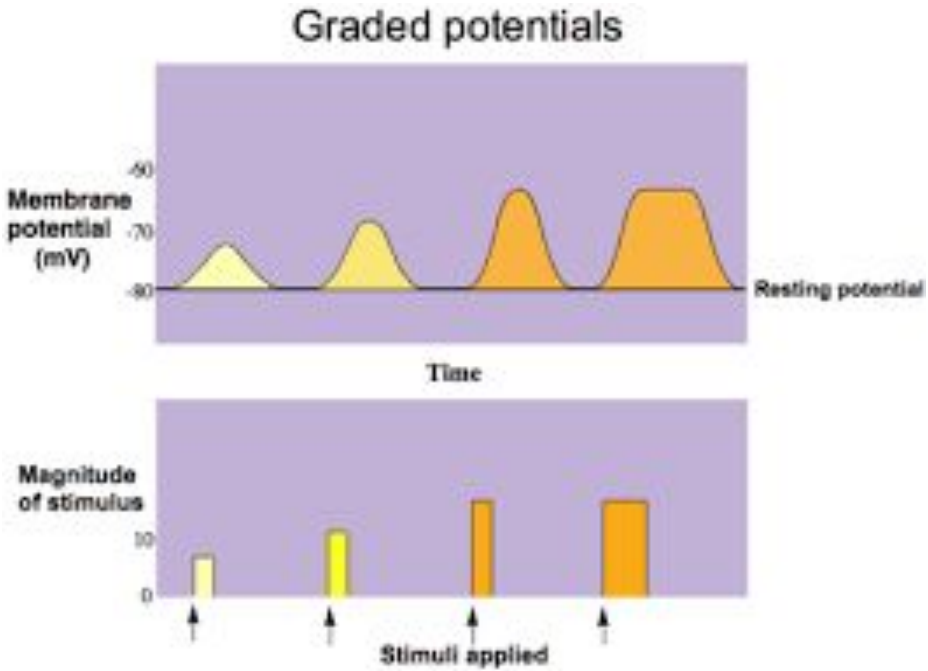
- An Action Potential always has the same amplitude and velocity,regardless of the intensity of the stimulus that triggered it
- Either full response or no response at all

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 shealth
- Saltatory Conduction -- “Jumping” of the signal from node to node along axon

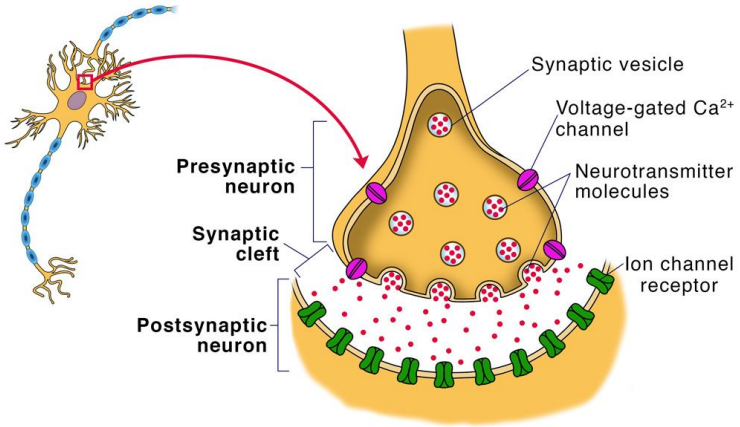


Graded potentials



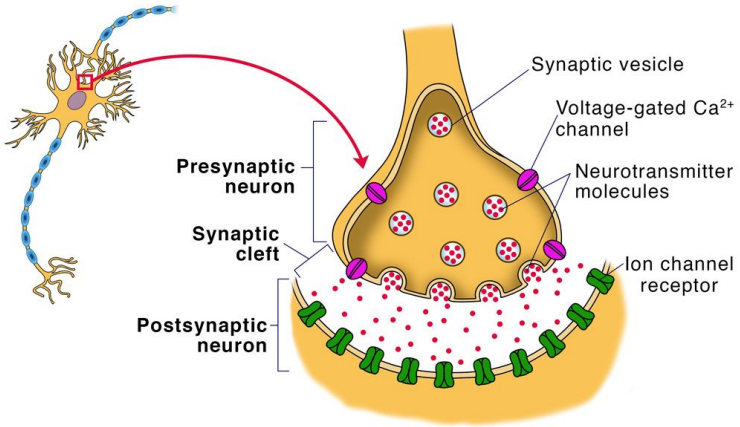
- Releasing NT from a Neuron does NOT always requires an Action Potential
- Can vary in amplitude
- i.e. Strong response due to strong stimulus; weak response due to weak stimulus
- Examples: some receptor cells (e.g. retina), lateral inhibitors, local Neurons, etc.

The synapse



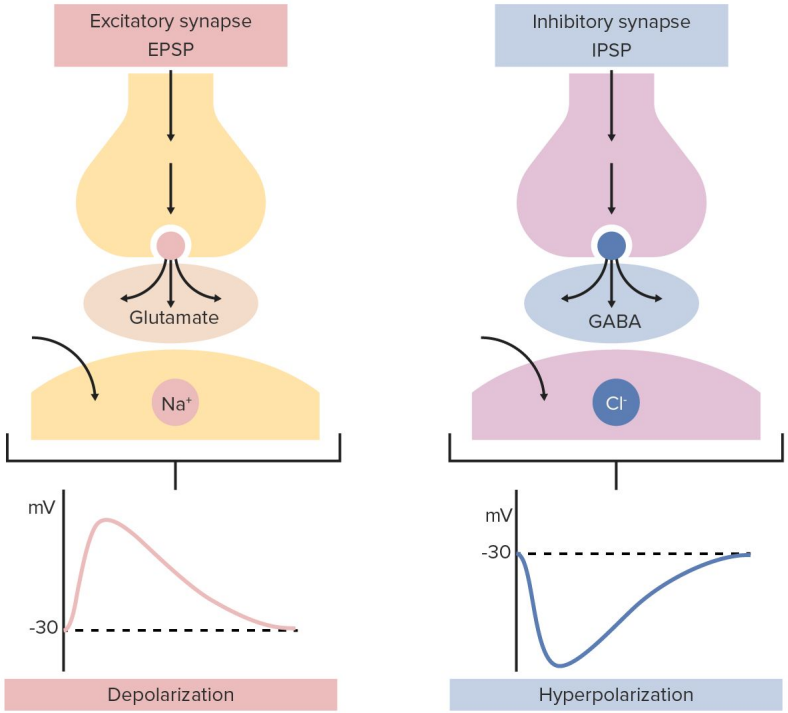
- Presynaptic cell releases NT into synaptic cleft, affects postsynaptic cell via Exocytosis (release of vesicles of NT).
- When membrane depolarization reaches the axon terminal, voltage-gated Ca++ channels open, causes influx of Ca++

The synapse



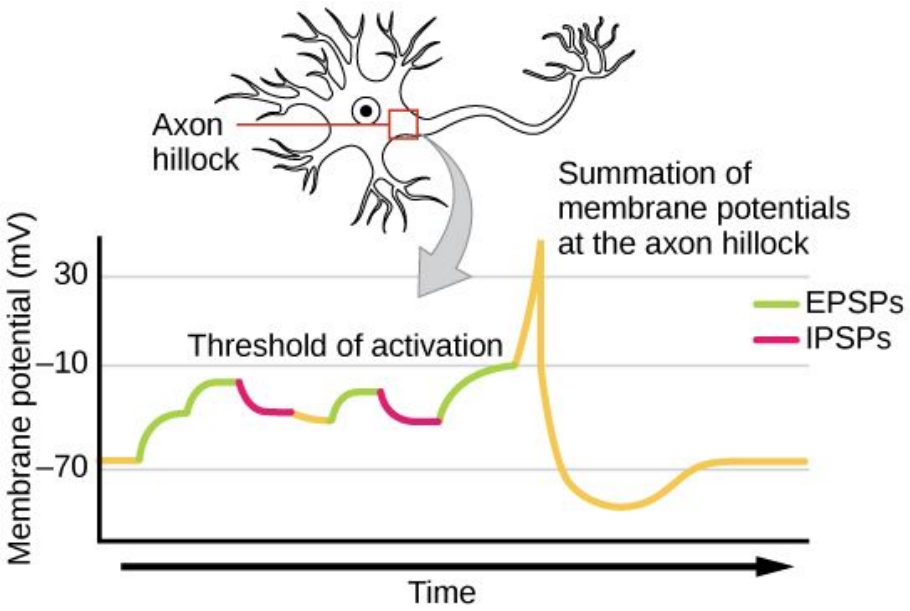
- NT passively diffuses across synaptic cleft
- NT binds to NT-specific receptor site on (usually) dendrites of postsynaptic cell
- Postsynaptic cell may fire its NT, etc.
- NT soon detaches from receptor
- NT is often then deactivated by enzymes or Glia

EPSP Vs. IPSP



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

Summation

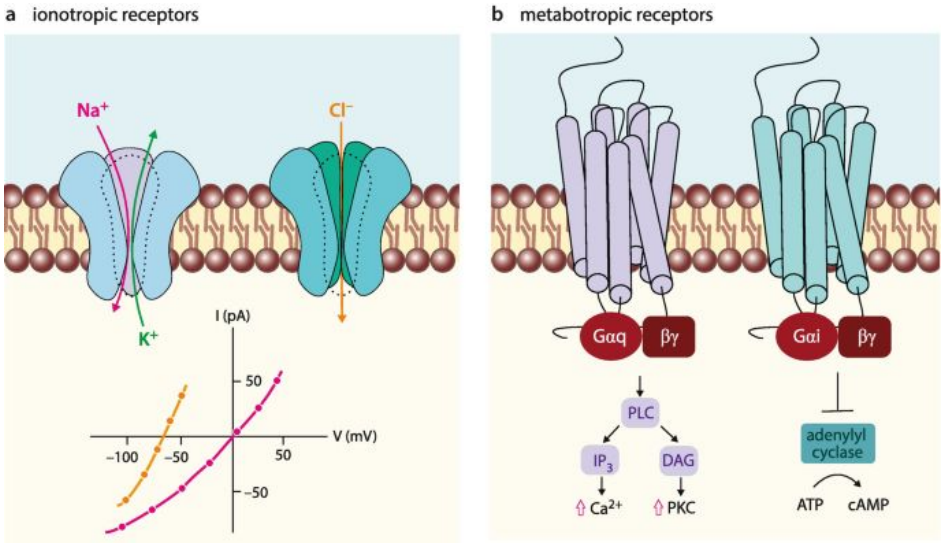


- The response of a given neuron is nearly always the product of a summation of EPSPs and/or IPSPs
- Two types of summation: Spatial summation and Temporal summation

Ionotropic Vs. Metabotropic

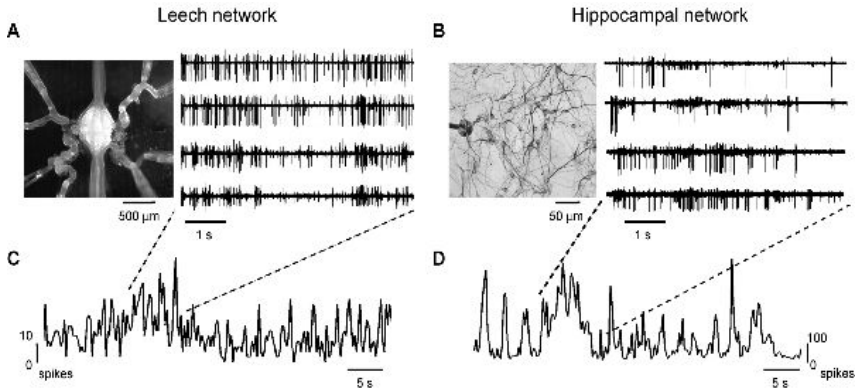
- Ionotropic: NT directly affects ion gates
  - Effects are rapid, short-lived

- 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



Spontaneous Activity

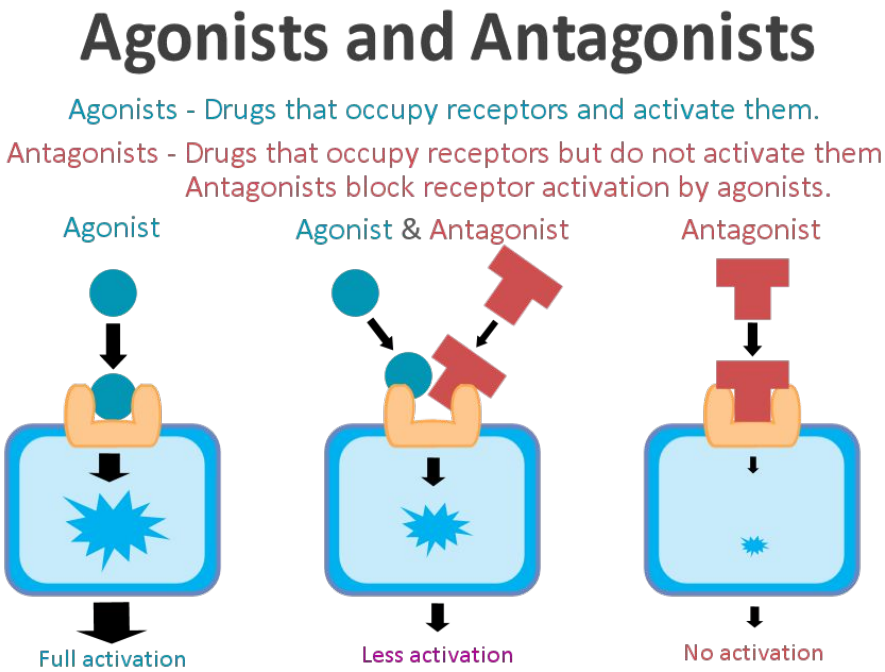
- Some Neurons show spontaneous Firing, in absence of incoming NT
- Usually graded potentials
- Converging NTs increase or decrease such cells' activity, modifying how much NT they will then release



Agonism Vs. Antagonism

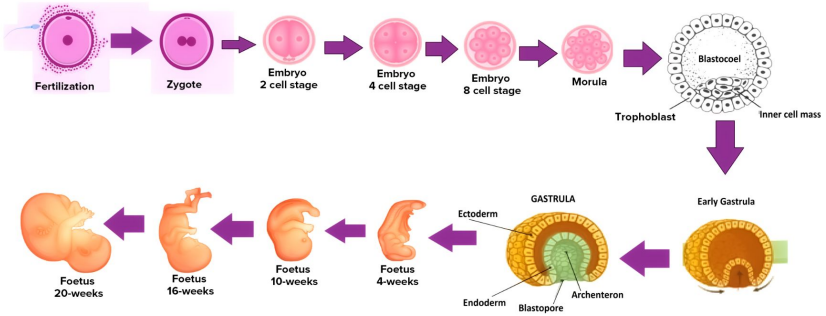
- Agonist: chemicals that increase effect of a NT

- Antagonist: chemicals that decrease effect of a NT



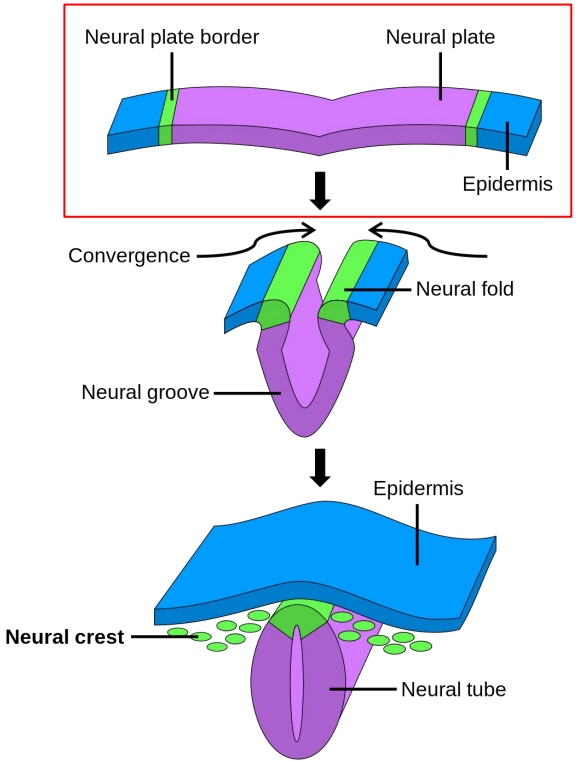
Development

Embryonic Development



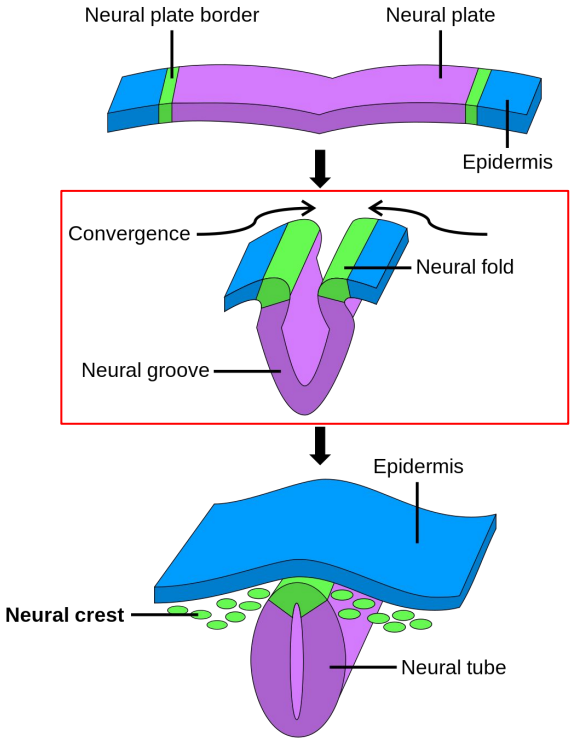
- A new embryo develops three cell layers: Ectoderm (outer layer, becomes nervous system & skin), Mesoderm (middle layer, becomes bones, muscles, blood vessels), endoderm (inner layer, becomes organs, glands)

Embryonic Development



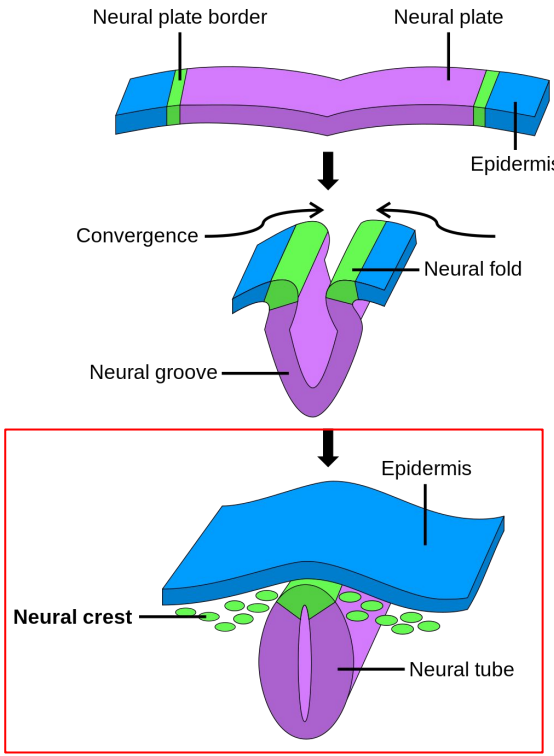
- Over first 2 weeks, embryo changes from a sphere of cells to an elongated “worm”, still 3 layered
- Then dorsal Ectoderm begins to thicken and forms hard Neural Plate

Embryonic Development



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

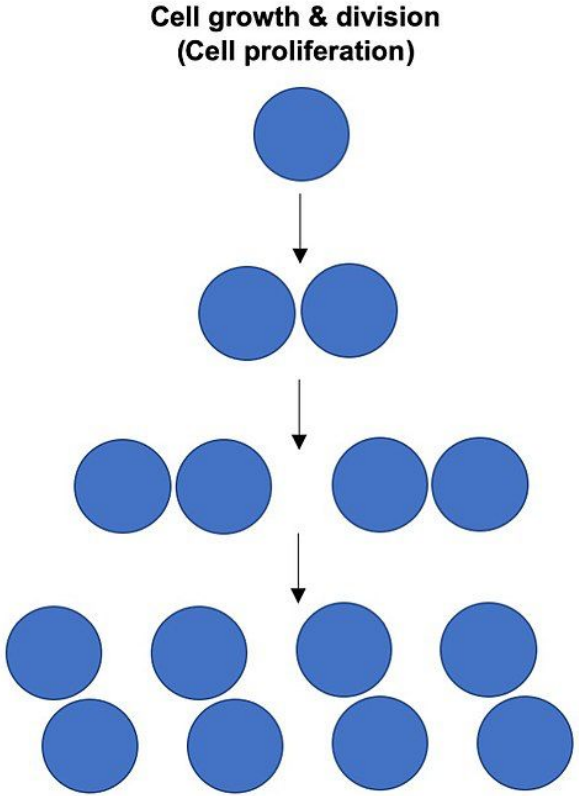
Embryonic Development



- 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

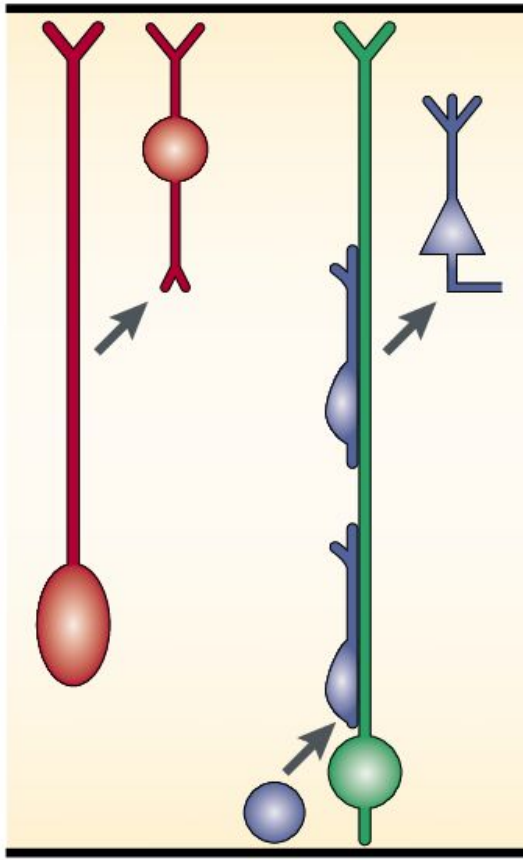
Proliferation

- 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

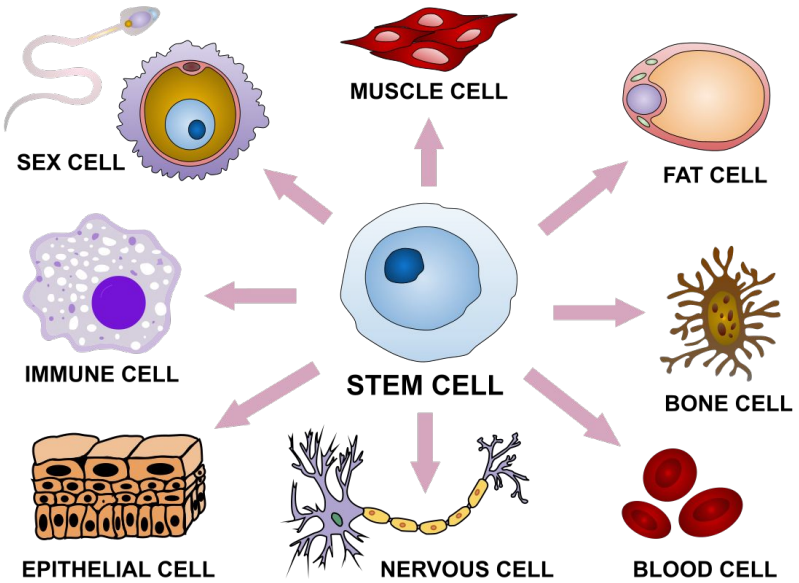


Migration

- 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



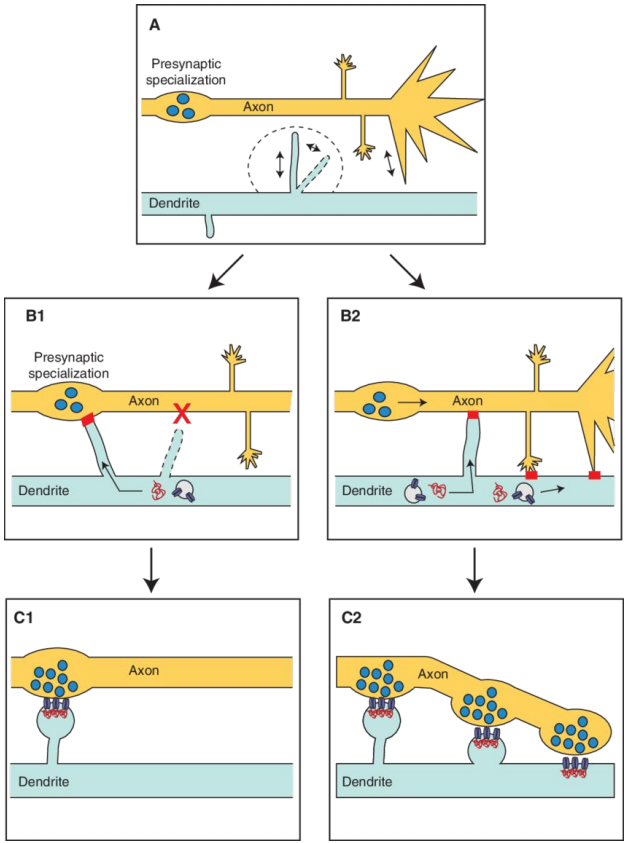
Differentiation



- Transition of a cell from one cell type to another

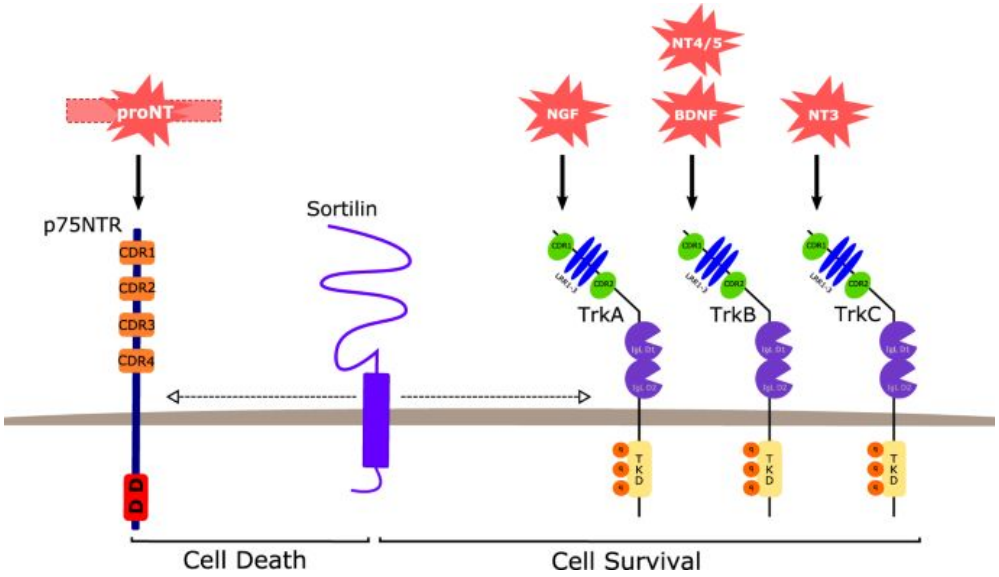
- Per Cell-Autonomous (genetic) and Induction (chemical influences from local environments) factors

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

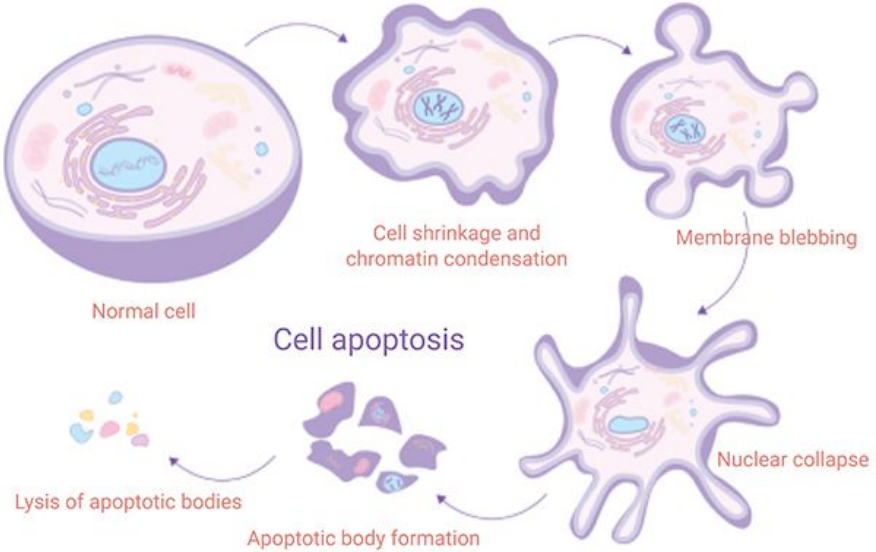
Neurotrophins



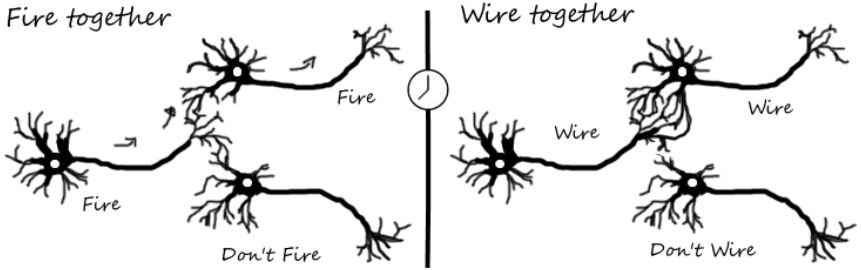
- chemicals that attract/repel and promote survival and activity of Neurons

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

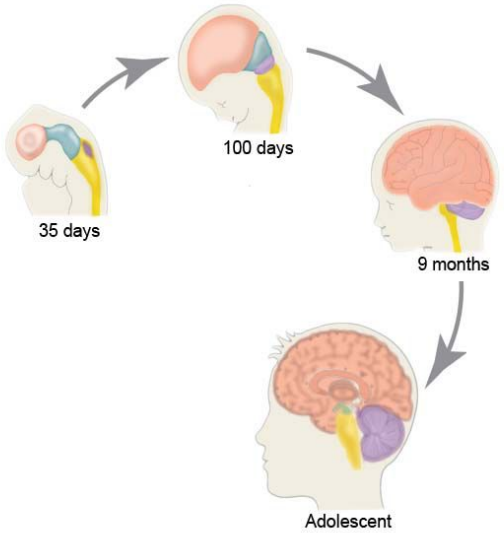


Cells that Fire Together, Wire Together

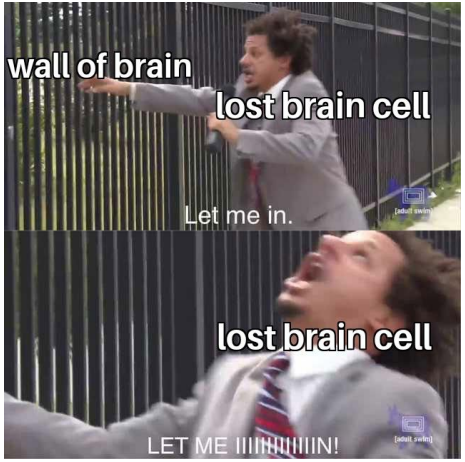


- Patterns of co-activity often determine outcome of competition
- Adjacent Presynaptic cells tend to correlate their bursts of activity, so tend to develop connections to adjacent Targets

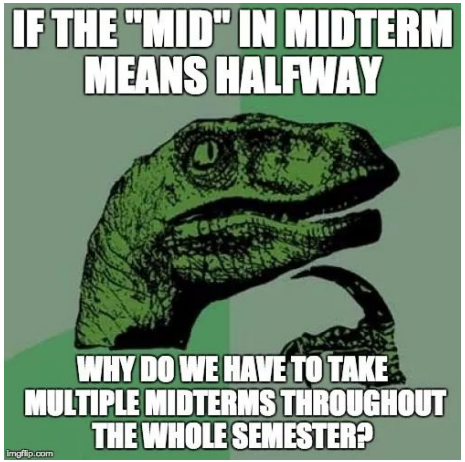
Further Development



- 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

OR: