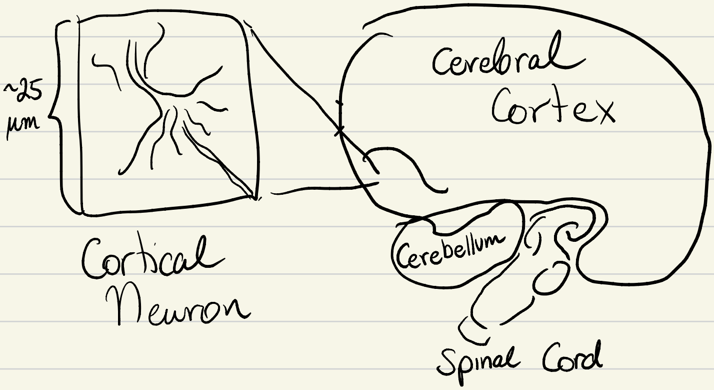
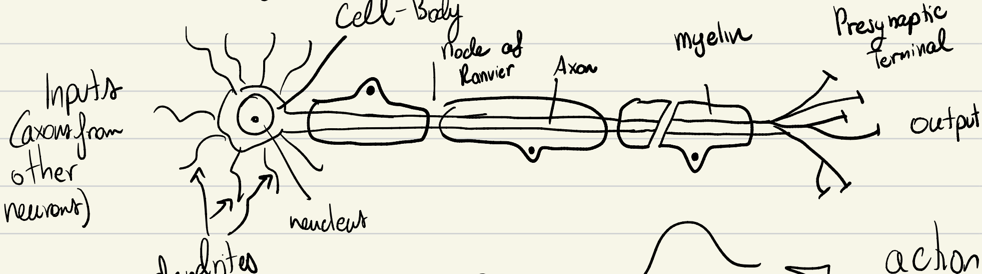
# ◦Neurons, Synapses & Brain Regions



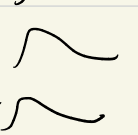

Neural Zoo: ∈ Visual Cortex (neurons), Cerebellum, Optic Tectum
- Visual Cortex: tree-root structure
- Cerebellum: tree-branch structure
- Optic Tectum: kinda mix based on depth

· Neuron Doctrine:
- Neuron is fundamental structure + functional unit of brain
- Neurons are discrete cells & not continuous
- Information flows from dendrites to axon via cell body

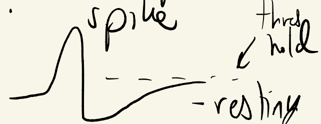
Idealized Model




EPSP
excitatory Post-Synaptic Potential

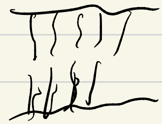


Σ: action-potential



Neuron - "leaky bag of charged liquid

- Contents enclosed within <u>cell membrane</u>




Cell membrane: lipid bi-layer
- bi-layer impermeable to charged ion species (such as $Na^+$, $Cl^-$, $K^+$)

- Each neuron maintains a potential difference across its membrane
  ↳ Inside is $-70mV$ relative to outside


- more sodium, chlorine & water than inside

- Ionic Pump maintains $-70\ mV$ difference by expelling $Na^+$ <u>out</u> & letting $K^+$ ions <u>in</u>

⇒ How do we influence Electric Personality?
↳ "How can elec. potential be changed?"

<u>Ionic Channels</u>: Gatekeepers
in membranes selective proteins' allowing only specific ions to pass (ex: $Na^+$, not $K^+$ or $Cl^-$)

# Ionic Channels are Gated

- Voltage gated: Depends on membrane voltage
- Chemically gated: Binding to chemical causes channel to open
- Mechanically gated: Sensitive to pressure/touch

# Gated Channels allow Neural Signaling

• Inputs from other neurons → chemically gated channels (@ synapses) open
→ Changes in local membrane potential

Synapse: Junctions b/w neurons

⇒ Causes Opening/closing of voltage-gated channels in dendrites, body, & axon resulting in depolarization (positive change in voltage)

or hyperpolarization (neg. change in voltage)

• Strong enough voltage causes polarization, causes a 'spike' or 'action potential'

To recap,

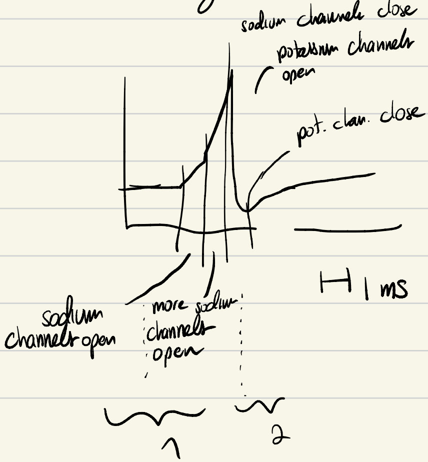
Spikes (Output) occurs from a neuron when

Other Neuron's outputs cause some of ~~the~~ gates to open & allow in a different concentration of ions, leading to a strong depolarization & increase chance of a spike.

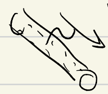
· Voltage-Gated Channels cause action-potentials (spikes)

1. Strong Depolarization opens $Na^+$ Channels, causing rapid $Na^+$ influx & more channels to open

2. $K^+$ outflux restores membrane potential

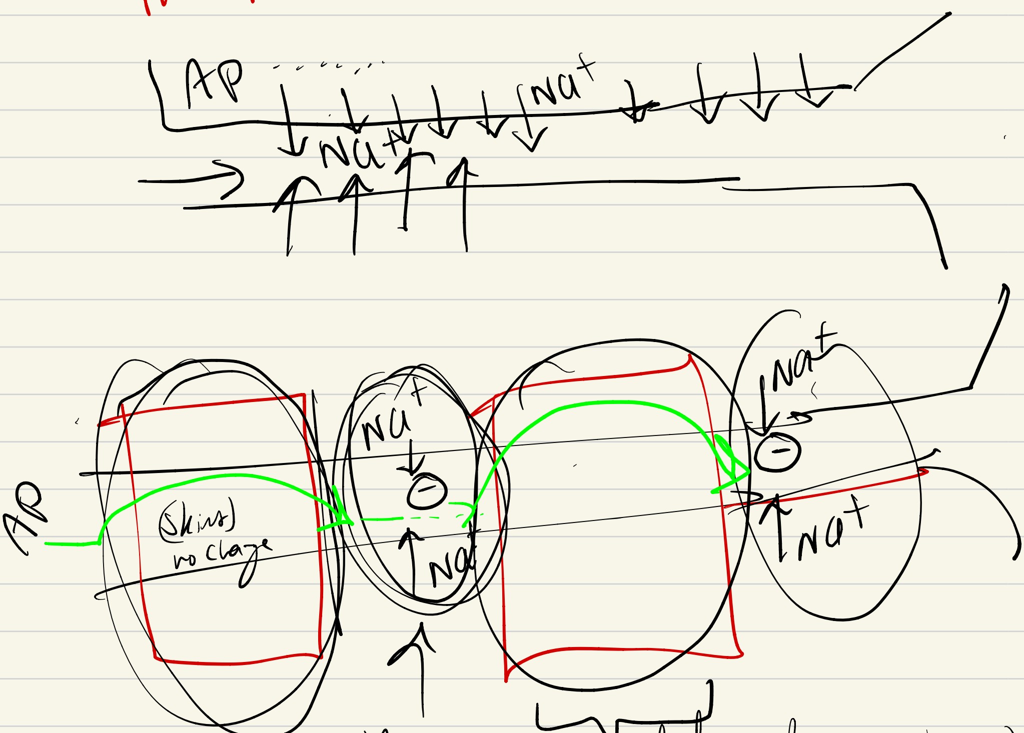



· propogation flows along Axon



# Myelination of Axons

nomyelin

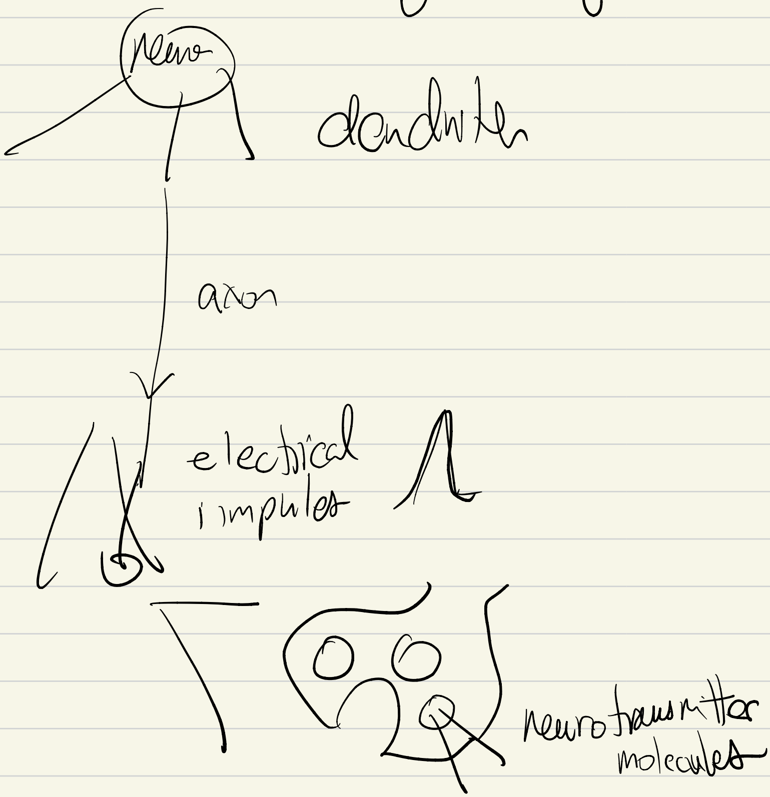



Node of Ranvier

(insulates from charge)

✱ due to oligodendrocytes (glial cells) wrap axons and enable fast-long-range spike communication

· AP "hops" from one node of Ranvier to another (saltatory conduction) "active wire" allows lossless signal propagation

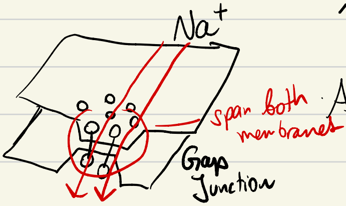


# Synapses

- What happens to the spike (action potential) when it reaches the end of the axon?

Synapse: Connection/Junction b/w two neurons

- Electrical Synapse: gap junction



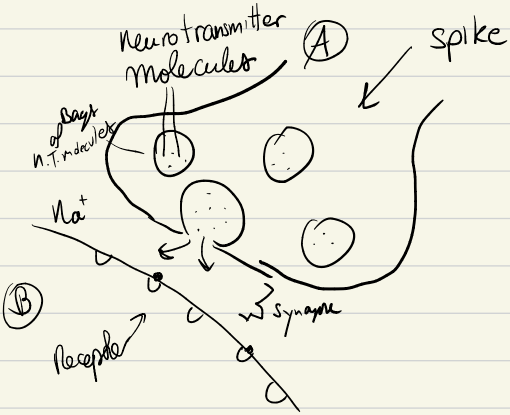

* Smooth

- Allow electrical activity of A directly comm w/ neuB via Gap Junction

Useful in fast connections

Chemical Synapse

use neurotransmitters




- basis for learning + memory in brain

• Synapses can be excitatory or Inhibitory

increase or decrease postsynaptic membrane potential

$$A := \text{pre}$$
$$\Big\downarrow \text{synapse}$$
$$B := \text{post}$$

Excitatory: Input spike → neurotransmitter release (eg glutamate)
→ Binds to ion channel receptors
→ ion channels open
→ $Na^+$ influx
→ Depolarization due to EPSP (excitatory postsynaptic potential)

Synapse Doctrine

Synapses are basis for memory + learning

How do Brains learn? Synaptic Plasticity

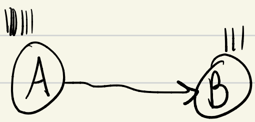
Hebbian plasticity: If neuron A repeatedly takes part in firing Neuron B, then the synapse from A to B is strengthened.

$$A \to B \;\Rightarrow\; A \longrightarrow B$$

Mantra: Neurons that fire together wire together

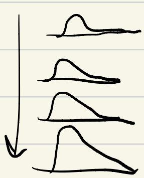
LTP: Long Term Potentiation

LTP = Experimentally observed increase in synaptic strength that lasts for hours or days

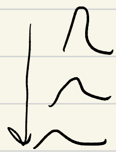



Inverse: Long Term Depression
observed decrease

Increase in EPSP size over time for same input



time



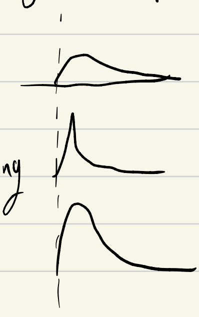
LTP/LTD depends on relative timing of input/output spikes

Input spike before output spike

EPSP before

Input-Output pairing

EPSP After



A fired first → B fired after

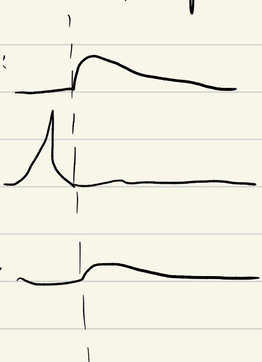
LTP

Reverse: Input spike occurs after output spike

before:

pairing

after



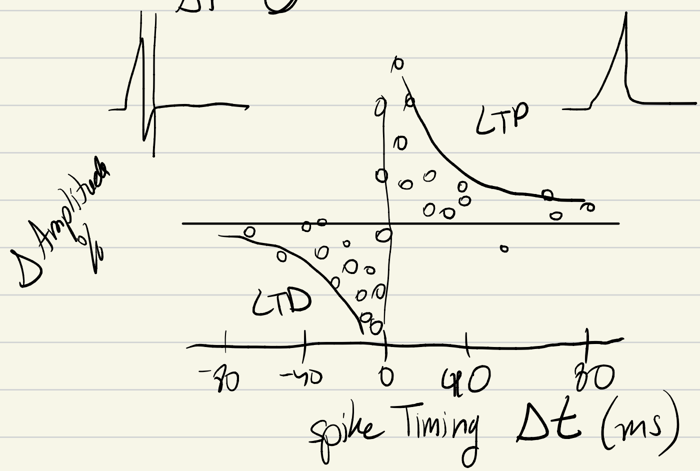
*Output neuron fires before input neuron due to inputs B receives from other neurons

LTD

# Spike-Timing Dependent Plasticity

Input after output
$\Delta t < 0$

Input before Output




·very sensitive to timing

Know about Channels, neurons, synapses

Not knowledge about neural networks + consciousness
cognition

# Organization + Function of Nervous System

Peripheral Nervous System (PNS) | Central Nervous System

· Somatic : Nerves connecting to voluntary skeletal muscles + sensory receptors
· Automatic

↳ Send commands to muscles & get textile info from senses called sensory receptors

Afferent: Nerve Fibers (incoming): Axons that carry info away from periphery to CNS

Efferent: Nerve Fibers (outgoing): Axons carrying info from CNS to periphery

Central Nervous System (CNS)
↳ Spinal Cord + Brain

Spinal Cord:
↓ responsible

* Local feedback loops control reflexes ("reflex arcs")
  ie moving hand away when burned subconciously
* Descending motor control signals from brain activate spinal motor neurons
* Ascending sensory axons convey ~~sens.~~ info from muscles + skin back to brain

CNS = Spinal Cord + Brain

Hindbrain: • Medulla Oblongata - controls breathing, muscle tone + blood pressure

Pons: sleep + arousal

Cerebellum - Coord + timing, volunt. movement, language.

Midbrain: Eye-movement, visual + auditory reflex

• Reticular Formation:

• Thalamus - "Relay" station for $\forall$ sensory info (except smell) regulates sleep + wakefulness

HypoThalamus: Regulate basic needs

Fighting, Fleeing, Feeding, Fucking (Mating)

Cerebrum: Cerebral cortex, basal ganglia, hippocampus, amygdala

↳ perception, motor control, cognition, memory, language

Cerebral Cortex: Convoluted cerebrum, about 1/8th of inch thick

~ 30 billion neurons

Each neuron ~ 10,000 synapses

⇒ 300 trillion connections total

6 layers
- rel. uniform
- common computational principle

1 ⇐ (input here)
2+3 ⇒ output to 'higher' cortical
input ⇒ 4
output to sub regions ⇐ 5
⇐ 6

?∃ common computational principle operating across cortex.

Try to understand comp through brain via 3 models.

# Neural V. Digital Computing

Human brain: $10^{11}$ neurons ($10^4$ conn each)

Silicon: $10^{10}$ transistors

Biology: 100µs temporal resolution

Digital: 100ps clock (10 GHz)

° Computing Paradigm

Brain: Parallel computation + adaptive connectivity
Digital: Seq. computing

Capabilities: D