Mid 1

29 January 2023 04:50 PM

Next Gen HCI → Brain computer interaction (4)

Virtual reality (1) | Augmented reality (2) | 3D Holographic projection (3)

industries

Attention monitoring → comms

Real time applications → Auto motion, Device control, Games

Brain → most near spine & central part.

1.5 kg with 10^{-10} to 10^{11} neurons → electrochemical signalling

Activities

- Facial neurons and Speech
- Sensation of Taste
- Decision Making

- Sensation of Smell
- Interprets Smell

- Processing of tactile information
- Awareness of body in space
- Controlling movements of the body

- Sight
- Interprets Information (Image recognition and image perception)

- Responsible for hearing
- Language comprehension

Brain targeting

- invasive — into the brain, cutting, etc.
  - cortical surface (ECoG)
  - intracortical — penetration of electrodes in the cortical region
- non-invasive — not into the brain
  - EEG — recording & monitoring EEG signals from the scalp
  - MEG — uses magnetic field to induce EF
  - fMRI
  - fNIRS

Neurons → receive info from 100s & process & send to 100s

- inside & outside → maintains ratio of anions & cations
- ↑ producing e^- charge → neuron firing
- approx 100 dendrites
- electrochemical signaling {responsible} → input from other cells from dendrites & send through axon.

Workflow of BCI Architecture:

user (initial) → signal acquisition → BCI {signal processing} → feature extractor → feature translator → user application → end

- Signal enhancement
- Artifact processing
- Noise removal
- Feature identification
- Feature selection
- Dimension reduction
- Post processing
- Feature classification

From brain to spinal cord & cord to rest

Nervous system

- sensory: send info to spinal cord.
- motor: send nerves to the rest

sensitive to factors ↑ BCI

filtering techniques : Bandpass

Independent component analysis
Principal component analysis

Feature extraction ↓

BCI signal processing

techniques

Artifact removal :
- Independent component analysis
- Principal component analysis
- Sparsity-based methods
- Wavelet-based methods

Channel selection :
- Common spatial
- sequential feat forward

Feature extraction
- Statistical features
- Derivative features
- Time domain features
- Frequency domain features
- Wavelet domain features
- Entropy features
- Cross-correlation features

Reasons for feature selection
- Eagy to interpret after simplication
- Shorter training times
- Avoid curse of dimensionality
- Reduced over fitting

Feature classification
- ML algos: SVM, LDA, kNN,
- DL algos: RBM, CNN, LSTM,
- optimisation techniques : Sparsity approach

Motivation for BCI's
- Potential for restoring lost sensory and motor function
- To control prosthetic devices such as prosthetic arms or legs for amputees and patients with spinal-cord injuries
- Wheelchairs for paralyzed individuals
- Cursors and word spellers for communication by locked-in patients
- Sensory prosthetic devices such as cochlear implant for the deaf, retinal implant for the blind

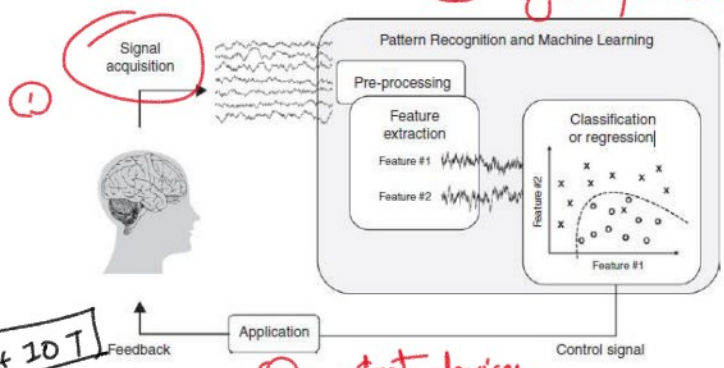
3 parts

A system which can translate thoughts

Brain computer Interface
- signal acquisition.
- signal processing
- output device
- provides interface for connection

BCI Applications / Domains / Fields it is working on
- Device Control
- User State Monitoring
- Training and Education
- Games and Entertainment.
- Cognitive improvement
- Safety and Security

(2) signal processing



(1)

(3) output devices

(1) prevention
- smoking
- alcoholism
- motion sickness

BCI + IOT

Medical Applications
- neuromarketing & advertisement
- neuroergonims & smart env.
- prosthetic arm & leg

(2) detection and diagnosis
- tumors
- brain disorders
- sleep disorders

(3) rehabilitation and restoration
- brain stroke
- disability
- psychological disorders

Challenges :
- Usability
- Hardware
- Signal processing
- System integration
- Cost

diagnosis	• brain disorders • sleep disorders	rehabilitation and restoration	• brain stroke • disability • psychological disorders

Cost

leaky bag of fluid.

Neuron

membrane: passage of few ions

of a lipid bi-layer that is impermeable except for openings called ionic channel.

CNS & PNS

Nervous System

Central NS

Peripheral NS

nerves connected to muscles, etc

PNS

also heart.

Somatic (skeletal NS.) — out: Efferent (from CNS to periphery); incoming: Afferent (to CNS from periphery)

Brain

CNS

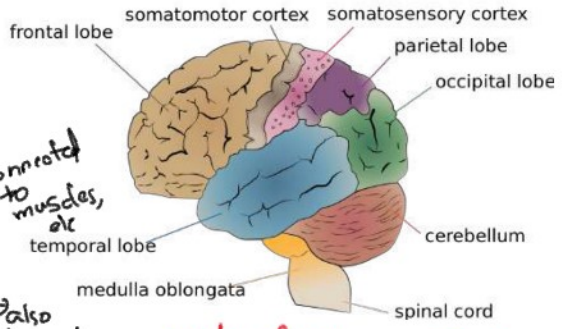
Nerve cord

spinal cord

in & out of CNS

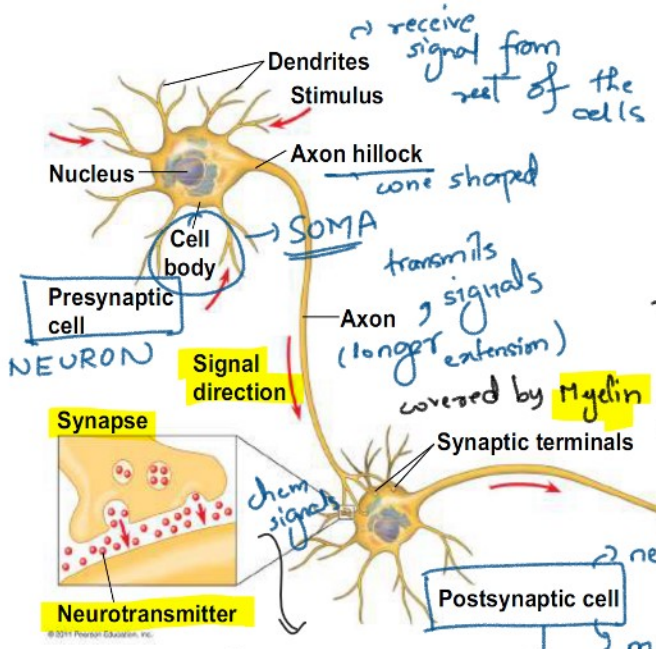
nerves

↳ voluntary skeletal: somatic (skin) & automatic (heart)

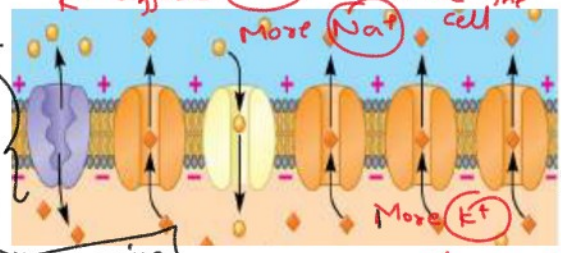


parts of Human Brain

workflow: sensors detect internal info & external info through sensory neurons → sensory info → Brain contains interneurons which integrates the info → output travels through motor neurons & trigger muscle activity

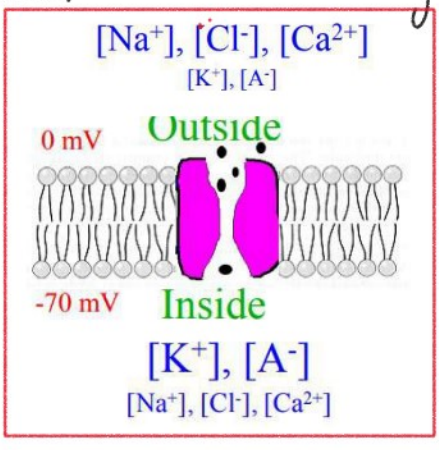


junction between axon & another ← interconnection



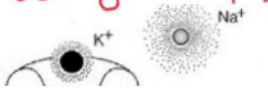
Transmission — processing

Resting potential — only contains more K+ open channels — membrane potential of a neuron not sending signals



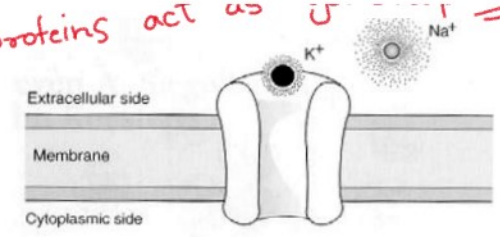
How does voltage change then in a neuron?

proteins act as gatekeepers



Through Ionic channels → depends on mem V → voltage-gated

proteins act as



Through **Ionic channels**

- open & close based on stimuli
- gated
  - voltage-gated (dep- ↑ mem V)
  - Chemically-gated → only open to some chemicals
  - Mechanically gated → sensitive to pressure & stretch

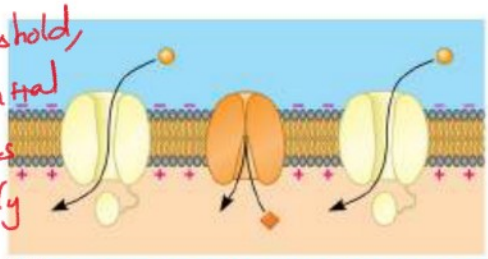
Chemically gated: ① change in local membrane potential.

↓

depolarization (+ve change) or **hyperpolarization** (-ve change)

Generation of Action potential (steps):

After threshold, the potential increases drastically

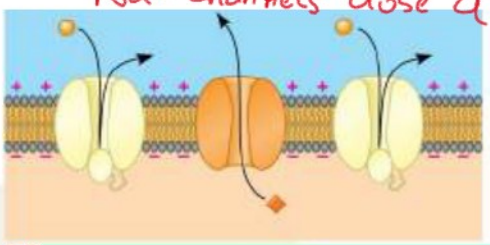


3 Rising phase of the action potential

Key: Na+, K+

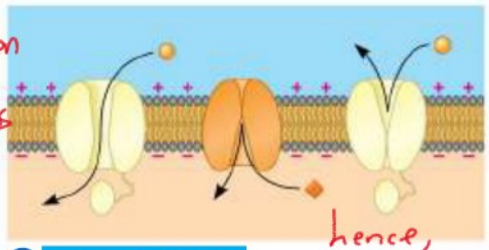
Na+ channels close & K+ open

K+ flows out of the cell.



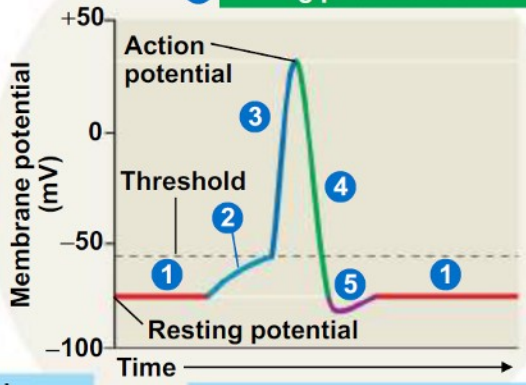
4 Falling phase of the action potential

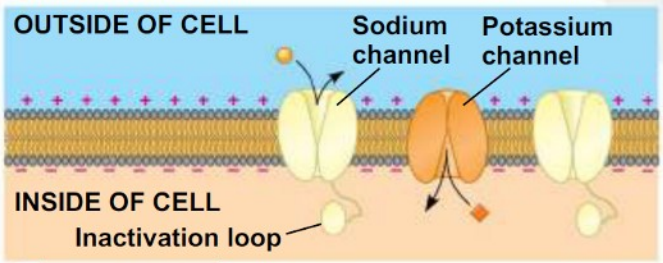
Na+ open first & Na+ flows into the cells



2 Depolarization

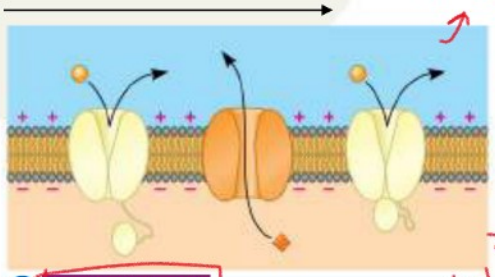
hence, increases





1 Resting state

most Na+ & K+ are closed → maintaining **resting potential**



5 Undershoot

Here K+ is higher

K+ ions channels close & resting potential restored

inactivation channels of Na+ & K+ is hard second time

Due to **refractory period** after an action potential,

When an action potential arrives from a presynaptic neuron, it causes the release of chemicals known as neurotransmitters into the synaptic cleft. → Gap

⇒

These chemicals in turn bind to the ionic channels (or receptors) on the postsynaptic neuron, causing these *channels to open*, thereby influencing the local membrane potential of the postsynaptic cell.

neuron, muscle, gland

membrane potential alters

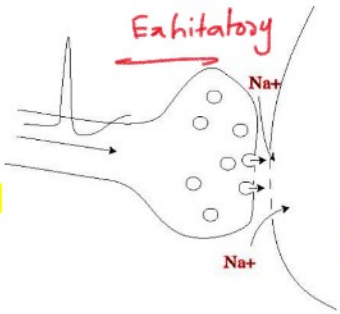
Synapses ⇒ based on the kind of synapse it forms with postsynaptic neurons

Excitatory

Increase in V of postsynaptic ↓ EPSP ↓ Lead to higher P of firing a spike

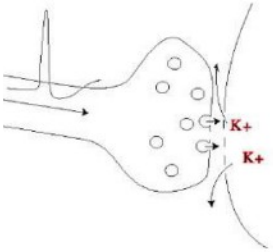
Inhibitory

opposite to Ex Temporarily decrease the local membrane potential. IPSP



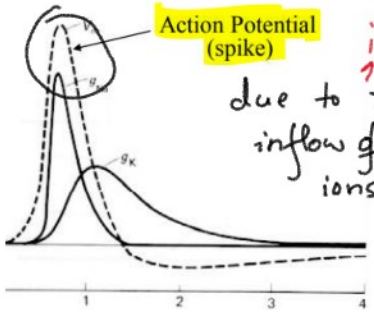
Exhitatory

Input spike → Neurotransmitter release → Binds to Na channels (which open) → Na+ influx → Depolarization due to EPSP (excitatory postsynaptic potential)



Input spike → Neurotransmitter release → Binds to K channels → K+ leaves cell → Hyperpolarization due to IPSP (inhibitory postsynaptic potential)

Inhibitory



(spike) increase ↑ due to rapid inflow of Na+ ions (or) outflow of K+ ions ↓ decrease

When the neuron receives sufficiently strong inputs from its synapses for its membrane potential to cross a neuron-specific threshold, a spike is emitted.

(After Threshold)

LTP Long Term potentiation ↑ for hours or more

Increase in synaptic connection between 2 neurons caused by correlated firing of 2 neurons

depression (drop)

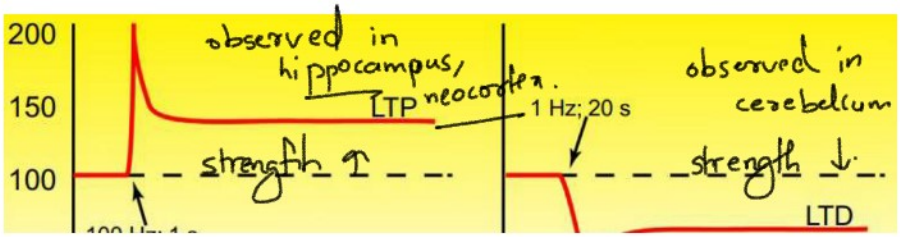
LTD → Decrease in strength of synaptic connection caused (uncorrelated firing)

observed in. Cerebellum

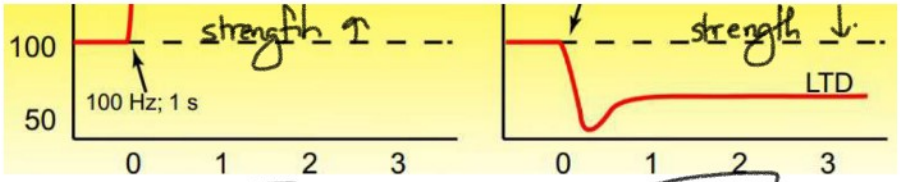
Measured by increase in excitatory EPSP caused by presynaptic spikes.

if neuron A fires neuron B strength needs to increased

found in regions → Hippocampus, Neocortex, etc



BCI design depends on which part of the brain to record from & stimulate.



LTP

LTD

which part of the brain to record from & stimulate.

Breathing ← BP ↑ → muscle tone

Medulla

connects with cerebellum

Pons

sleep & arousal

Major parts of Brain

controls reflexes

Descending motor signals

Ascending sensory signals

Brain

Autonomic & CNS

heart

glands

blood vessels

spinal cord

cerebellum

voluntary movements

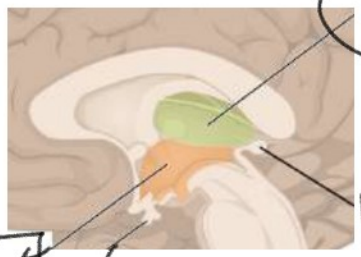
equilibrium

midbrain

eye mov

visual rf

audio rf



Thalamus

all sensory info except smell

pineal gland

Hypo thalamus

pituitary gland

fighting fleeing feeding & mating

memory ↑ ↗ perception & motion control

Cerebral Hemispheres ∴ ↗ cognitive functions

↘ emotion & learning

Cortex, basal ganglia, hippocampus