ELECTROENCEPHALOGRAPHY

P.Y. 10.12

Learning objectives

- Describe the EEG in terms of:
- What it represents?
- How it is recorded?
- Its physiological basis.
- List the different “waveforms” and state their characteristics.
- List the uses of EEG.
- Describe the different forms of epilepsy and explain their basis.

Definitions:

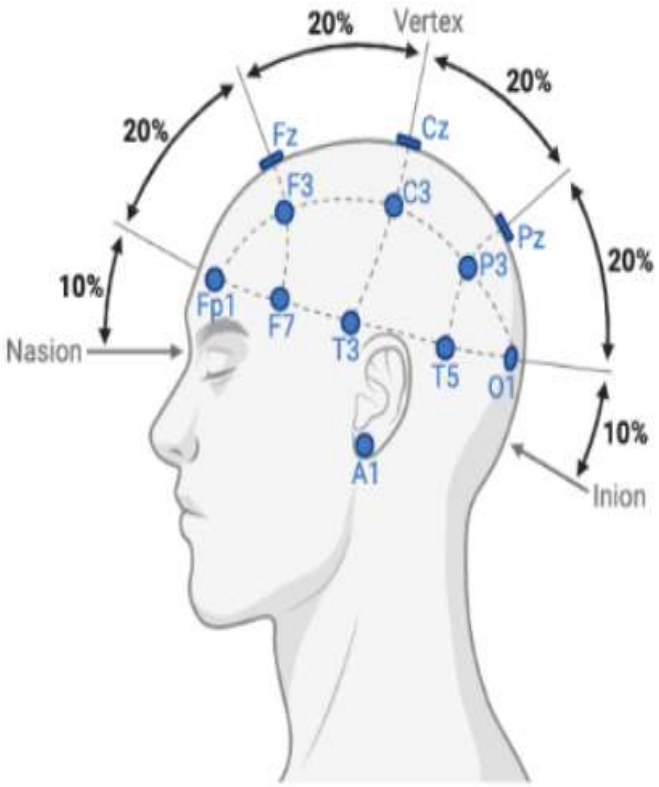
- **Electroencephalogram:** A record of electrical activity on the brain surface.
- **Electroencephalography:** The process of recording the electrical activity of the brain, by multiple surface electrodes applied on the scalp.
- **Electrocorticogram:** Electrical activity of brain recorded when the electrodes are applied on the pial surface of the cortex.

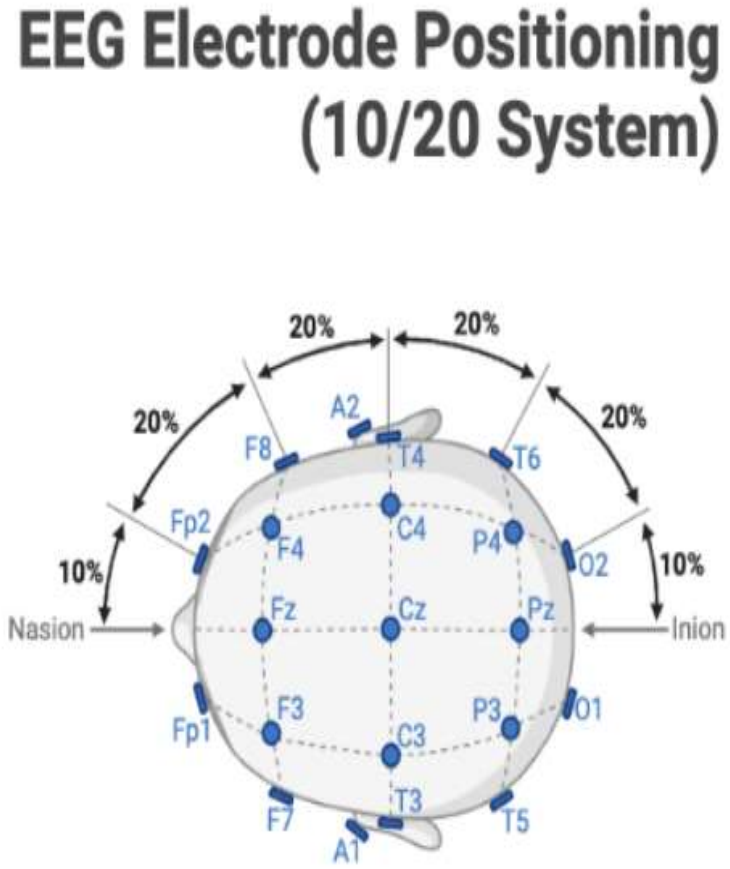
Recording:

Two reference points; Nasion and Inion

10-20 system of electrode placement

Letter identity of the sites e.g. F2, P3, O1, O2, F8,



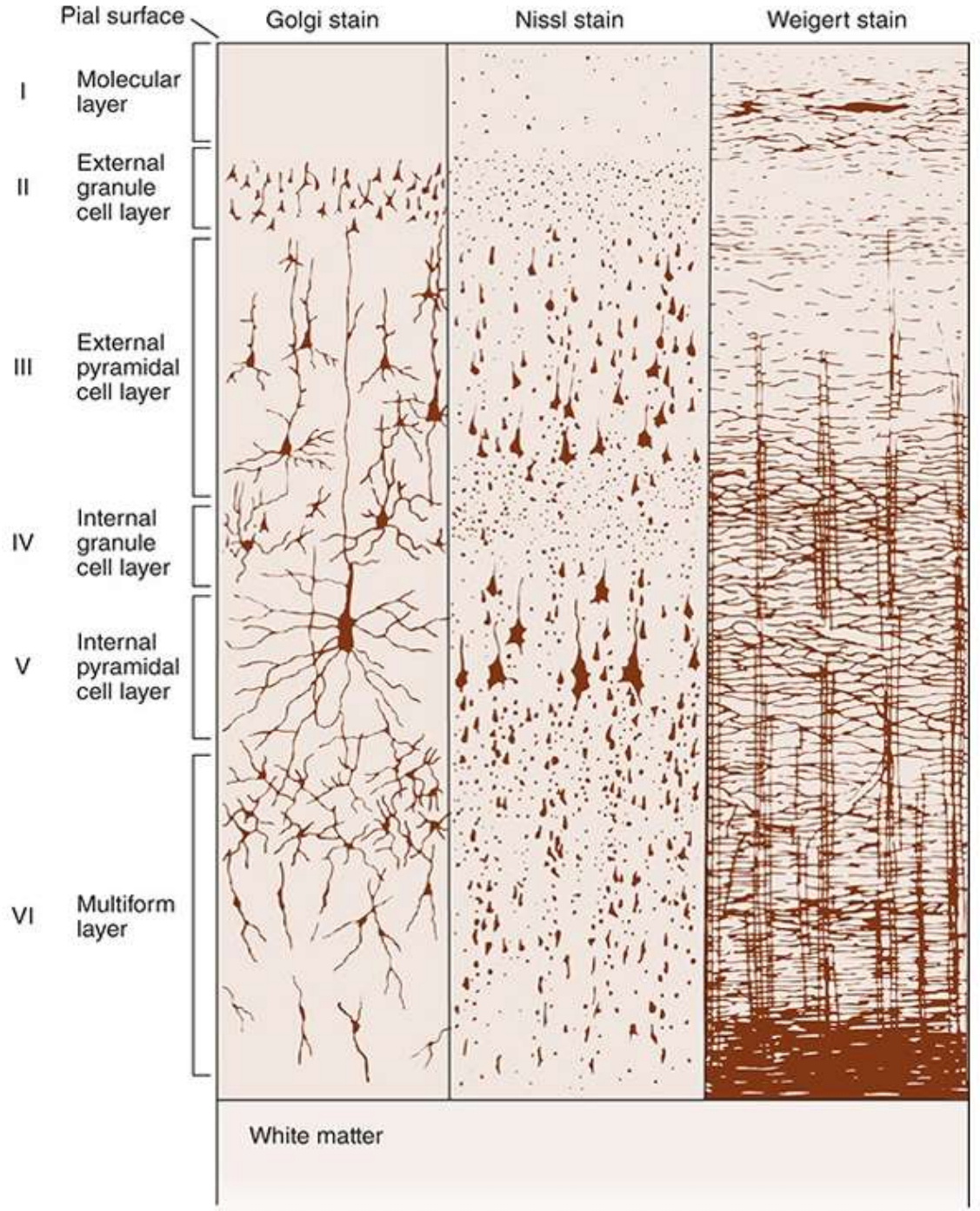


Electroencephalogram features

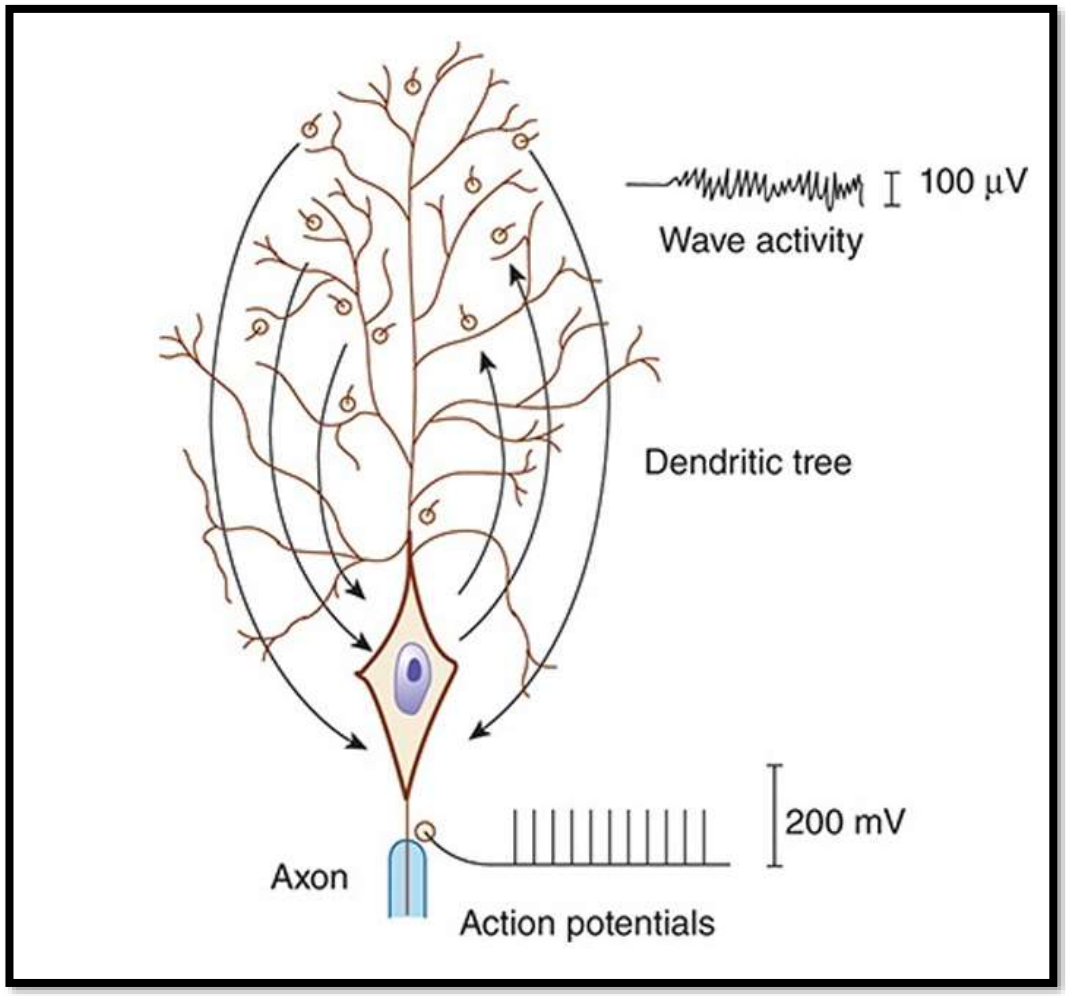
The electrical activity of outer most cortical layer- dendritic sheet of pyramidal neurons

The sum of dendritic post synaptic potentials:

- Recurrent collaterals from pyramidal neurons' axons
- Non specific thalamic nuclei
- Local inhibitory neurons-Basket cells



Physiological basis of EEG waves



1.The direction of current to or from the dendritic tree determines the wave activity:

Depolarized neuron
The dendrites will be Negative

Hyper polarized neuron
The dendrites will be positive

2. Intensity is determined by the number of neurons firing synchronously at the same time

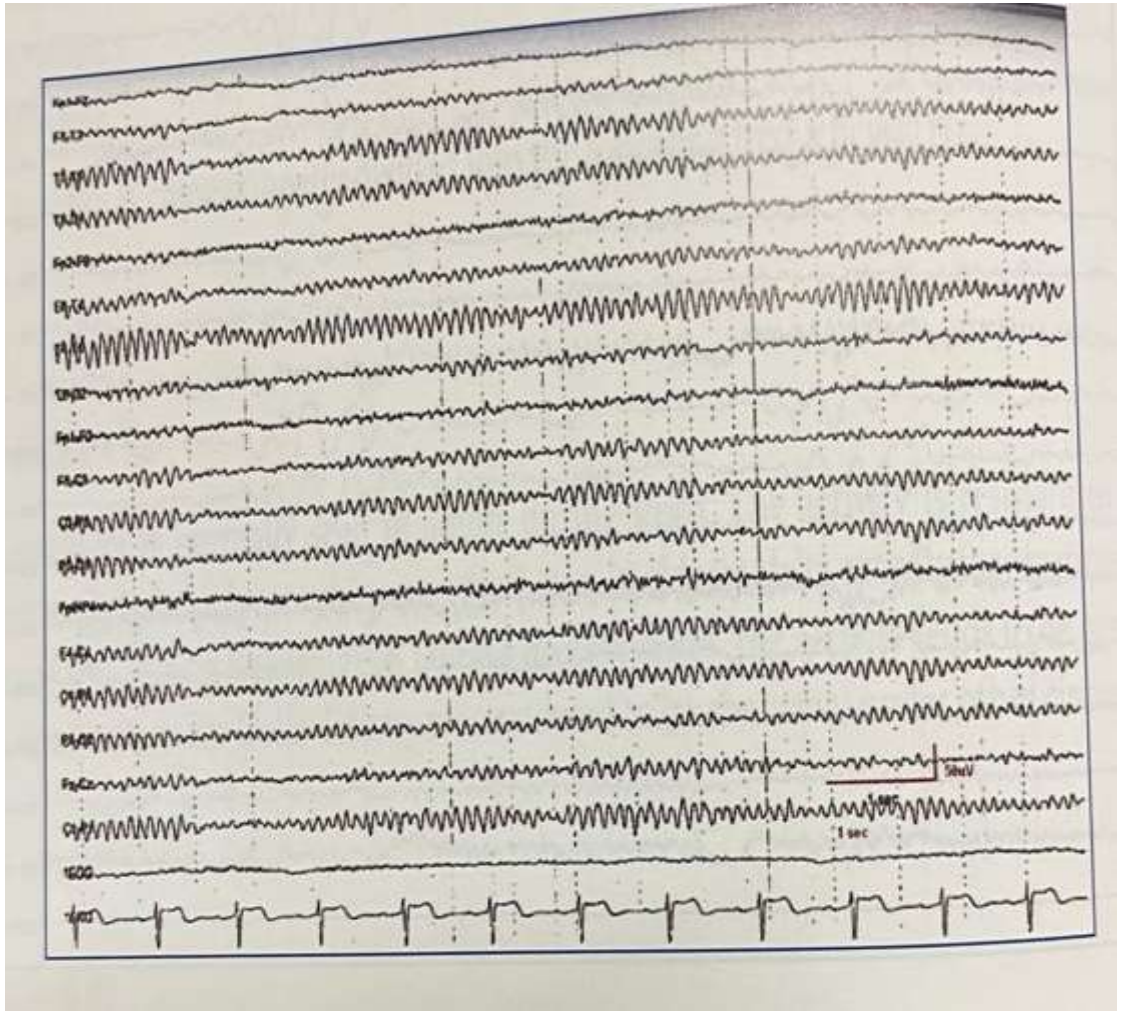
Normal EEG wave patterns

Alpha rhythm

The record of EEG obtained when person is awake, eyes closed and mind wandering.

Characteristics:

- Frequency: 8-12 Hz
- Amplitude: < 50 µV
- More synchronized
- Indicates wakefulness with less attention
- Mostly seen over occipital areas, sometimes also over parieto-temporal areas



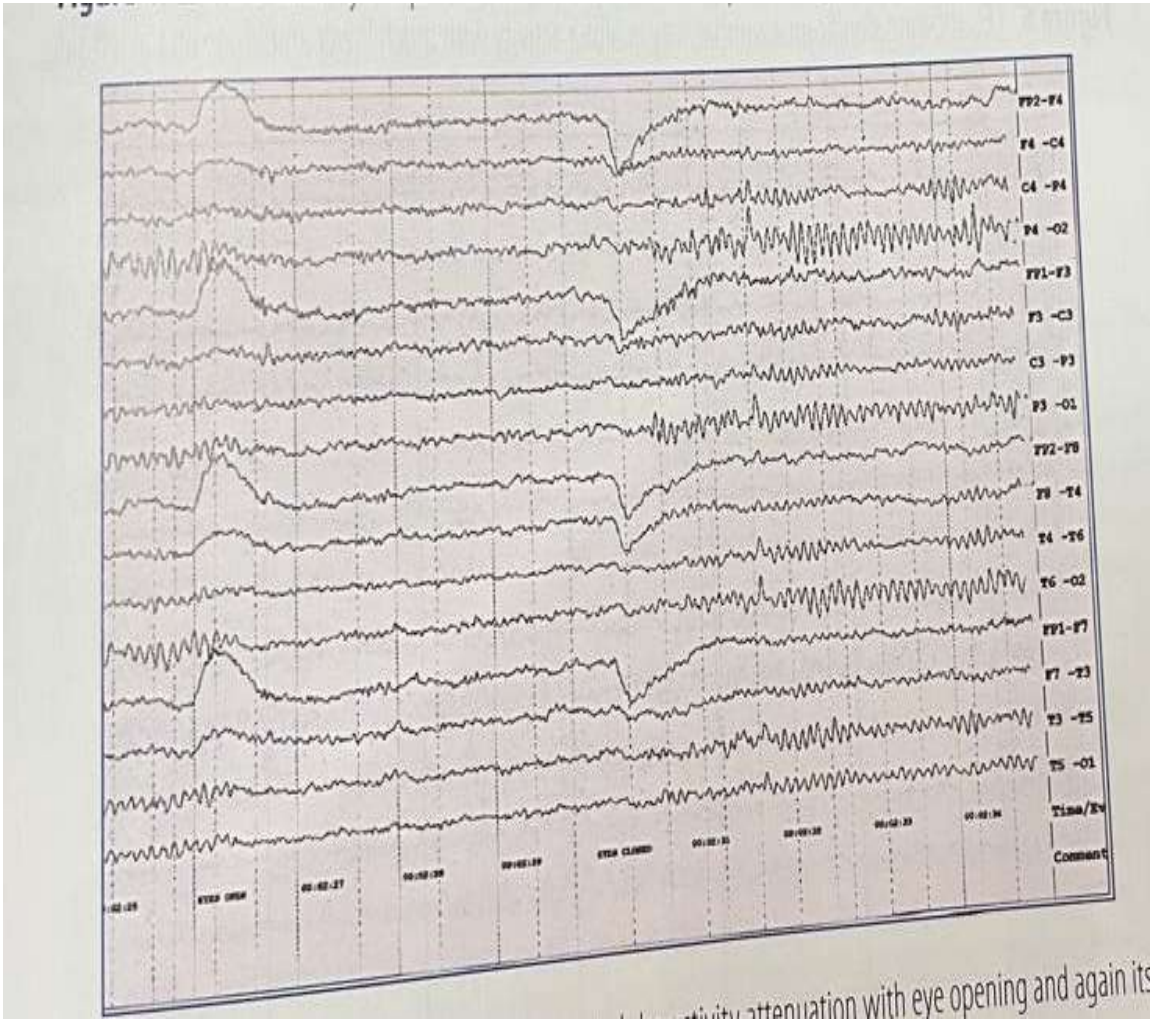
Normal EEG wave patterns

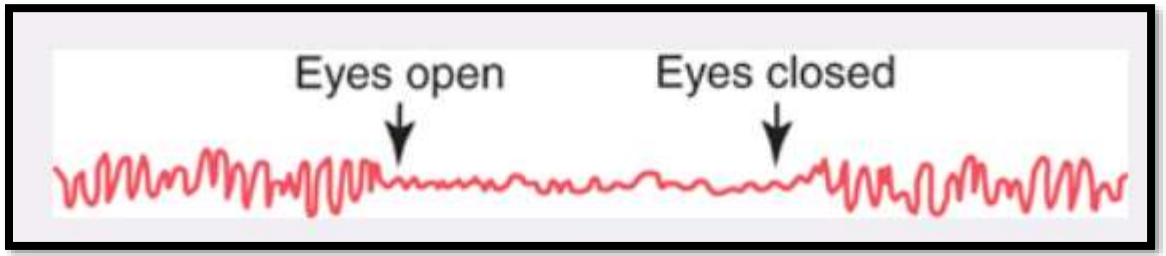
Beta Rhythm: The most prominent wave pattern when attention is focused on something.

Characteristics:

- Frequency: 13-30 Hz
- Amplitude < 30 µv
- Recorded mainly over parieto-frontal regions
- Arousal/ alerting response / **Alpha block**

Desynchronization of EEG





Normal EEG wave patterns

Theta waves: Waves seen during light sleep / earlier stages of sleep.

Characteristics:

- Frequency: 4-7 Hz
- Amplitude: High
- Recorded over parietotemporal region in children
- Also seen during emotional disturbances like disappointment and frustration.
- Often occur in degenerative brain disorders.

Normal EEG wave patterns

Delta waves: slower waves recorded during deep sleep and in infants.

Characteristics:

Frequency: 3-5 Hz

Amplitude: 2 to 4 times greater than any other wave

*Feature of cortical neural activities, independent of subcortical structures.

Normal EEG waves - summary

TYPES OF EEG WAVES

	Frequency (Hz)	Amplitude	When Seen
Beta	>14 (as high as 80)	Lowest	Alertness, active thinking
Alpha	8–13	Low	Awake, quiet resting state, eyes closed
Theta	4–6	High	Light sleep
Delta	<4	Highest	Deep sleep

EEG – Clinical uses

Epilepsy diagnosis and prognosis

Sleep studies

Comatose patients’ evaluation

Part of Brain Death evaluation

Epilepsy and seizures

Seizure: Disruption of brain functions due to excessive uncontrolled neuronal activities

Epilepsy: Chronic condition of recurrent seizures.

Manifestations: barely noticeable to vigorous shaking and convulsions

Causes: Trauma, tumor infections or degenerative changes, genetic predisposition

Types:

- Focal (Partial): limited to focal area of one cerebral hemisphere
- Generalized: Diffusely present into both the hemispheres

Focal / Partial seizures

Types:

Simple partial seizures: Without loss of consciousness

Complex partial seizures: With altered consciousness

Example: Jerking movements in one hand progressing to entire hand's clonic movements, duration 60-90 sec - Jacksonian march

Auras: the events of abnormal sensations that precede the seizures

Postictal period: The time after the seizures until normal neuronal activity resumes.

Generalized seizures

Widespread electrical activity that involves both the hemispheres simultaneously.

Convulsive / Tonic-Clonic seizures / Grand mal epilepsy:
Abrupt loss of consciousness with extreme neuronal discharge in all cerebral regions and brain stem as well.
Duration: 3-4 minutes
Generalized tonic contractions & Loss of consciousness

↓

entire rigidity jerky movements

↓

Loss of bladder or bowel control

↓

extreme salivary secretions

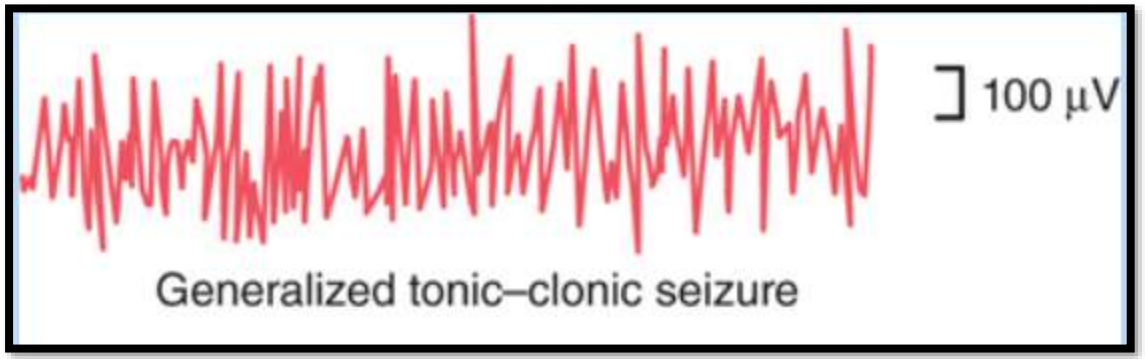
↓

Tongue biting or reflux

↓

Cyanosis

EEG findings:
Higher frequency, higher voltage discharge all over the cortex



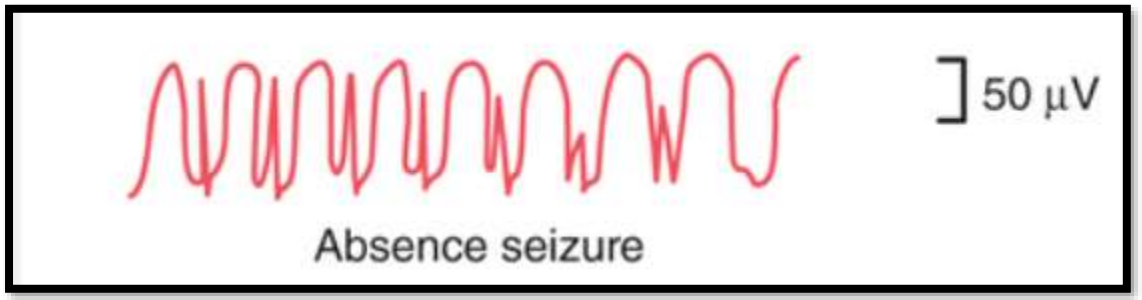
Generalized tonic–clonic seizure

Generalized seizures

Non-convulsive / Absence / Petit mal:
Nonconvulsive generalized seizures characterized by a momentary loss of consciousness.

- Duration: 3-30 sec
- Increased discharge of thalamocortical activating system
- 15-20% epilepsy cases among children and adolescents
- Twitch like contractions-mainly in the head region
- Not accompanied by auras or postictal period

EEG findings:
Spike and dome pattern



Treatment

Anti-epileptic drugs:

Voltage gated Na channel blockers (Carbamazepine & Phenytoin): Reduced action of glutamate

Altered Ca currents (ethosuximide): reduced low threshold T- Ca++ currents in thalamic neurons

Increased GABA activity (Gabapentin): reduced Ca entry and reduced glutamate release

Inhibition of glutamate receptors (Perampanel)

Mixed effects (Topiramate)

Evoked potentials

The electrical events recorded on the surface of particular cortical region after a particular sensory receptor is stimulated.

Primary	**Secondary**
• First positive negative	Prolonged positive deflection
Wave sequence	
• Latency: 5-12 ms	latency: 20-80 ms
• Location specific	Not highly localized
• Where the sensory pathway ends	All over the cortex due to midline intralaminar thalamic nuclei

SLEEP

P.Y.11.11

Learning objectives

- List the stages of sleep.
- List the features of different stages of sleep.
- Describe the physiological basis of sleep.
- List the essential features of common sleep disorders.

Sleep

A temporary state of unconsciousness through which a person can be aroused by sensory stimuli.

Types:

Slow wave sleep / Non-Rapid Eye Movement (NREM) sleep: EEG waves are strong but of low frequency

Rapid Eye Movement (Sleep): High frequency, low amplitude like awake state

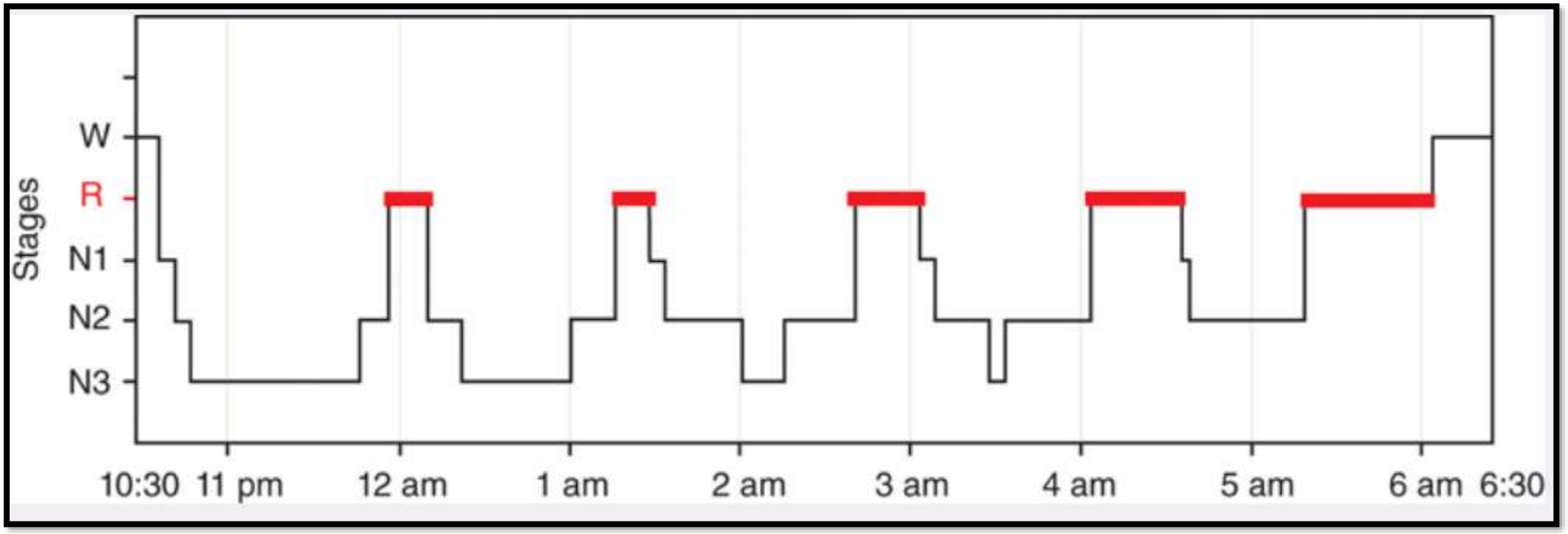
Sleep stages

A Comparison of the Original and Current Classification of the Stages of Sleep

Rechtschaffen and Kales (1968)	American Academy of Sleep Medicine (2007)
Stage W (wakefulness)	Stage W (wakefulness)
Stage 1 (S1)	Stage N1/NREM1
Stage 2 (S2)	Stage N2/NREM 2
Stage 3 (S3)	Stage N3/NREM 3
Stage 4 (S4)	
Stage REM (rapid eye movement)	Stage R (rapid eye movement)

Note that the original S3 and S4 stages have been merged into a single stage (N3).

Distribution of sleep stages during entire sleep



Observations:

1. REM sleep constitutes 25% of total sleep duration (5-30 minutes)
2. Every 90 minutes, Sleep cycle repeats
3. The depth of sleep decreases with each sleep cycle
4. The duration of REM sleep increases with each sleep cycle
5. 4-6 REM episodes occur every night sleep

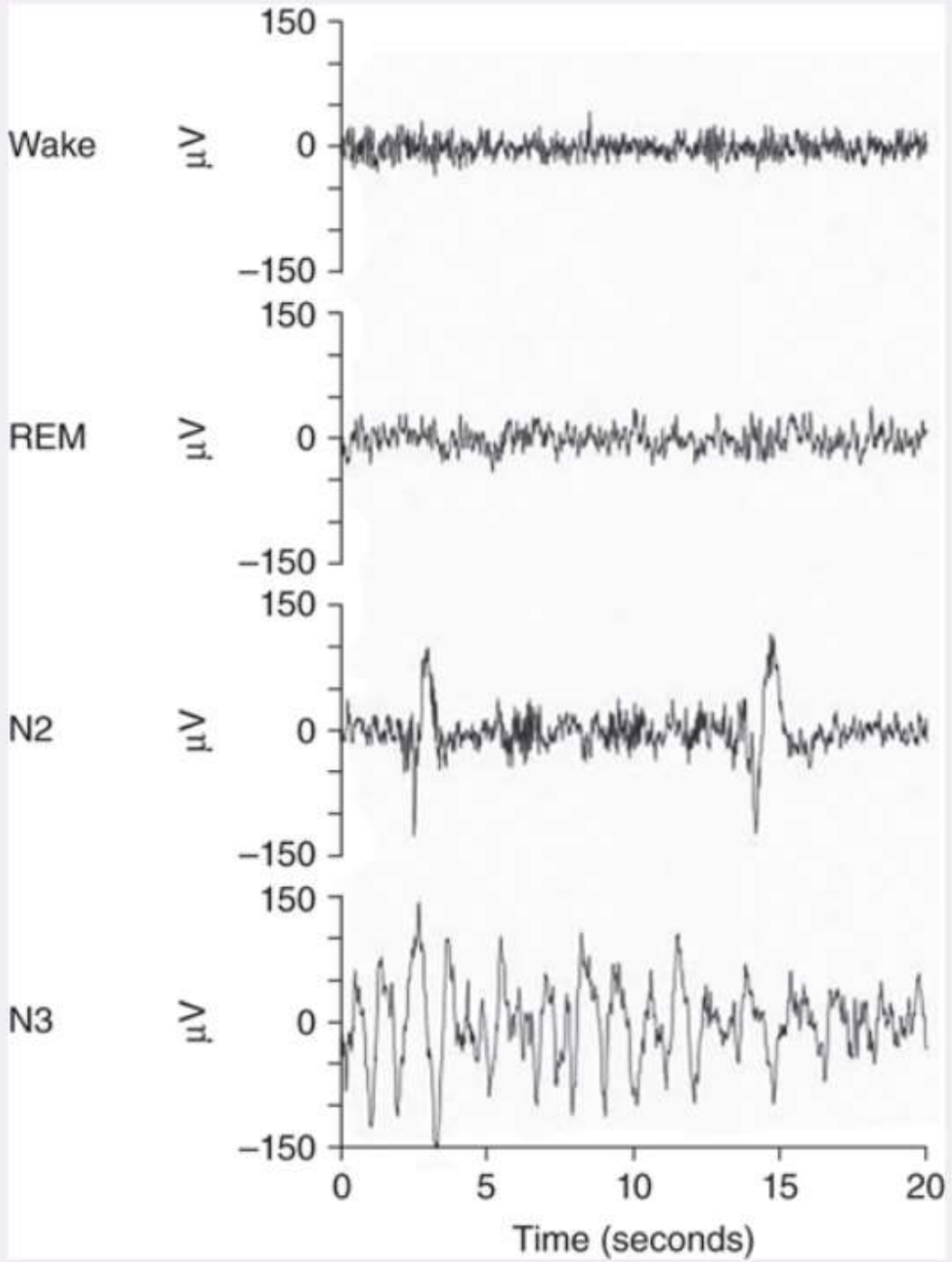
EEG changes in different sleep stages

High frequency low amplitude

Reduction in arousal and muscle tone

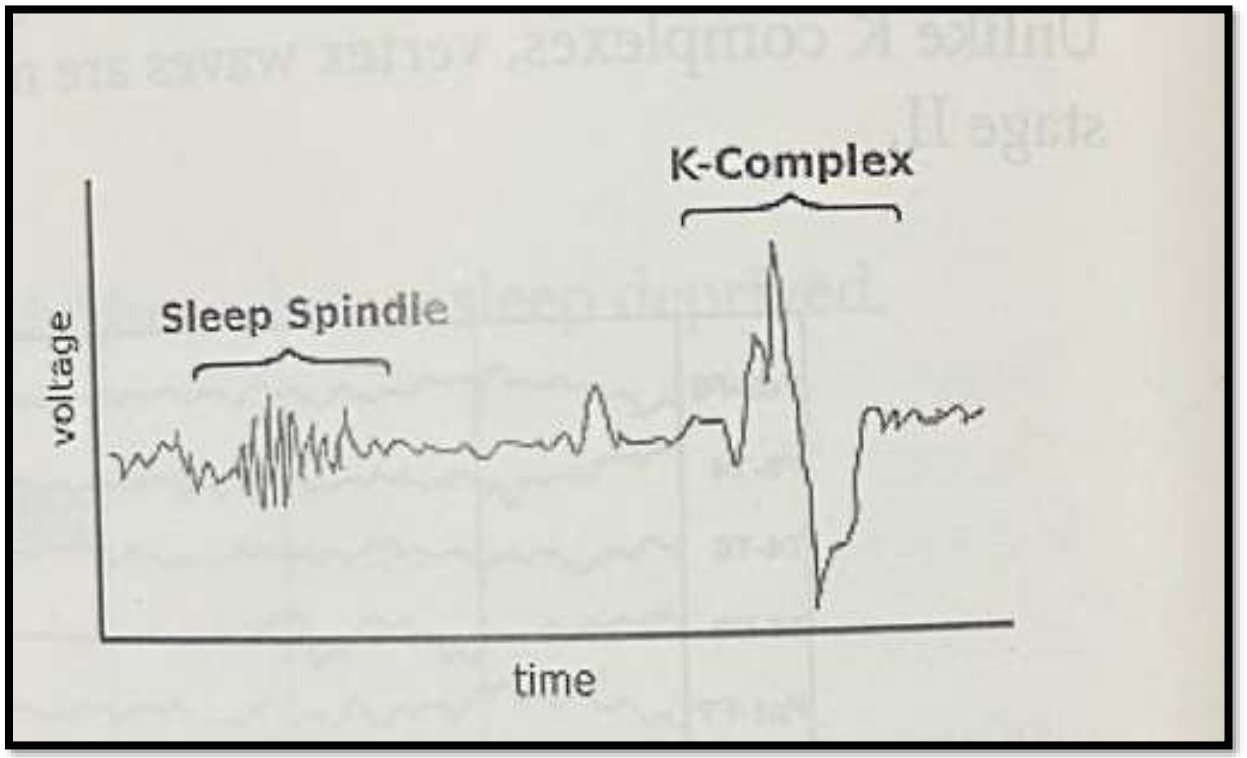
Slow waves with K complexes and sleep spindles

Low frequency high amplitude slow waves (1-3 waves/sec- Delta waves)



Sleep spindles:

- Sinusoidal waves of low medium amplitude and 12-14 Hz frequency
- Occurs for a second
- Repeated after every 5-15 seconds
- Associated with rhythmic discharge from thalamo-cortical system



K complex

- K for “Knock”
- High voltage, biphasic/polyphasic slow waves of duration of 0.5 to 2 sec.
- Can occur spontaneously or with sudden sensory stimuli

REM / paradoxical / desynchronized sleep characteristics

- Rapid eye movements- Ponto geniculo occipital spikes (PGO)
- Depressed muscle tone across the body
- Decreased external arousability
- Increased internal arousability
- Irregular heart rate and respiratory rate
- Increased brain metabolism
- Associated with dreaming
- Penile erection (Distinguish b/w of psychogenic and organic impotence)
- Thermoregulation is reduced
- Decreased activity in pre-frontal, parietal cortex and primary visual cortex
- Increased activity in pons, amygdala anterior cingulate gyrus and visual association area.

Differences b/w REM and NREM Sleep

REM	NREM

Polysomnography - The sleep study

- Electroencephalography (EEG): this allows for the evaluation of the stages of sleep.
- Electrocardiography (ECG) records the electrical activity of the heart over time.
- Electromyography (EMG) records muscle activity (note tone reduces during REM sleep).
- Electrooculography (EOG) records eye movements.
- Pulse oximetry measures the oxygen saturation of the blood.
- Respiratory flow and respiratory effort are measured to assess ventilator responses.
- Other measurements can additionally be made based on specific needs.

Basic sleep theories

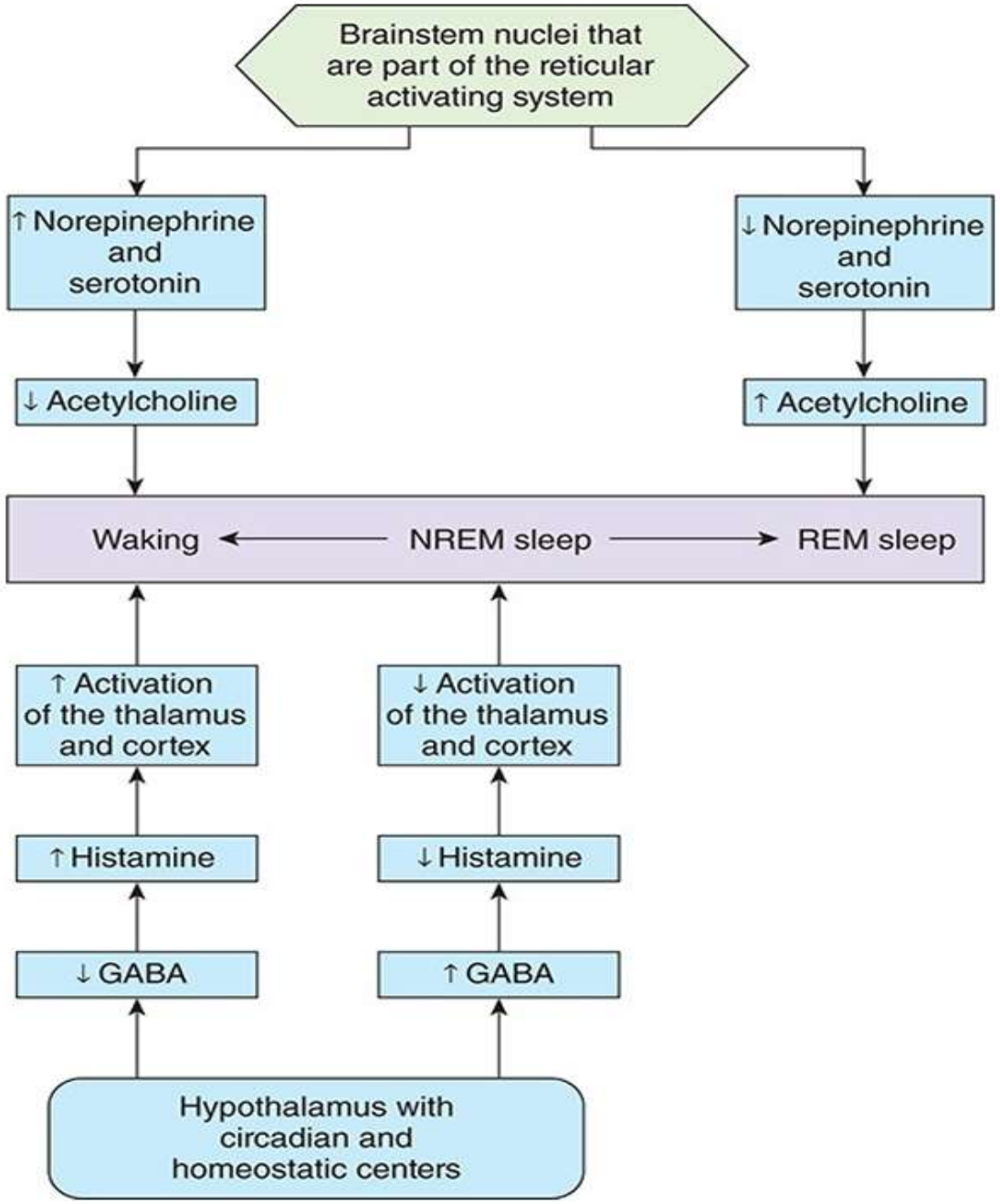
1. **Neurotransmitter modulations through brain stem nuclei**:

- Five neurotransmitters

Dopamine
Serotonin
Acetylcholine
Histamine
GABA

} Interactions

- Waking and REM are two opposite extremes of this modulation
- NREM sleep is the balance between these two



Basic sleep theories

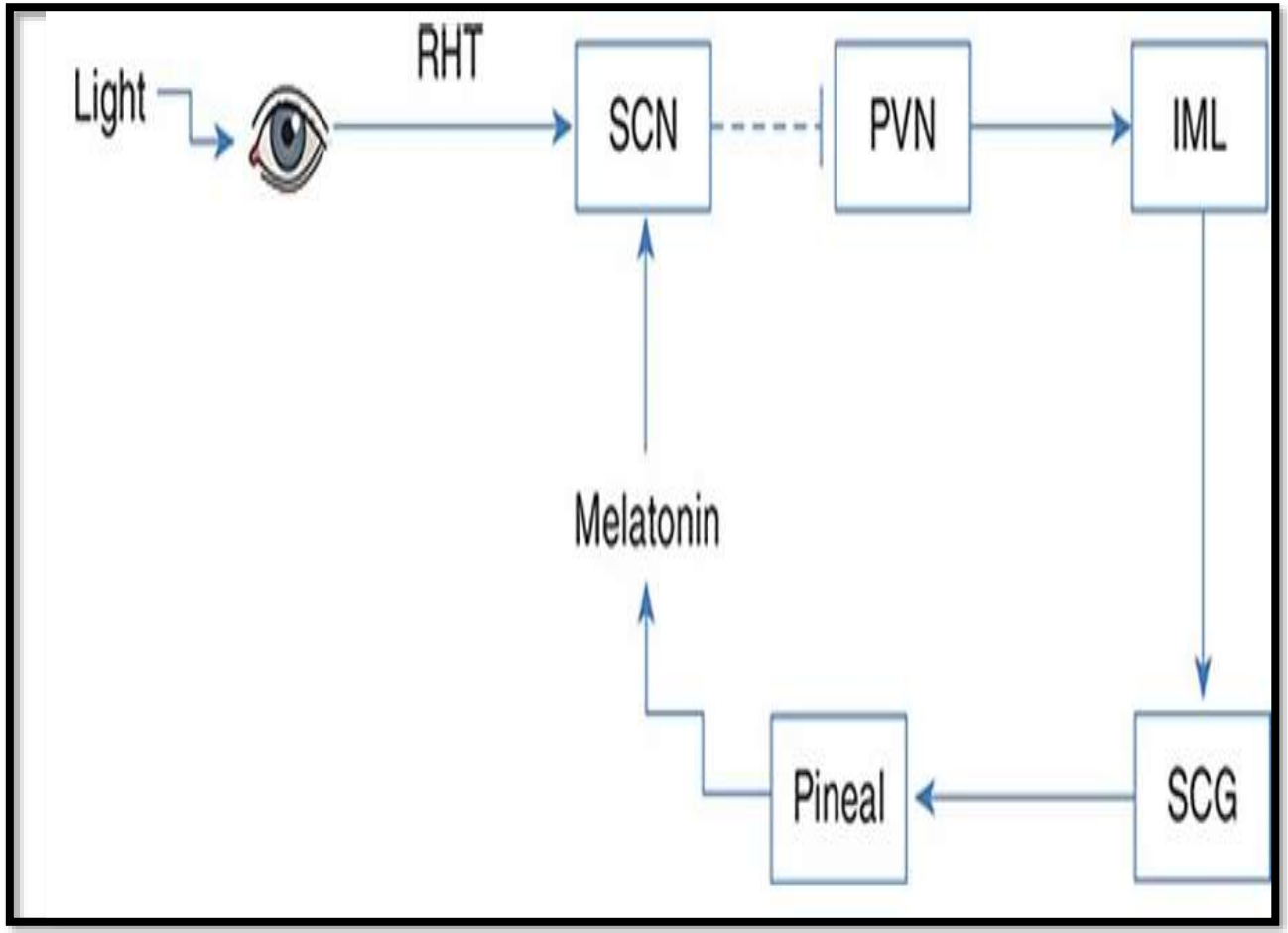
2. **Role of suprachiasmatic nuclei and pineal gland:**

Neurotransmitters:

GABA

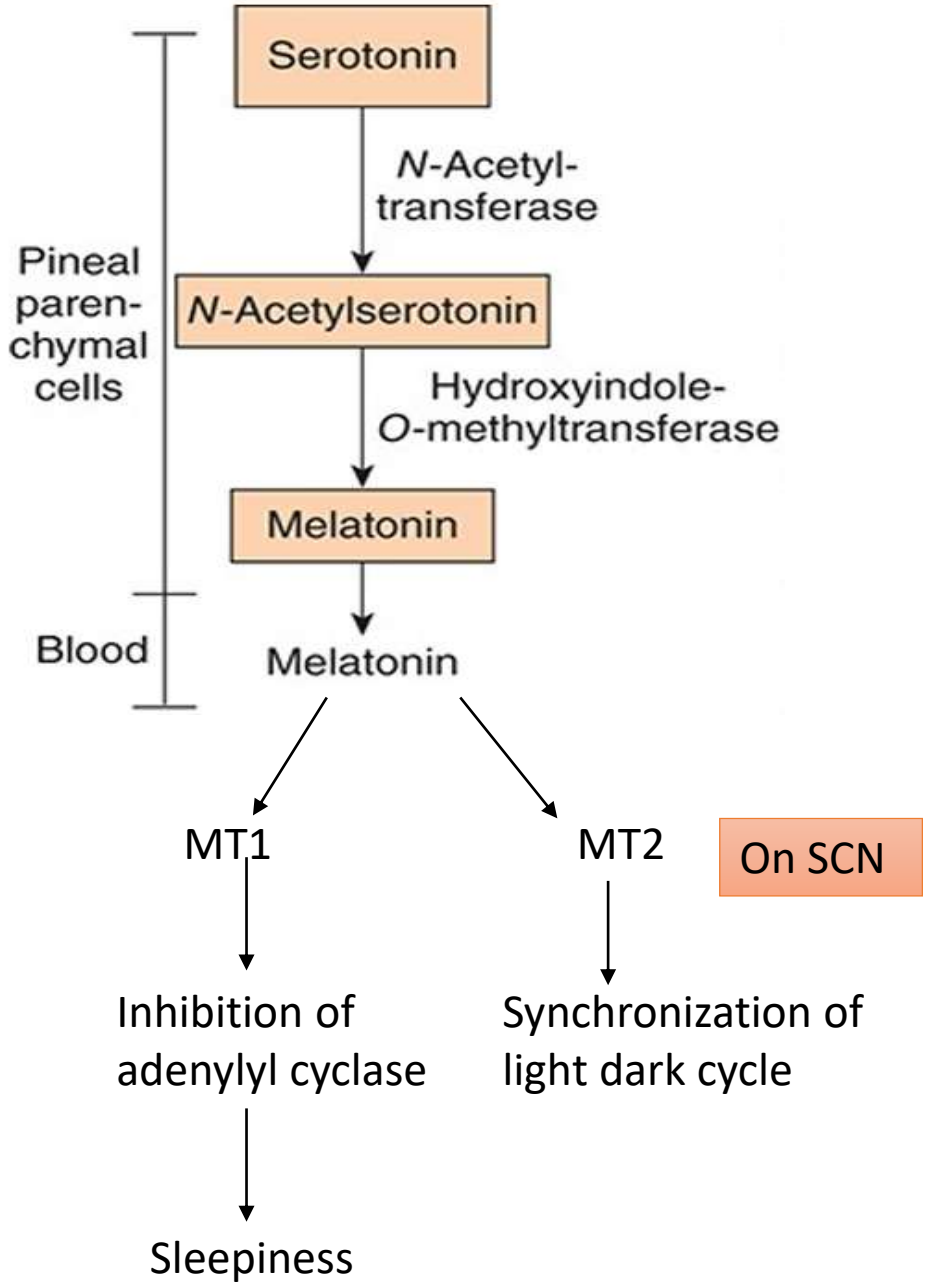
Norepinephrine

Melatonin



Basic sleep theories

Role of melatonin



Basic sleep theories

Role of Orexins / Hypocretin:

- Secreted from hypothalamus
- Most active during wakefulness

Narcolepsy: due to lack of Orexin production or defective receptors

Physiological importance of sleep

- Neural maturation
- Facilitation of learning and memory
- Cognition
- Clearance of metabolic waste products generated by neural activity of awake brain
- Metabolic and caloric balance
- Thermal equilibrium
- Immune competence

Sleep disorders

Narcolepsy

Brain’s inability to regulate sleep-wake cycle

Irresistible urge to sleep during day time – begins with REM sleep

Sometimes features sudden loss of muscle tone – cataplexy

Fewer hypocretin / orexin producing neurons due to autoimmune degeneration

Sleep disorders

Insomnia

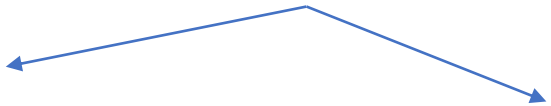
Difficulty in initiation or maintenance of sleep several time in a week

Disturbance in circadian rhythm or sleep wake cycle

Transient

Jet lag/ shift change

Chronic (Sleep phase syndrome)



Delayed

Advanced

Sleep disorders

Obstructive sleep apnea:

Cessation of breathing for more than 10 s during frequent episodes of obstruction of the upper airway (especially the pharynx) due to a reduction in muscle tone

Followed by a brief period of arousal

Progressively louder snoring

Not much reduction in sleeping time

The duration of N1 stage increases (from 10% to 30-50%)

Sleep disorders

Progressive limb movement disorders (PMLD)

Rhythmic extension of the big toe and dorsiflexion of the ankle and knee during sleep lasting for about 0.5–10 s and recurring at intervals of 20–90 s

EEEG shows increased activity during first few hours of sleep –in NREM stages

The duration of N1 increases and N3-N4 decreases

Sleep walking(somnambulism)

Bed-wetting (nocturnal enuresis)

Night terrors (parasomnias)

Therapeutic insights

Narcolepsy: Amphetamine like stimulants modafinil, methamphetamine

OSA : Continuous positive airflow pressure (CPAP)

PMLD: Dopamine

Circadian rhythm disorders: Light therapy, Melatonin (Ramelteon), Zolpidem- to promote sleep onset