physiology team 429

# Physiology of Sleep and EEG

Done By :

**Nujud Al-Hejin**

# ❖Definition

- ## Sleep :

**unconsciousness from which the person can be aroused by sensory stimuli.**

- **EEG Findings :**

**various waves that are characteristic of different sleep stage**

- ## Coma :

is **state of loss of consciousness (LOC) from which the person cannot be aroused**

- **EEG Findings :**

**slow waves [ theta + Delta ]**

# ❖Why do we sleep?

1- restores both normal levels of brain activity and normal balance
- Waking life disrupts homeostasis
- Sleep may conserve some energy

2- Protection with the circadian cycle.

3- Circadian synthesis of hormones .

4- Consolidation* of learning.

5- Remodeling of synaptic function.

*strengthening

## ❖Sleep deprivation experiments have shown

**(1) progressively Increasing sluggishness of thoughts.**

**(2) becomes markedly irritable.**

**(3) may become psychotic .**

## ❖EEG waves

- The frequencies most brain waves range from are 0.5-500 Hz.

1. Alpha waves [ 8-13 Hz ]
2. Beta waves [ Greater than 13 Hz ]
3. Theta waves [ 3.5-7.5 Hz ]
4. Delta waves [ 3 Hz or less ]

# Alpha waves

[8-13 Hz]

seen in <u>all age groups</u> but are most common in adults.

- Most marked in the parieto-occipital area.

- They occur rhythmically on *both sides* of the head but are often slightly higher in amplitude on the nondominant side

  especially in right-handed individuals

- They are especially prominent with :

**Closed eyes and with relaxation, wondering mind.**

- They disappears normally with :

**Attention** (arousal or alerting response)

# * Alpha block :

1. When the Alpha waves disappears due to attention.
2. Then become replaced with irregular low voltage activity.
3. Called arousal or alerting response .
4. Also called desynchronization as it represents breakup of synchronized neuronal activity.

- An abnormal exception is alpha coma:

caused by hypoxic-ischemic encephalopathy of destructive processes in the pons (eg: intracerebral hemorrhage).

- alpha waves are distributed uniformly both anteriorly and posteriorly in patients who are unresponsive to stimuli

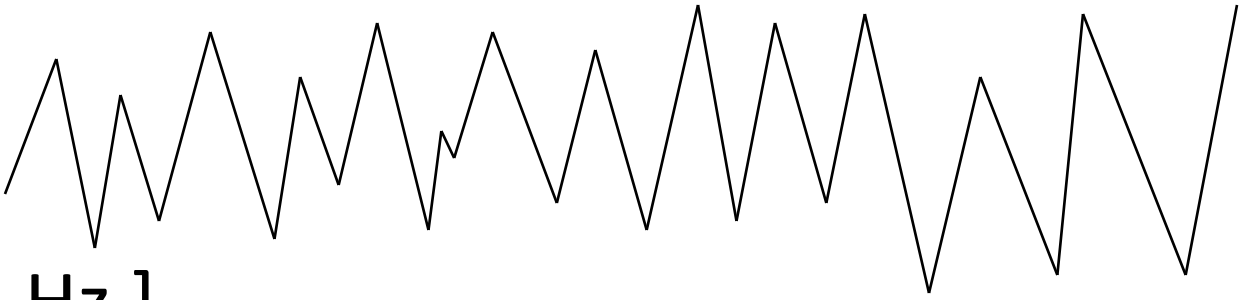
# Beta waves

[Greater than 13 Hz/sec]

- Beta waves are observed in <u>all age groups</u>.
- They tend to be small in amplitude and usually are symmetric and more evident anteriorly.
- Drugs [ barbiturates - benzodiazepines] augment * beta waves.

*to make larger

# Theta waves

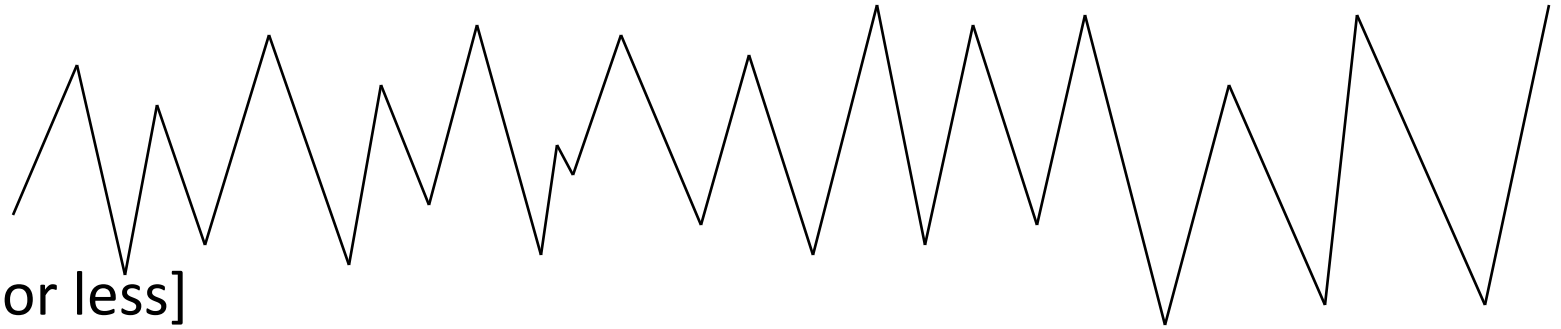


[3.5-7.5 Hz ]

- Theta waves normally are seen **in sleep** at any age.
- **In awake adults, these waves are abnormal if they occur in excess.**

- Theta and delta waves are known collectively as ***slow waves***.

# Delta waves



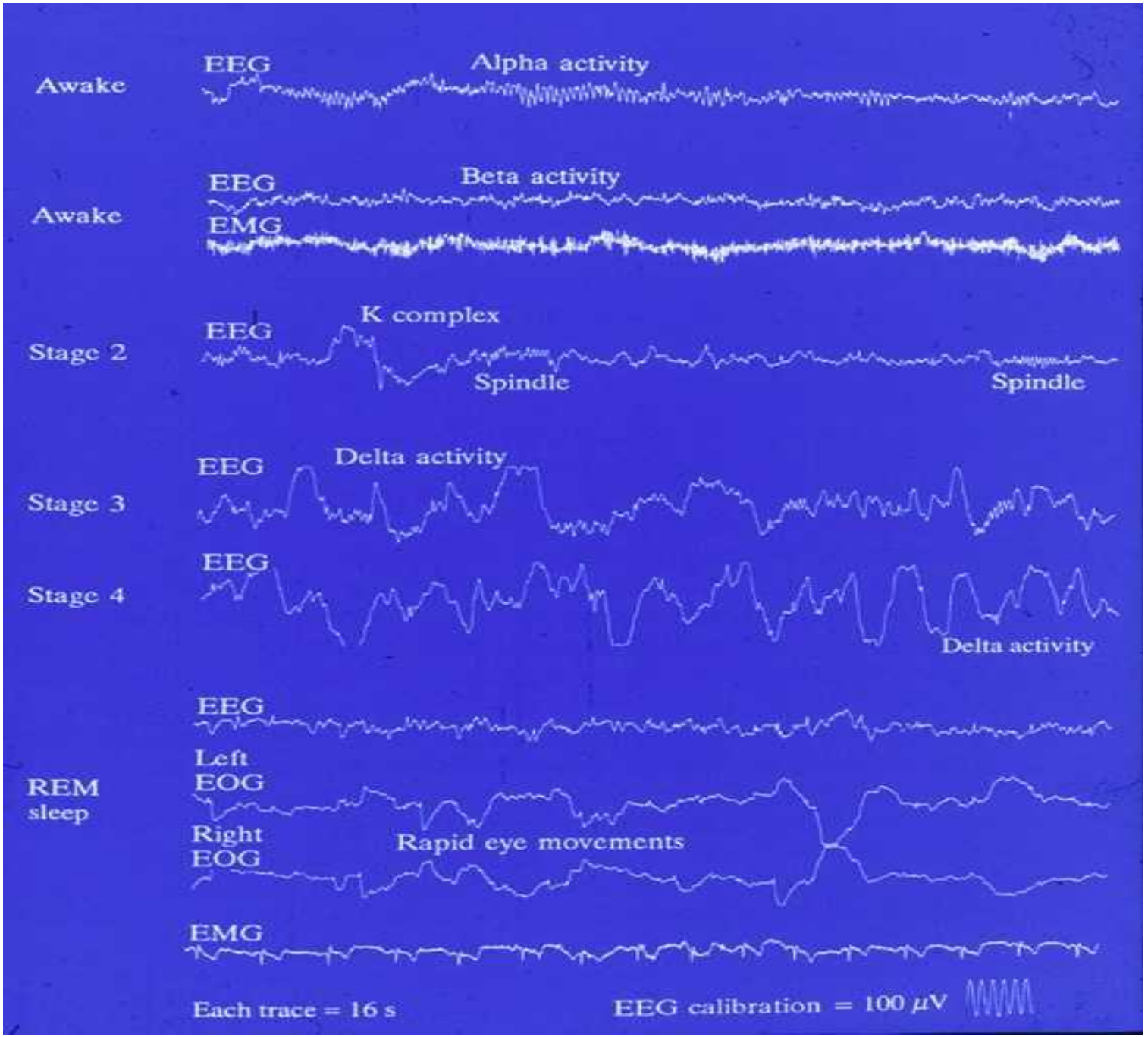
[3 Hz or less]

- They normally are seen in all age groups.
- in **deep sleep**
- Delta waves are abnormal in the awake adult.
- Often, they have the *largest amplitude* of all waves.
- Delta waves can be focal (local pathology) or diffuse (generalized dysfunction).

# Sleep spindles

These are bursts of alpha-like 10-14 z , 50 uV waves .

- Spindles are groups of waves that occur during many sleep stages but especially in **stage 2**.
- They have frequencies in the upper levels of alpha or lower levels of beta.
- Lasting for a second or less, they increase in amplitude initially and then decrease slowly. The waveform resembles a spindle.
- They usually are symmetric and are most obvious in the parasagittal regions.


Awake
EEG
Alpha activity
Awake
EEG
Beta activity
EMG
Stage 2
EEG
K complex
Spindle
Spindle
Stage 3
EEG
Delta activity
Stage 4
EEG
Delta activity
EEG
REM sleep
Left EOG
Right EOG
Rapid eye movements
EMG
Each trace = 16 s
EEG calibration = 100 μV

# Types of sleep

Depending on EEG criteria ,during each night we go through 2 types of sleep that alternate with each other.

## 1. Slow-wave sleep ( SWS ) (non- Rapid Eye Movement sleep)→ (NREM) :

- **restful type of sleep**
- -75% of sleep time.
- - Decrease in Peripheral vascular resistance .
- - Decrease in Blood pressure (10-30%)
- - Decrease in Respiratory rate.
- - Decrease in Basal metabolic Rate .
- It is not associated with rapid eye movement.

### ➢ EEG:

- Theta + delta waves.
- Dreams occur But are not remembered as they are not consolidated in memory.

# ➢Mechanism of slow-wave sleep

Active process produced by

inhibition of areas in *Reticular activating system*

**Reticular activating system** : [responsible for alert conscious state of wakefulness]

- **Sleep Zones:**

Stimulation of the following sites will lead to sleep and synchronization of slow –wave sleep EEG:

- 1. Diencephalon :

-Suprachiasmatic region of post hypothalamus.

-Thalamic nuclei: intra- laminal + anterior thalamic

→ Slow frequency stim of diencephalon → sleep.

High frequency stim of diencephalon → arousal.

- 2. Medulla oblongata:

Medullary synchronizing zone at the level of NTS.

- 3. Basal forebrain: pre-optic area: → High or slow frequency stim→ synchronization + sleep.

**1,2&3 are connected together and with reticular area of the brain stem.**

# 2. Rapid Eye Movement Sleep (REM):

[paradoxical sleep ] : The paradox being that the person is asleep although he looks awake

- **Not as restful as Slow Wave Sleep .**
- Occur in episodes of 5-30 min, recurring every 90 min.
- **Tiredness shortens the duration of each episode:**

So When the person is extremely sleepy, each REM sleep is short, and it may even be absent.

- **As you become restful through the night, the duration of each episode increases:**

So as the person becomes more rested through the night, the durations of the REM increases.

- Active dreaming, remembered later.

## REM, continued•

- Rapid rolling movement of the eyes.

- Decrease in muscle tone (due to excitation of reticular inhibitory centers).

Exception: Respiratory + Eye muscles.

- Heart Rate & Respiratory & Blood Pressure are irregular.

- Despite the extreme inhibition of the peripheral Muscles irregular , active bodily muscle movements do occur :

1-Erection of penis .

2-Engorgement of clitoris .

3- Twitches of facial & limb muscles .

- More difficult to awake a person than in slow-wave sleep.

- The brain is highly active in REM sleep, and overall brain metabolism may be increased as much as 20 %

➢ EEG: [brain waves similar to those that occur during wakefulness]

- Low-voltage , fast activity (β-waves)

.

# ➢Mechanism of REM sleep:

- The mechanism producing REM sleep is **Cholinergic Neurons located in the Pons** (pontine reticular formation).

- **At the onset of REM sleep , large groups of spikes originate in the Pontine Reticular Formation.**

- **These spike discharges spread from the Pons to the Lateral Geniculate Nucleus** (in thalamus) **to the Occipital cortex .**

- PontineGeniculoOccipotal spikes stimulate the Inhibitory Reticular Area leading to ***Hypotonia*** .

- **Discharge of noradrenergic neurons of locus ceruleus + discharge of serotonergic neurons of midbrain raphe causes wakefulness →**

  [ They become silent when PGO active during REM]

# Importance of REM sleep

- 1. Expression of concerns in the sub-consciousness (Through dreams)

- 2. Long-term chemical and structural changes that the brain need to make learning & memory possible.

# Q : If dreams do occur during SWS : how do they differ from those of REM sleep ?



SWS dreams if they occur , differ from those of REM sleep in that :

(1) REM dreams are vivid dreams .

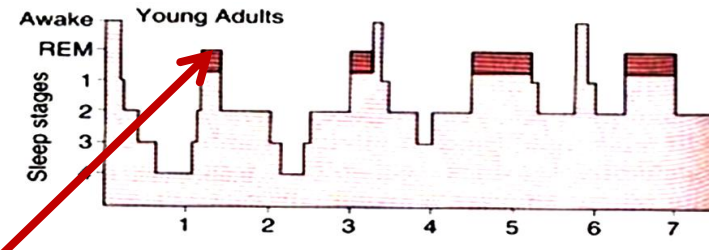
(2) REM dreams are associated with more bodily muscle activity .

(3) the dreams of SWS are not remembered usually , on waking up

# Distribution of Sleep Stages

- NREM occupies ( around 75-80n%)
- It is interrupted by intervening REM sleep periods

approximately every 90 minutes




REM sleep periods are shown in red

- In a typical night of sleep , a young adult :

(1) first enters NREM sleep , passes through stages 1 , 2 , 3 and 4 , then 60-100 minutes from sleep onset .

(2) goes into the first REM sleep episode.

- This cycle is repeated at intervals of about 90 minutes throughout the 8 hours or so of a night sleep.

- Therefore , there are 4-6 sleep cycles per night

( and 4-6 REM periods per night)

In a young adult NREM occupies 75-80% of a night sleep time & REM sleep occupies 20-25 % of the sleep time .

- As the night goes on → there is progressive reduction

in stages 3 and 4 sleep and a progressive

increase in REM sleep .

# ❖Distribution of sleep stages in a typical night

- Premature infants:

REM sleep occupies 80% of total sleep time.

- Full term neonates:

50% of sleep time is occupied by REM.

- In a young adult

NREM occupies 75-80% of a night sleep time & REM sleep occupies 20-25 % of the sleep time .

- Aged/elderly:

The proportion of REM sleep falls rapidly and plateaus at about 25% (20-69ys) until it falls further in old age.

- Children have more sleep time and stage 4 than adults

# Sleep architecture in young adults

- Wakefulness in sleep, <5% of night
- Stage I 2 - 5%
- Stage II 45 - 55%
- Stage III 3 - 8%
- Stage IV 10 - 15%
- $\Rightarrow$ NREM 75 - 80%
- REM 20 - 25% in 4-6 episodes

## ✓ What Makes Us Fall Asleep ?

Theories of sleep : old and modern :

- **The old theory of sleep :**

**that sleep is caused only by a passive process due to fatigue of RAS neurons after discharging for many hours of wakefulness .**

- **The new theory of sleep :**

**a strong active sleep-inducing inhibitory process that inhibits the RAS to produce sleep .**

- Sleep is an active field of ongoing research , and many chemicals ( e.g., adenosine , orexin etc ) are claimed by different sleep researchers to play a role , but what all Researcher Scientists and Medical doctors agree upon are 3 things :

(1) That the neurotransmitter **serotonin** ( produced by the Raphe Nuclei ) plays an important role in **SWS sleep**

(2) That **Ponto-Geniculo-Occipital circuit** plays an important role in generation of **REM sleep**.

(3) That the hormone **Melatonin** ( released from the Pineal Gland ) plays an important role in **day-night entrainment of sleep** .

- **Experimental findings supporting the modern theory are :**

**(1) Transecting the brainstem at the level of the midpons, leaves the animal in a state of intense wakefulness for a period of days.**

( N.B .: the Bulboreticular Facilitory Area + intralaminar thalamic nuclei constitute the reticular activating system , RAS)

**[Normally the serotonin-secreting Raphe fibers inhibit the Bulboreticular Facilitory Area to produce sleep]**

**(2) The transecting cuts the nerves going from the inhibitory serotonin-secreting Raphe Nuclei to the Bulbo reticular Facilitory Area.**

*** lesions that destroy the Raphe Nuclei themselves make the animal sleepless for days .**

**(3) Serotonin agonists and antagonists greatly influence Slow Wave Sleep in humans.**

**(4) Stimulation of the Suprachiasmal Nucleus of hypothalamus** (which inhibits Melatonin release) **produces *sleep.***

# ❖Sleep/wakefulness rhythm

Alternating " Sleep-Wake Cycles " are under marked Circadian Control .

Circadian Control :

regulation of a biological rhythm ( e.g. sleep-wakefulness , hormone secretion , etc ) by day-night cycles .

- A circadian rhythm consist typically of **8 hours sleep and 16 hours awake**.
- ***controlled by*** the biological clock function of suprachiasmatic nucleus in the hypothalamus.
- The Suprachiasmatic Nucleus inhibits melatonin secretion → inhibits sleep & promotes wakefulness .
- Periods of sleep and wakefulness alternate about once a day.
- Within sleep portion of this circadian cycle NREM and REM sleep alternate.

# ❖ Why do we have sleep-waking cycles ?

During the morning , and after a restful night sleep :

1- The Bulboreticular Facilitory Area becomes active & overcomes any inhibition by the Raphe Nuclei .

2- Melatonin falls to very low levels in the morning .

- **This release of the Bulboreticular Facilitory Area :**

(1) activates ( through the thalamic nuclei ) the cerebral cortex to increased vigilance .

(2) excites the Peripheral Nervous System to become more receptive to incoming sensory stimuli + be more ready to respond by increasing muscle tone .

(3) Both (1) and (2) above send numerous positive feedback signals back to the Bulboreticular Facilitory Area to activate it still further.

Wakefulness has a natural tendency to sustain itself because of all this positive feedback activity

(4) After the brain remains activated for many hours, the activating neurons in the Bulboreticular Facilitory Area gradually become fatigued.

(5) Consequently, the positive feedback cycle between the mesencephalic reticular nuclei and the cerebral cortex fades .

(6) Then the effects of the sleep-promoting centers ( Raphe Nuclei ) , and the rising melatonin levels Take over leading to rapid transition from **wakefulness back to sleep**.

## ❖Role of neurotransmitters

- **Serotonin:**

Serotonin appears to modulate sleep through its effect on other hypnogenic factors in the anterior hypothalamus and suprachiasmatic nucleus.

- **Agonist:** (-) sleep.
- **Antagonist:** (+) slow-wave sleep.

Serotonin is a **melatonin** precursor.

- **Melatonin** is a hormone secreted by → *Pineal Gland* → During **darkness** through sympathetic activation from the **retino -hypothalamic tract** , **It inhibits RAS** & thereby induces sleep . [Melatonin enhances sleep]
- **prolonged bright light** stimulation suppresses melatonin and sleep .
- **subsequent melatonin injections** can restore normal sleep patterns.
- **Preoptic nucleus** of anterior Hypothalamus appears → **inhibit waking areas** in the rostral midbrain and mesopontine reticular core

- **Adenosine:**
- sleep inducing factor.
- It accumulates in brain with prolonged wakefulness.

- **Adenosine antagonists** [ example caffeine ] → **(+) alertness.**

# ❖Sleep disorders:

- Insomnia:

Inability to sleep

- Fatal familial insomnia:

impaired autonomic & motor function , dementia, death.

- Disorders during slow wave sleep :

Sleep walking - Bed wetting - Night terrors

- Narcolepsy:

episodic sudden loss of muscle tone → irresistible urge to sleep during day time (Bursts of REM).

- Sleep apnea :

airway obstruction

[ Normally in REM sleep , all muscles become hypotonic except respiratory muscles ( & eye muscles ) ,

But here respiratory muscles are also hypotonic which causes a temporary inability to breathe during sleep ]