فريق دوبامين العلمي - THE SCIENTIFIC TEAM OF DOPAMINE -
APPROVED
0530309

بسم الله الرحمن الرحيم

DOPAMINE
SCIENTIFIC TEAM

Brain Activity & Sleep

FINAL | Lecture 9

﴿ إِنِّي تَوَكَّلْتُ عَلَى ٱللَّهِ رَبِّي وَرَبِّكُم مَّا مِن دَآبَّةٍ إِلَّا هُوَ ءَاخِذٌۢ بِنَاصِيَتِهَآ إِنَّ رَبِّي عَلَىٰ صِرَٰطٍ مُّسْتَقِيمٍ ﴾

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PHYSIOLOGY

رحلة اليقين مع سورة يس

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

وَلَوۡ نَشَآءُ لَطَمَسۡنَا عَلَىٰٓ أَعۡيُنِهِمۡ فَٱسۡتَبَقُواْ ٱلصِّرَٰطَ
فَأَنَّىٰ يُبۡصِرُونَ ٦٦

وَلَوۡ نَشَآءُ لَمَسَخۡنَٰهُمۡ عَلَىٰ مَكَانَتِهِمۡ فَمَا ٱسۡتَطَٰعُواْ
مُضِيّٗا وَلَا يَرۡجِعُونَ ٦٧

ولو نشاء إذهاب أبصارهم لأذهبناها فلم يبصروا، فتسابقوا إلى الصراط ليعبروا منه إلى الجنة، فبعيد أن يعبروا وقد ذهبت أبصارهم.

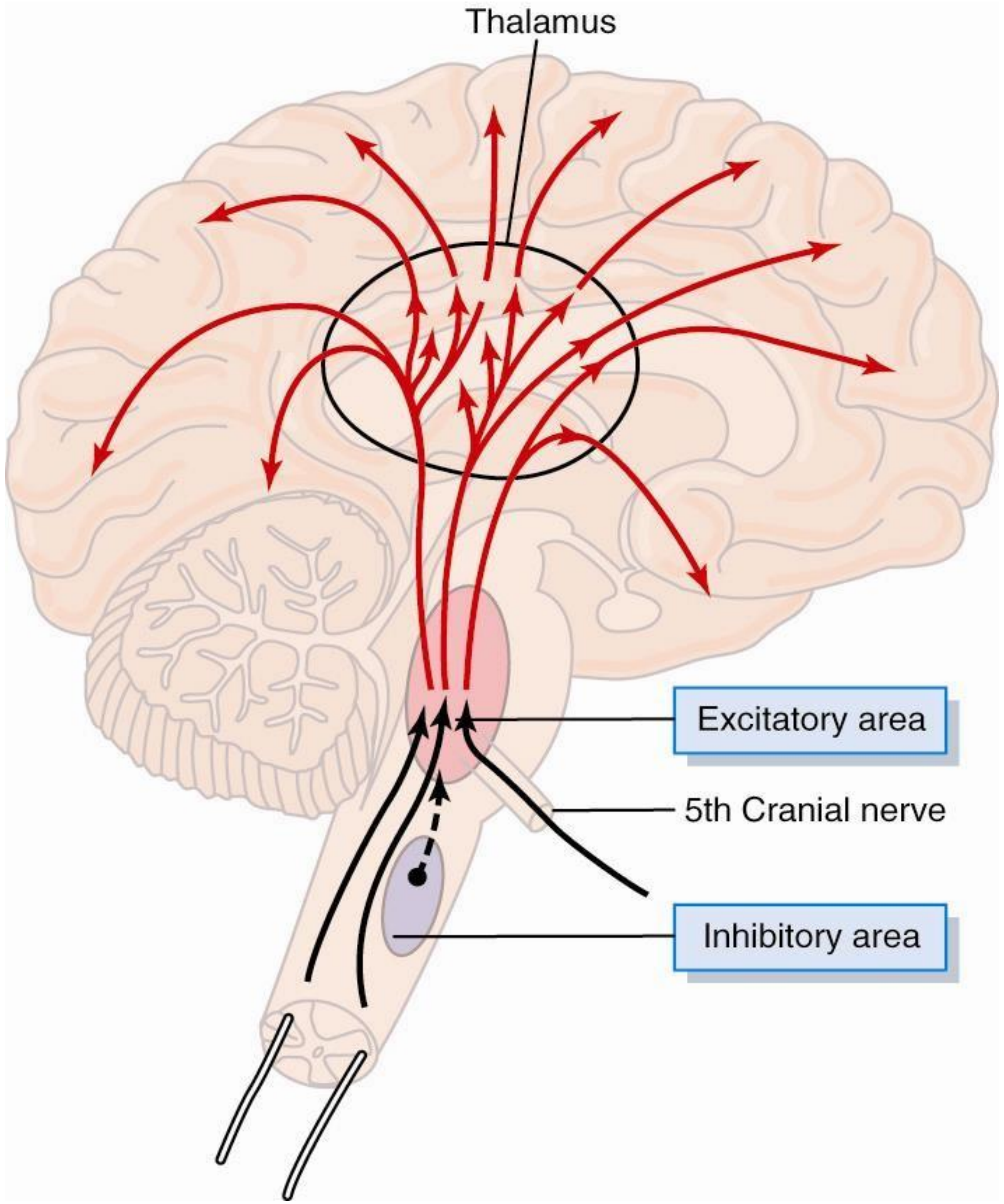
ولو نشاء تغيير خلقهم وإقعادهم على أرجلهم لغيَّرنا خلقهم وأقعدناهم على أرجلهم، فلا يستطيعون أن يبرحوا مكانهم، ولا يستطيعون ذهابًا إلى أمام، ولا رجوعًا إلى وراء.

Brain activity and Sleep L

Faisal I. Mohammed, MD, PhD

Objectives

- List types of sleep
- Describe sleep
- Outline the reticular activating system function



Location of excitatory and inhibitory areas of the brain

Reticular formation is located in the brainstem. It has two main areas:

1. An excitatory (bulboreticular) area in the pons, which is intrinsically active and activates the cortex, preventing sleep.
2. An inhibitory area, which inhibits the excitatory area, allowing sleep.

Activating Systems of the Brain

- Cerebrum requires a constant input to remain active.
- Signals from the brainstem activate wide areas of the cortex (background activation) or specific areas to perform discrete tasks.

Background activation refers to the baseline level of activity in the cerebral cortex that keeps it awake, alert and ready to process information. Even when you're not thinking about anything specific, your cortex is not silent – it's being continuously "switched on" at a low level.

Excitatory Signals from the Brainstem

- Bulboreticular facilitory area (the excitatory area, called "bulbo" because it contains the cranial nerve nuclei)
  - sends excitatory signals to the antigravity muscles
  - sends excitatory signals to the thalamus and from here they are distributed to widespread areas of the cortex
- Bulboreticular area is excited by signals from the periphery, especially pain signals and also descending signals from the cortex (positive feedback or corticospinal pathway). *See next slide*

Excitatory Signals from the Brainstem

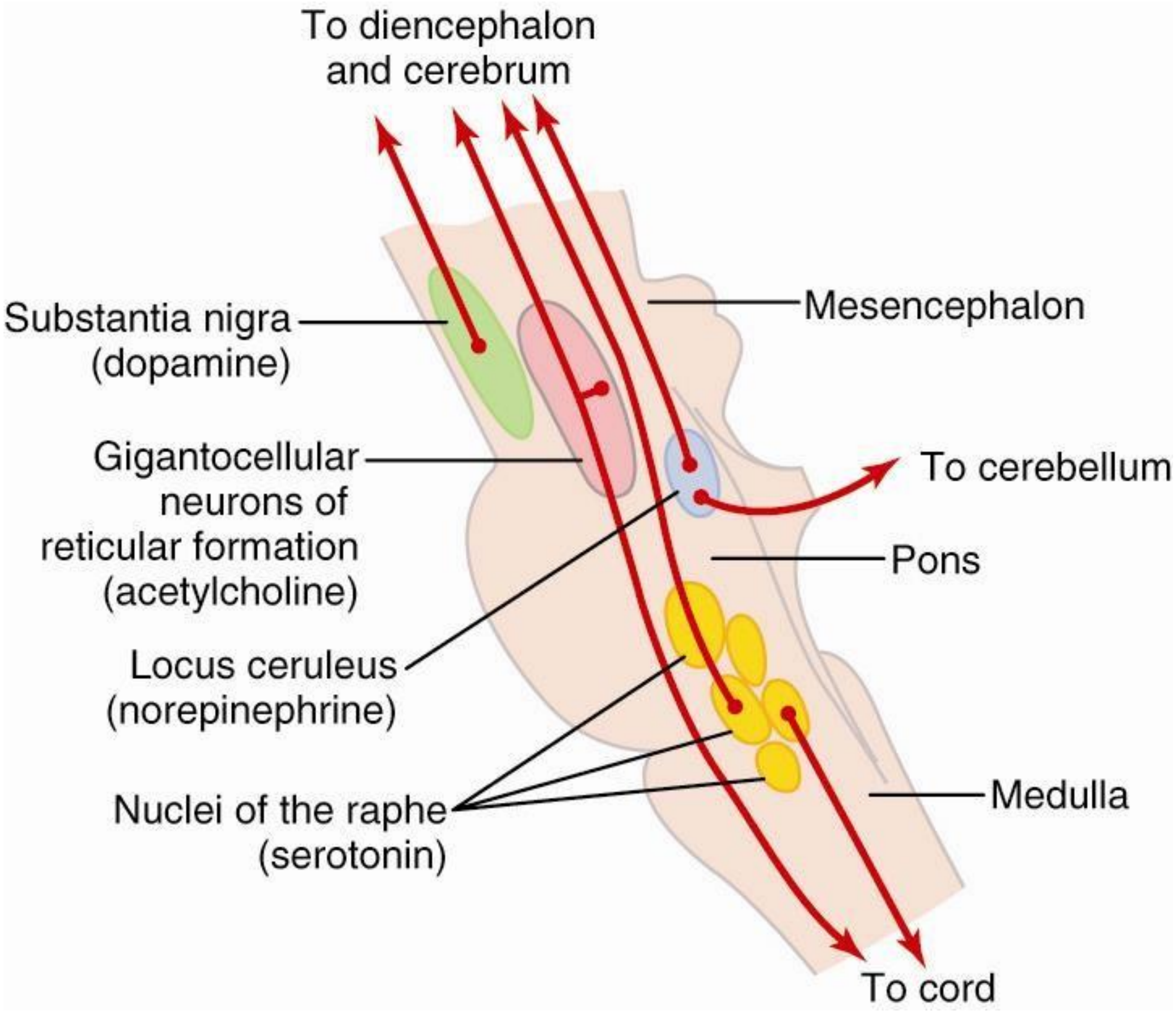
- Bulboreticular area can be excited by many pathways from the ascending periphery, including loud noises, optic pathways, and pain. Most importantly, 50% of the slow pain fibers (paleospinothalamic tract), such as in dental pain, reach the reticular formation, explaining why patients with this type of pain often complain of lack of sleep.

- Not only ascending fibers can stimulate this area but also descending ones. An example of that is a soldier working a night shift. He keeps walking and moving in the same area, and the corticospinal tracts passing by the brainstem stimulates the excitatory reticular area.

Inhibitory Signals from the Brainstem

- reticular inhibitory area (in medulla)
  - sends inhibitory signals to the bulboreticular area
  - when the inhibitory area is excited, it will decrease the activity of the excitatory area and decrease the activity of the cortex
  - The person will go into sleep

Neurohumoral Control of Brain Activity



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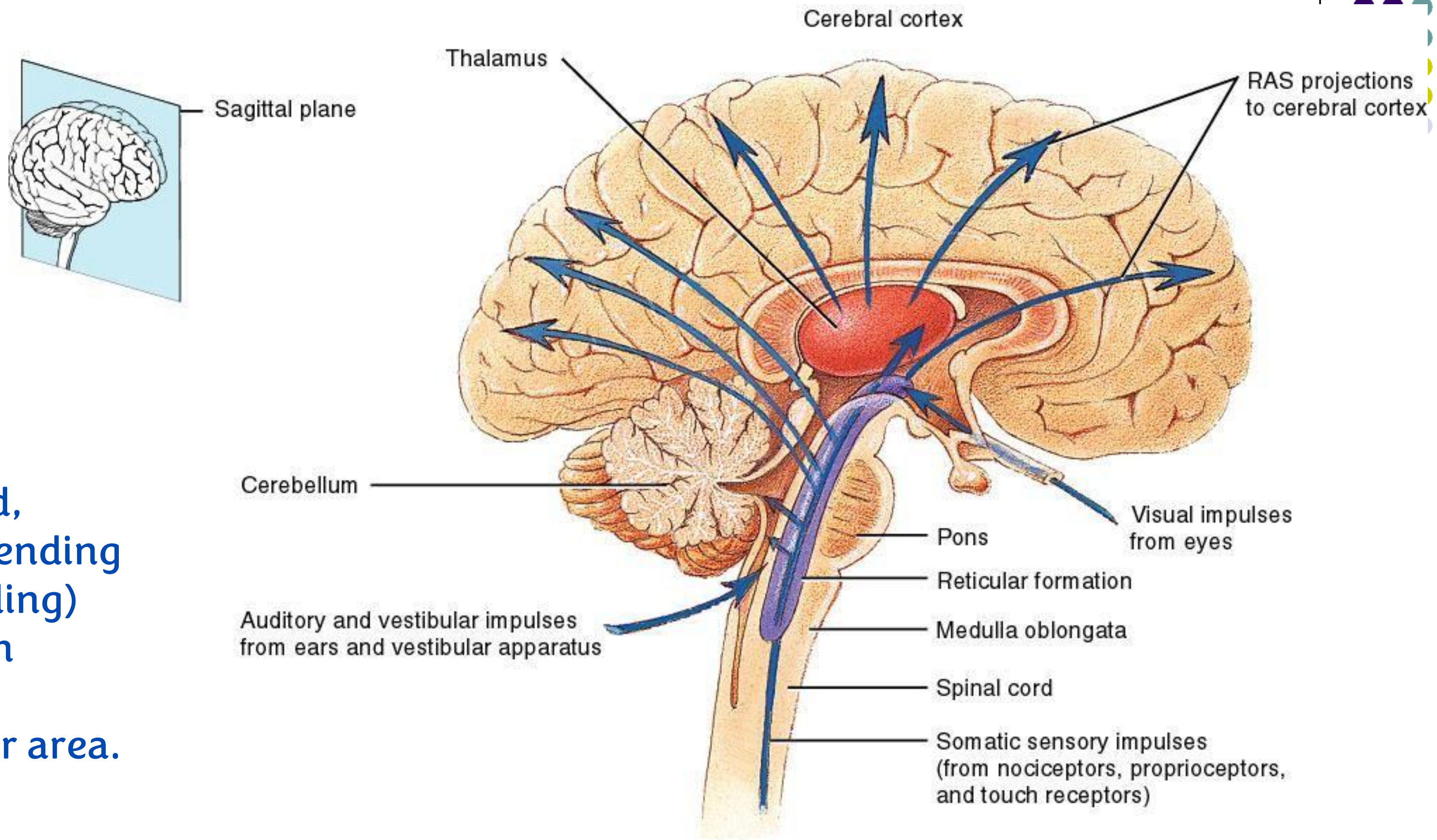
Sleep as an Active Process

The previous figure shows areas of the brainstem that influence sleep.

1. Gigantocellular neurons in the bulboreticular area release acetylcholine and send information to the cerebral cortex through the thalamus. They also send descending fibers to the spinal cord (pontine reticulospinal).
2. Nuclei of the raphe, including raphe nucleus magnus, secrete serotonin both as part of the pain suppression system through descending fibers, and also in ascending fibers to the cortex, inducing sleep.
3. Substantia nigra might also stimulate sleep by releasing dopamine.
4. Locus ceruleus, a nucleus that releases norepinephrine and is important for rapid eye movement sleep “REM”.

As mentioned, different ascending (and descending) pathways can stimulate the bulboreticular area.



Sagittal section through brain and spinal cord

15.10

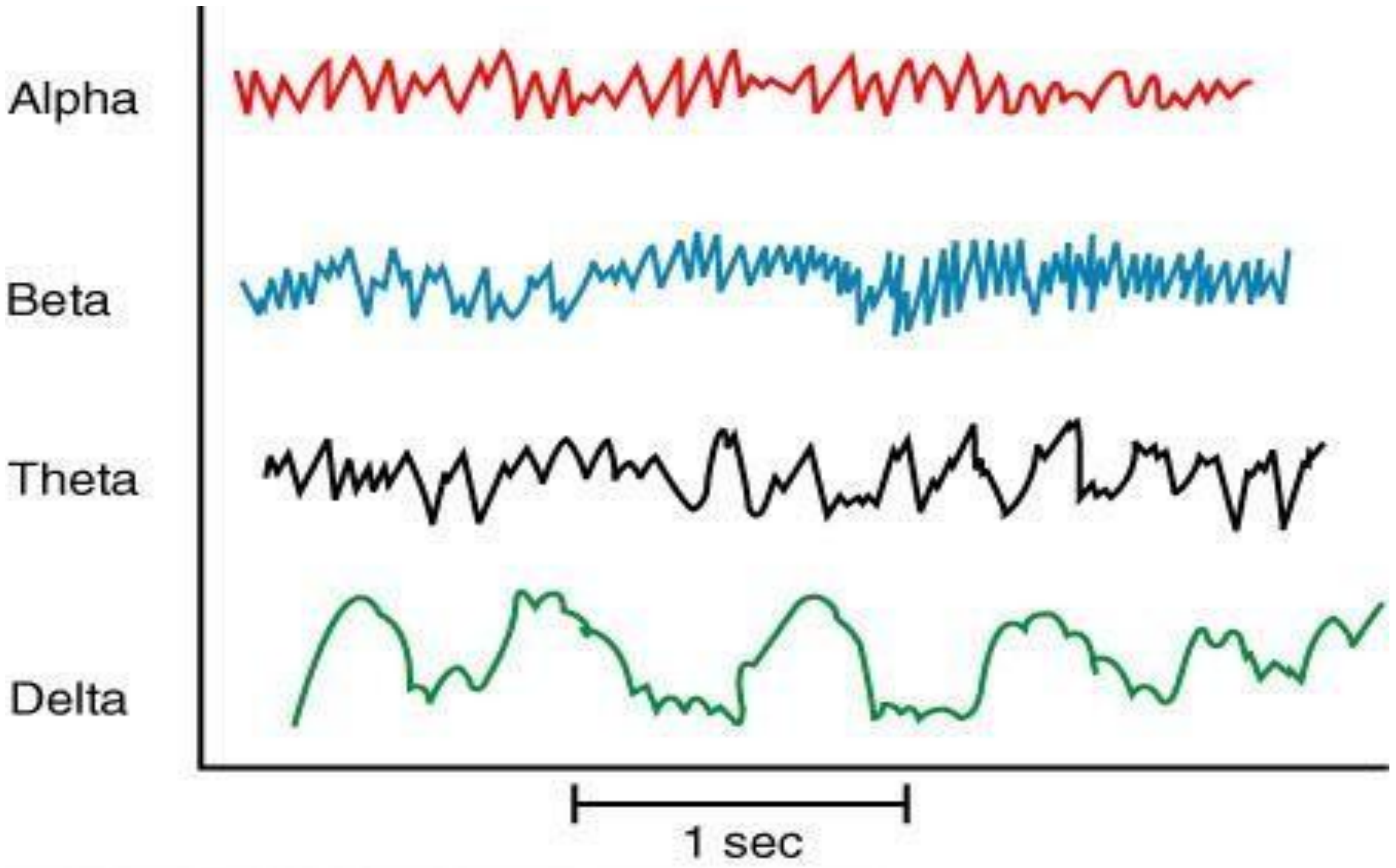
Sleep

- A state of unconsciousness from which one **can** be aroused by sensory stimulus
- different from *coma*, which is also a state of unconsciousness from which one **cannot** be aroused
- two types of sleep:
  - slow wave or deep sleep or restful sleep or non-REM (NREM) sleep
  - REM sleep or paradoxical sleep

Coma can probably occur due to destruction or inhibition (by trauma, edema, or hemorrhage) of the excitatory area, like after a blunt force to the base of the skull, affecting the brainstem.

EEG waves

Electroencephalogram (EEG) is easy to read but hard to preform, because there are approximately 20 electrodes. unlike ECG of the heart which is easy to preform but hard to read. In EEG we do not record action potential; instead, we record excitatory post-synaptic potentials (EPSPs).



Electroencephalography (EEG) Waves and Brain Activity

- **Electroencephalography (EEG) waves** are used to monitor **brain activity** and are classified based on their **frequency (Hz)** and **amplitude.**
- **Alpha waves** (**8–13 Hz**) are typically seen when a person is **relaxed but awake**, often with **eyes closed**, representing a **calm, restful state** of the brain without active complex processing.
- **Beta waves** (**>14 Hz**, usually **14–50 Hz**, sometimes up to **80 Hz**) are observed during **active thinking**, **alertness**, **problem-solving**, or other **mental tasks**, indicating **high cortical activity**.
- **Theta waves** (**4–7 Hz**) usually appear during **light sleep** or **drowsiness** and can also be seen during **meditation** or **deep relaxation.**
- **Delta waves** (**<4 Hz**) dominate during **deep sleep** (**slow-wave sleep**) and are associated with **high amplitude** and **low frequency**, reflecting a state of **restoration** and **minimal cortical activity**.
- In terms of **amplitude comparison**, the order from **highest to lowest amplitude** is generally: **Delta > Theta > Alpha > Beta**, meaning **deep sleep waves** have the **largest amplitude** while **active thinking waves** have the **smallest.**

Slow Wave Sleep

It's called slow wave because if EEG is recorded during this state, it shows slow "delta waves". To be explained later

- restful sleep at the beginning of the sleep period
- associated with a **decrease in vegetative functions**, like heart rate and respiratory rate, with an **increase in parasympathetic function** like GI activity noted by heavy salivation during deep sleep.
- usually not associated with dreaming; dreams do occur but they are not remembered, because for dreams to be remembered, the cortex must be active. Dreams in this stage are usually nightmares, where a person wakes up frightened, but cannot remember the dream.

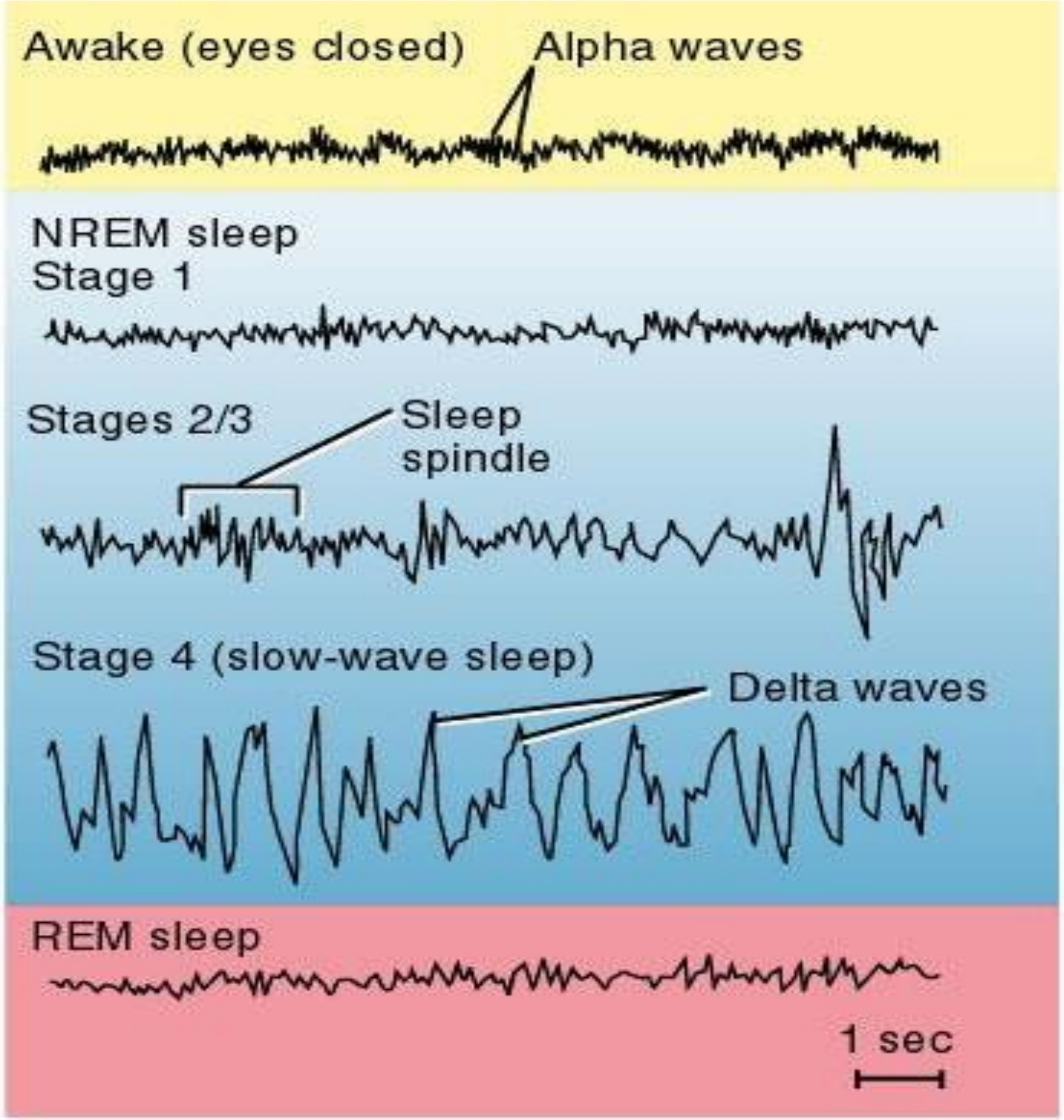
Rapid Eye Movement (REM) Sleep

- associated with **<u>active dreaming</u>**
- peripheral muscle tone is **<u>inhibited</u>**
- associated with an **<u>increase in cortical activity</u>** and metabolism
- brain waves similar to wakefulness
- begin about 90 minutes after falling asleep and reappear at 90 minute intervals
  - last for progressively longer periods of time each time they occur, a few minutes at first, 30 minutes toward the end of the sleep period

Rapid Eye Movement (REM) Sleep (paradoxical sleep)

It's called paradoxical sleep because the patient is truly asleep, but the eyes are rapidly moving

- associated with active dreaming
- peripheral muscle tone is greatly inhibited – **difficult to arouse by sensory stimulation**
- associated with an increase in cortical activity and metabolism
- Irregular heart rate and respiration
- brain waves similar to wakefulness
- begin about 60-90 minutes after falling asleep and reappear at 60-90 minute intervals
  - last for progressively longer periods of time each time they occur, a few minutes (around 5 min) at first, 30 minutes toward the end of the sleep period



(a) EEG waves during sleep stages

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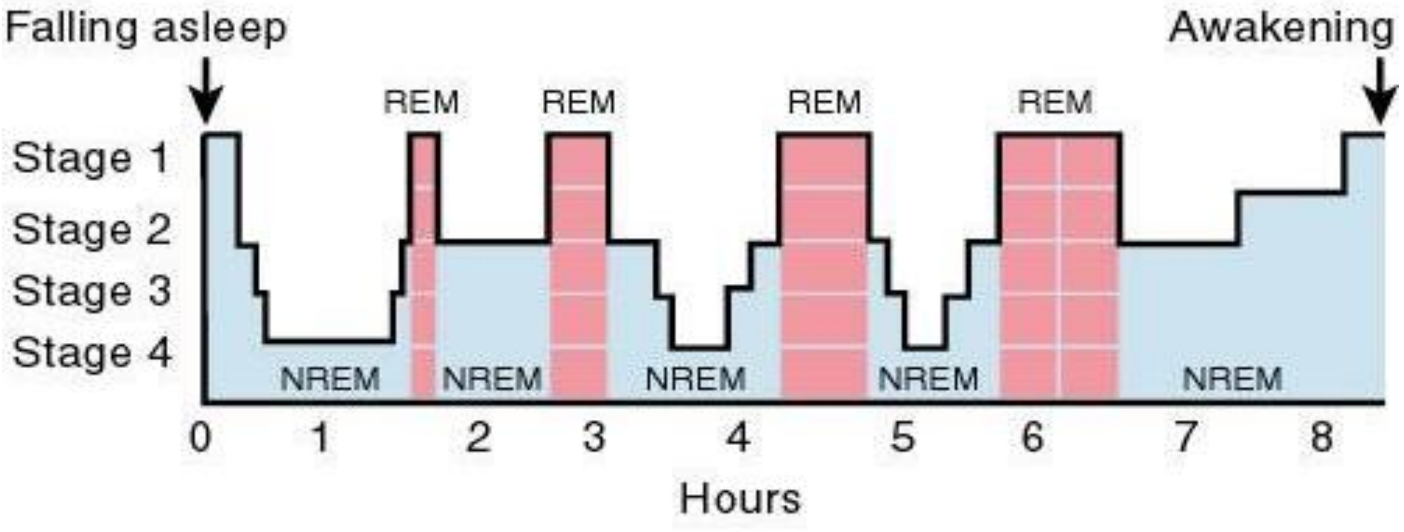


(b) Pattern of NREM and REM sleep over one sleep period

Physiology of Sleep: REM vs. NREM

Sleep is broadly divided into two main types: **REM (Rapid Eye Movement)** and **NREM (Non-Rapid Eye Movement)**. NREM is further divided into stages.

1. **REM Sleep (Paradoxical Sleep)**

   Brain Activity: Characterized by high cortical activity, almost similar to the awake state.

   Brain Waves: Primarily **Beta waves** (low amplitude, high frequency), which are typical of an alert, awake person.

   Muscle State: The body experiences **muscle atonia** (complete relaxation/paralysis), which is why it is called "paradoxical"—an active brain in a paralyzed body.

   Functions: Associated with **dreaming** and plays a vital role in **memory consolidation**, particularly for emotional and procedural memories.

2. **Slow-Wave Sleep (Deep, NREM Sleep)**

   Brain Activity: Cortical activity is markedly decreased.

   Brain Waves: Primarily **Delta waves** (high amplitude, low frequency).

   Functions: Crucial for **physical restoration**, energy conservation, and overall recovery of the body's systems; increases after a tiring day.

Physiology of Sleep: REM vs. NREM

- **REM sleep** is considered a state of **active dreaming**. During this stage, **brain activity is very high**, with fast electrical activity (**beta-like waves**), similar to the **awake state**.
- In contrast, **slow-wave sleep** (**deep NREM sleep**) represents **deep, restorative sleep**. During this stage, overall **brain activity is reduced**, and the body is in a state of **relaxation and recovery**.
- One key difference between **REM** and **slow-wave sleep** is **muscle tone** (**muscle activity**). In **slow-wave sleep**, **muscle tone is decreased** but still present, meaning muscles can still contract slightly. In **REM sleep**, there is almost **complete inhibition of muscle tone** (**muscle atonia**), so muscles are essentially **paralyzed**.
- This leads to an important comparison: a **paralyzed person** has **loss of muscle tone** due to **pathology** (**damage to nerves or muscles**), whereas in **REM sleep**, the **loss of muscle tone** is **physiological and reversible**, caused by **active inhibition** from the **brainstem**.
- Regarding **arousal** (**waking up**), it is generally **easier to wake someone from slow-wave sleep**. It is **more difficult to wake someone during REM sleep**, because the **brain is engaged in intense internal activity** (**dreaming**), and the inhibited muscle tone is characteristic of this phase.
- There is also **individual variation** in **sleep architecture**. Although the average is about **25% REM** and **75% NREM**, some individuals may have **higher REM percentages** (for example, up to **50%**), which increases the chance of catching them during **REM sleep**.
- **REM sleep** is characterized by **increased cortical (brain) activity**, **near-complete inhibition of peripheral muscle tone**, **rapid eye movements**, **irregular heart rate**, **irregular respiratory rate**, and **vivid dreaming**.
- **Sleep disorders** such as **sleepwalking** (**somnambulism**) and **sleep talking** (**somniloquy**) occur during **deep sleep** (**slow-wave sleep, NREM**), not during **REM**.

Sleep Cycles and Patterns

1. The 90-Minute Cycle

Sleep occurs in repetitive cycles, with each cycle typically lasting about **90 minutes**. A person alternates between **NREM** and **REM** sleep multiple times throughout the night.

Impact of Fatigue: If a person is extremely tired, they tend to enter **Slow-Wave Sleep (Deep Sleep)** more quickly and stay in it longer.

2. Sleep Distribution Throughout the Night

As shown in the **Hypnogram** (*Figure b* in *slide 19*), the structure of sleep shifts as the night progresses:

Early Night: Slow-Wave Sleep dominates the first few cycles.

Late Night: REM sleep periods become progressively **longer**, while deep sleep decreases or disappears entirely toward morning.

Total Composition (Adults): Approximately **75% NREM** and **25% REM**.

3. Age-Related Differences (Infants vs. Adults)

The sleep pattern is significantly different in infants:

Infants: Spend about **50%** of their sleep in **REM**.

Reason: REM sleep is crucial for **neural development**, brain maturation, and synapse formation during early life.

Why Do We Sleep?

- mechanism is unknown
- probably an **active inhibitory process** in which the excitatory reticular neurons are inhibited
- stimulation of the *raphe nuclei* causes sleep
  - these nuclei release *serotonin* which is thought to induce sleep
  - blockade of serotonin formation causes prolonged wakefulness in animals, however, blood levels of serotonin are lower during sleep

Why Do We Sleep?

- stimulation of other brain regions can also induce sleep
- nucleus of the solitary tract
  - solitary tract stimulation will not produce sleep if the raphe nuclei are destroyed
  - therefore, solitary tract may be stimulating release of serotonin from the raphe nuclei
- suprachiasmatic area of the rostral hypothalamus (controlling circadian cycle and melatonin secretion from the pineal gland), diffuse thalamic nuclei

Why Do We Sleep?

- accumulation of sleep factors
  - muramyl peptide - found in CSF and urine of animals keep awake for prolonged periods, will cause sleep when injected into third ventricle
  - also a peptide isolated from the blood of sleeping animals
  - also substance from brain stem of animals keep awake
- lesions of the raphe nuclei can prevent sleep

REM Sleep

- function of REM sleep is unknown
  - lesions of the *locus ceruleus* prevent REM sleep
  - may be important for neural development
    (this explains why infants have long REM sleep)
  - testing the cortex to see if it can be brought to activity

Sleep Cycle

- no explanation for the sleep-wakefulness cycle
- however, there are many theories
  - Some theories suggest that the sleep cycle is a passive process, which may be caused by fatigue of excitatory areas to induce sleep and fatigue of inhibitory areas of the lower brain to awaken.
  - Newer and more accepted theory is that sleep probably is an active process driven by a center below the midpontine level of the brain stem.

Physiological Effect of Sleep

- little on the body itself
  - decrease in sympathetic tone, muscle tone, fall in arterial pressure
- profound effect on the brain
  - lack of sleep can lead to altered mental states
    - paranoia, psychoses
- sleep probably functions to balance the activity of the various areas of the brain, to reset/re-zero/reboot neuronal circuits

Brain Waves

- electrical recordings from the surface of the brain
- characterized as *alpha, beta, theta* and *delta* depending on the frequency
- each functional state of the brain has a characteristic pattern of brain waves (sleep, wakefulness, epilepsy, psychoses, etc.)

Alpha and Beta Waves

- Alpha waves
  - occur at 8-13 Hz
  - mostly from occipital cortex but can also be found in frontal and parietal regions as well
  - occur during quiet resting states of cerebration, they disappear when there is a specific mental activity (opening of the eyes, intense mental concentration or stress) or during sleep
  - will not occur without cortical connection to thalamus
- Beta waves
  - occur at 14-80 Hz
  - occur during intense mental activity or stress or during movement where moving the right hand causes the specific area in the left cortex to record beta waves

Theta and Delta Waves

- Theta waves
  - occur at 4-7 Hz
  - recorded from parietal and temporal regions in normal healthy children
  - occur during emotional stress in adults particularly in response to disappointment or frustration or depression and can diagnose some types of epilepsy
- Delta waves
  - all waves below 3.5 Hz
  - occur during deep sleep thought to be activity of the cortex independent of signals from lower brain areas

EEG Sleep Patterns

- There are two major types of sleep:
  - Non-rapid eye movement (NREM)
  - Rapid eye movement (REM)
- REM (rapid eye movement):
  - Dreams occur.
  - Low-amplitude, high-frequency oscillations.
  - Similar to wakefulness (beta waves).
- Non-Rem (resting):
  - High-amplitude, low-frequency waves (delta waves).

Non-REM Sleep

- Alpha, delta, theta activity are present in the EEG record
  - Stages 1 and 2: Alpha waves
  - Stages 3 and 4: delta activity (synchronized)
    - Termed slow-wave sleep (SWS)
- Light, even respiration
- Muscle control is present (toss and turn)
- Dreaming (could but not vivid, rational)
  - Difficult to rouse from stage 4 SWS (resting brain?)

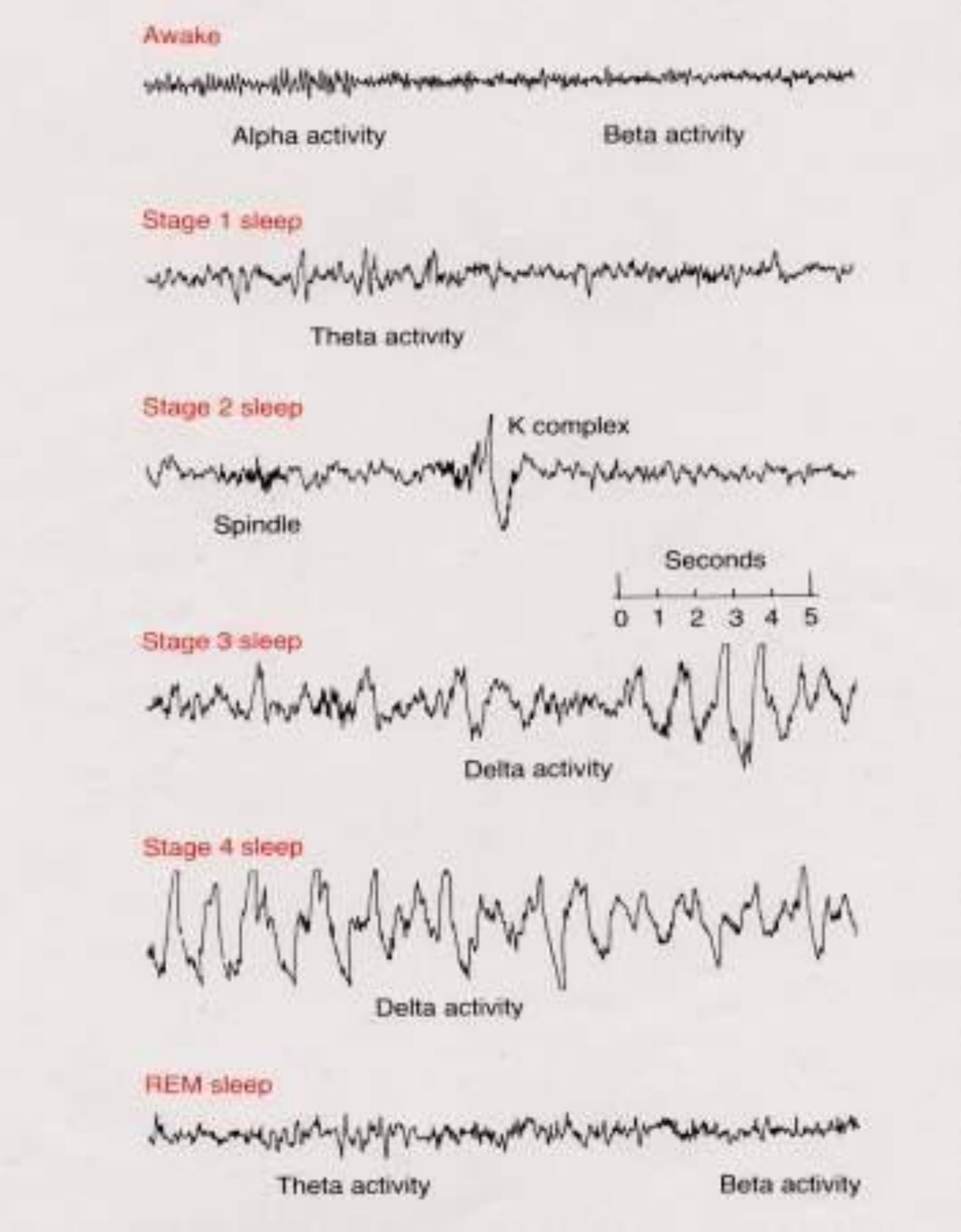
REM Sleep

- Presence of **beta activity** (desynchronized EEG pattern)
- Physiological arousal threshold increases
  - Heart-rate quickens
  - Breathing more irregular and rapid
  - Brainwave activity resembles wakefulness
  - Genital arousal
- Pontine-Geniculate-Occipital (PGO) waves?
- Loss of muscle tone (paralysis)
- Vivid (clear and rememberable), emotional dreams
- May be involved in memory consolidation (active cortex)

Types and Stages of Sleep: NREM

- Stage 1 – eyes are closed and relaxation begins; the EEG shows alpha waves; one can be easily aroused

- Stage 2 – EEG pattern is irregular with sleep spindles (high-voltage wave bursts); arousal is more difficult

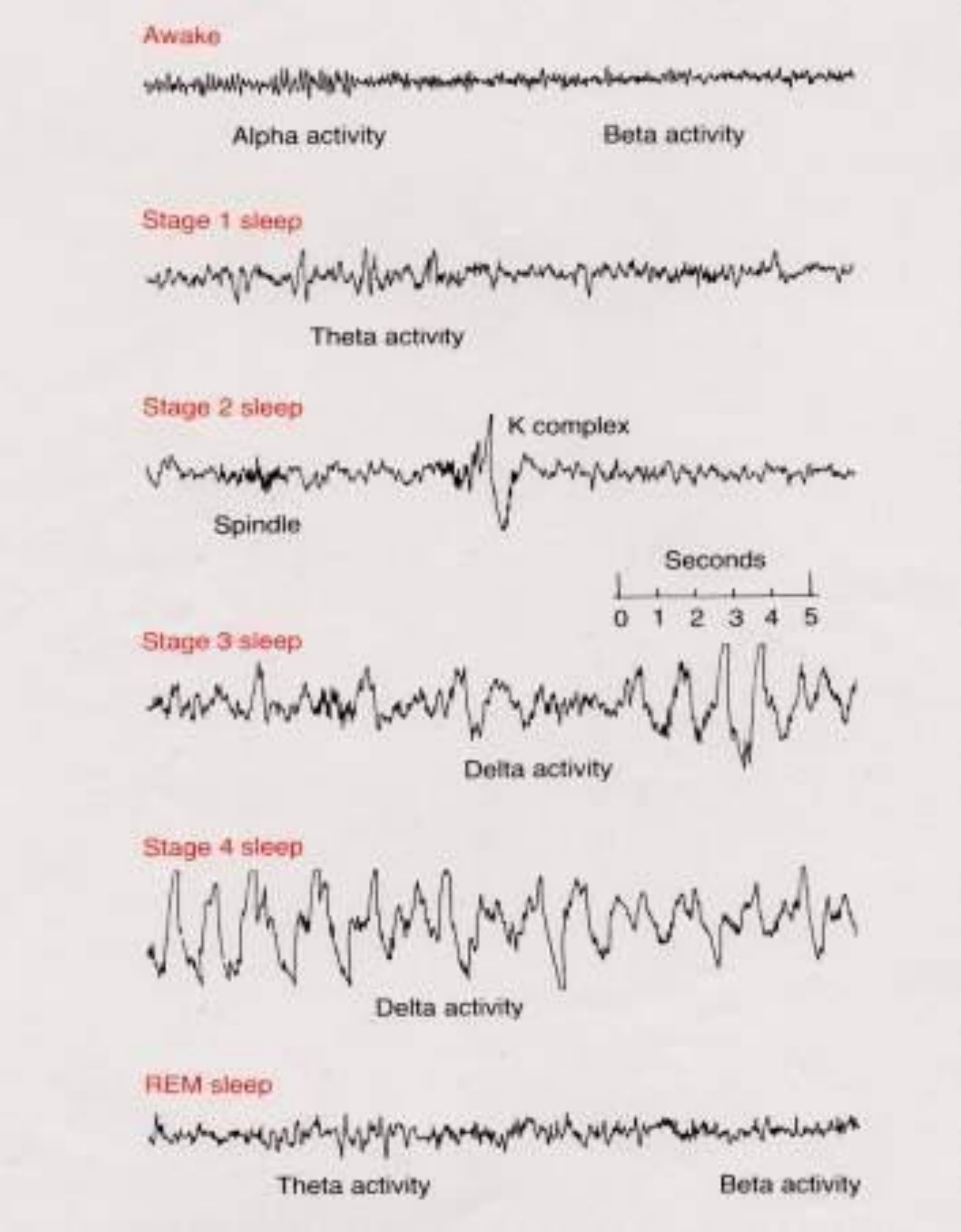


Notice that Theta waves and K-complexes can sometimes be seen in stages 1 or 2.

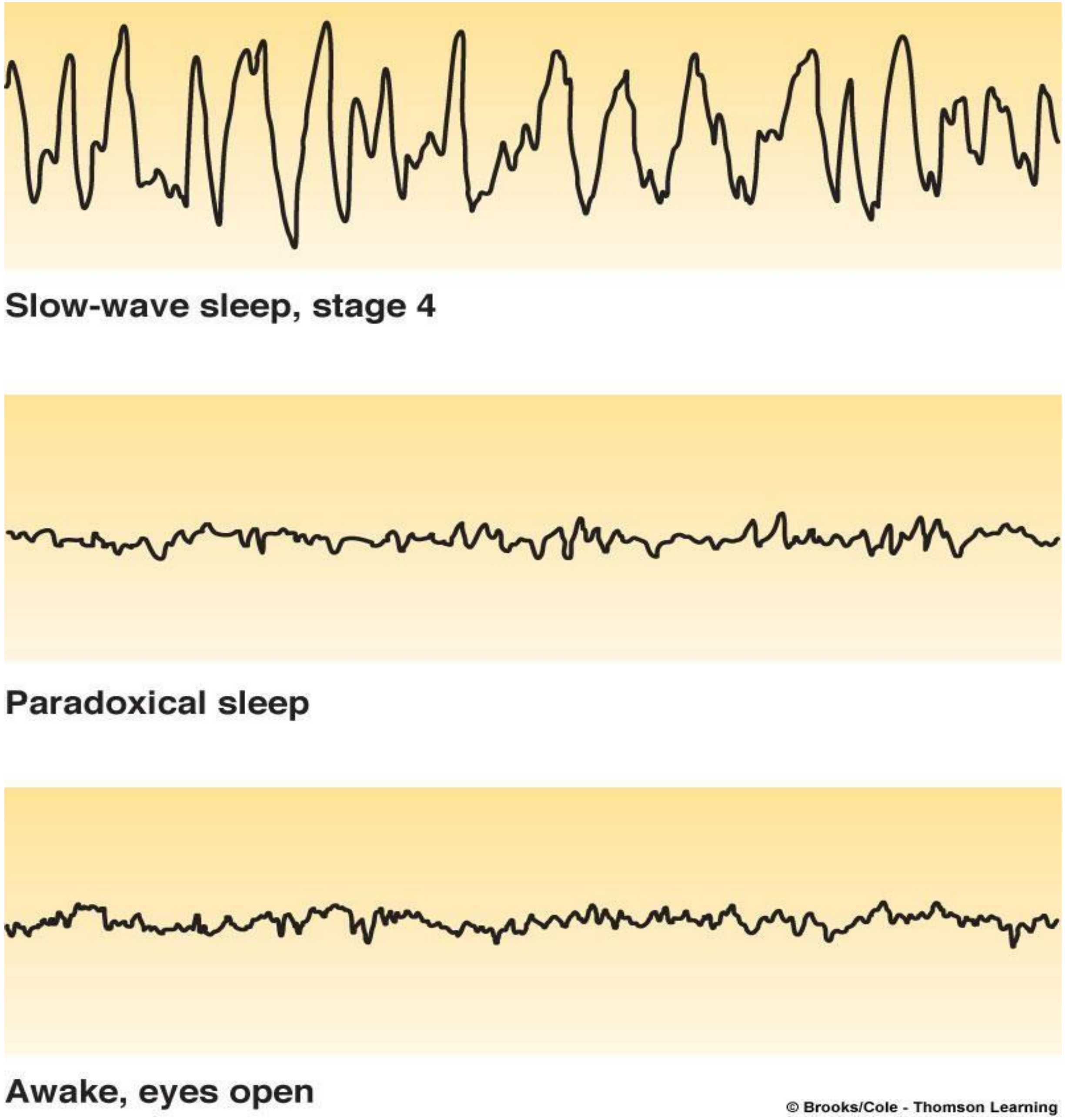
Stages 1 and 2 are sometimes called "daydreaming".

- Stage 3 – sleep deepens; theta and delta waves appear; vital signs decline; dreaming is common (nonvivid dreams)

- Stage 4 – EEG pattern is dominated by delta waves; skeletal muscles are relaxed; arousal is difficult, but not as difficult as in REM



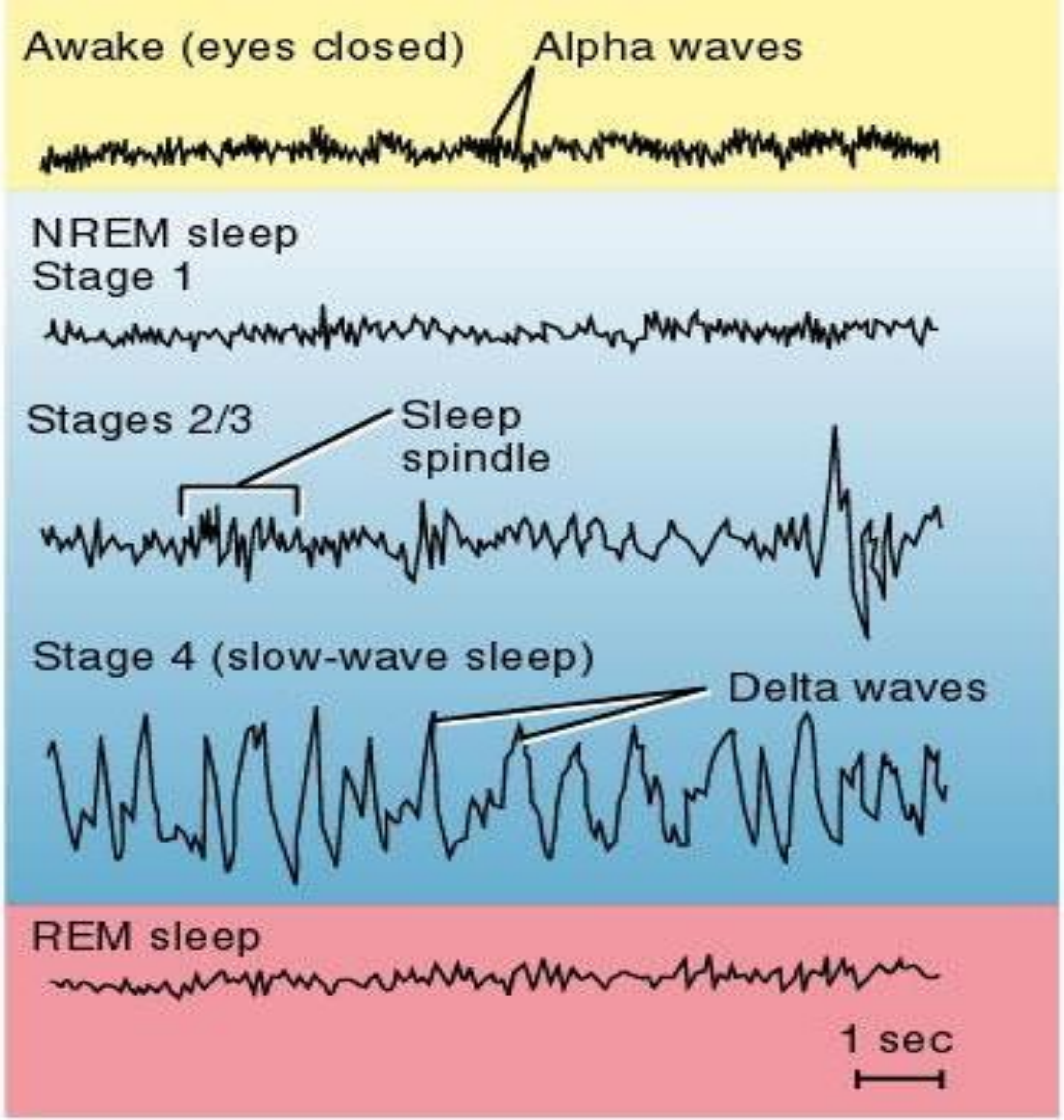
EEG Patterns During Different Types of Sleep



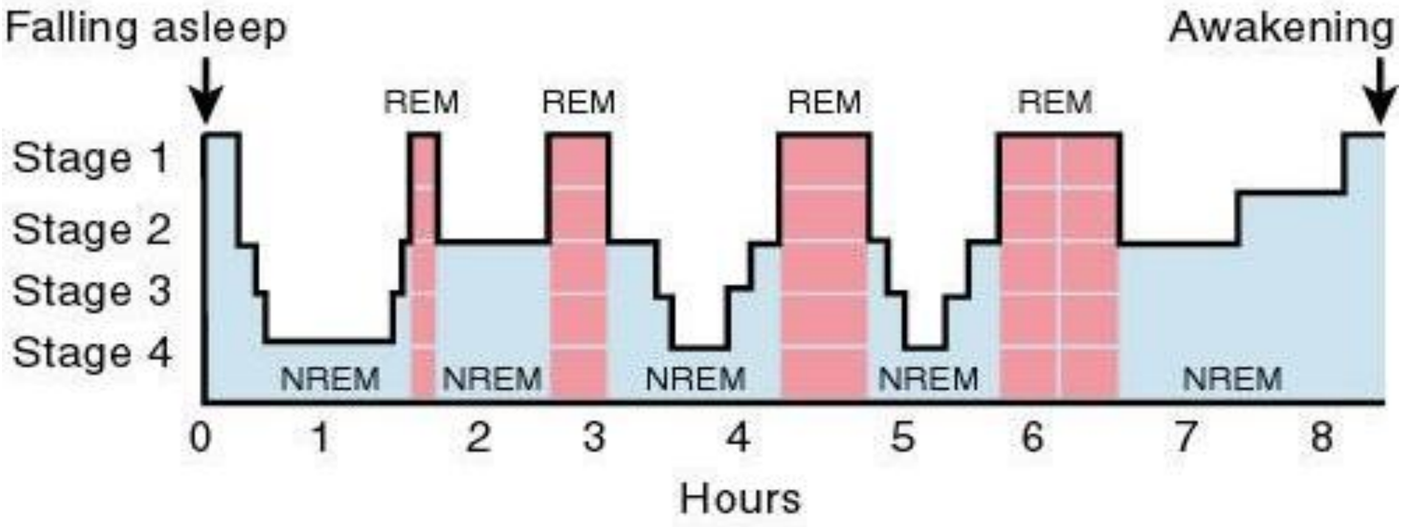
Delta waves

Beta waves

Alpha waves



(a) EEG waves during sleep stages

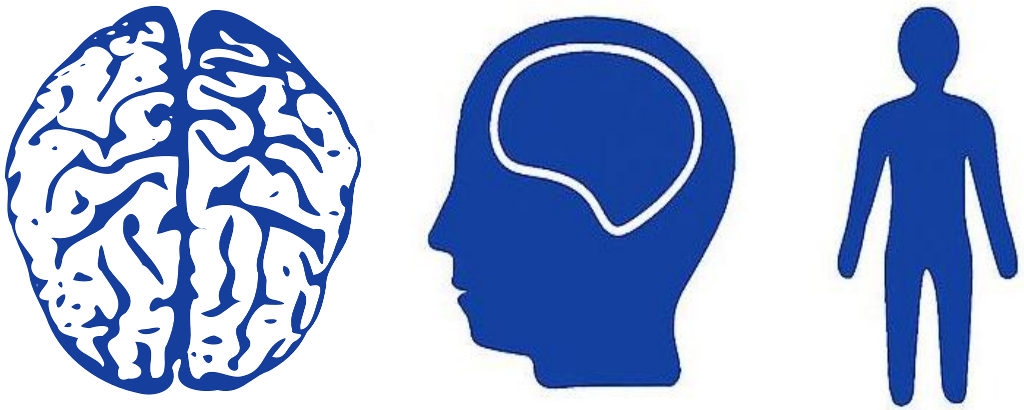


(b) Pattern of NREM and REM sleep over one sleep period

Comparison of Slow-Wave and Paradoxical Sleep

CHARACTERISTIC	TYPE OF SLEEP: Slow-wave sleep	TYPE OF SLEEP: Paradoxical sleep
EEG	Displays slow waves	Similar to EEG of alert, awake person
Motor Activity	Considerable muscle tone; frequent shifting	Abrupt inhibition of muscle tone; no movement
Heart Rate, Respiratory Rate, Blood Pressure	Minor reductions	Irregular
Dreaming	Rare (mental activity is extension of waking-time thoughts)	Common
Percentage of Sleeping Time	80% (75-80%)	20% (20-25%)
Other Important Characteristics	Has four stages; sleeper must pass through this type of sleep first	Rapid eye movements


THANK YOU
We're on Track
For a Cure



PHYSIOLOGY QUIZ
LECTURE 9

اللهم هذا مسرى نبيّك، وأنت القوي العزيز

Scan the QR code or click it for FEEDBACK

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			