CNS MODULE
PHYSIOLOGY (LECTURE 7)
AROUSAL MECHANISM; RETICULAR ACTIVATING SYSTEM (RAS)

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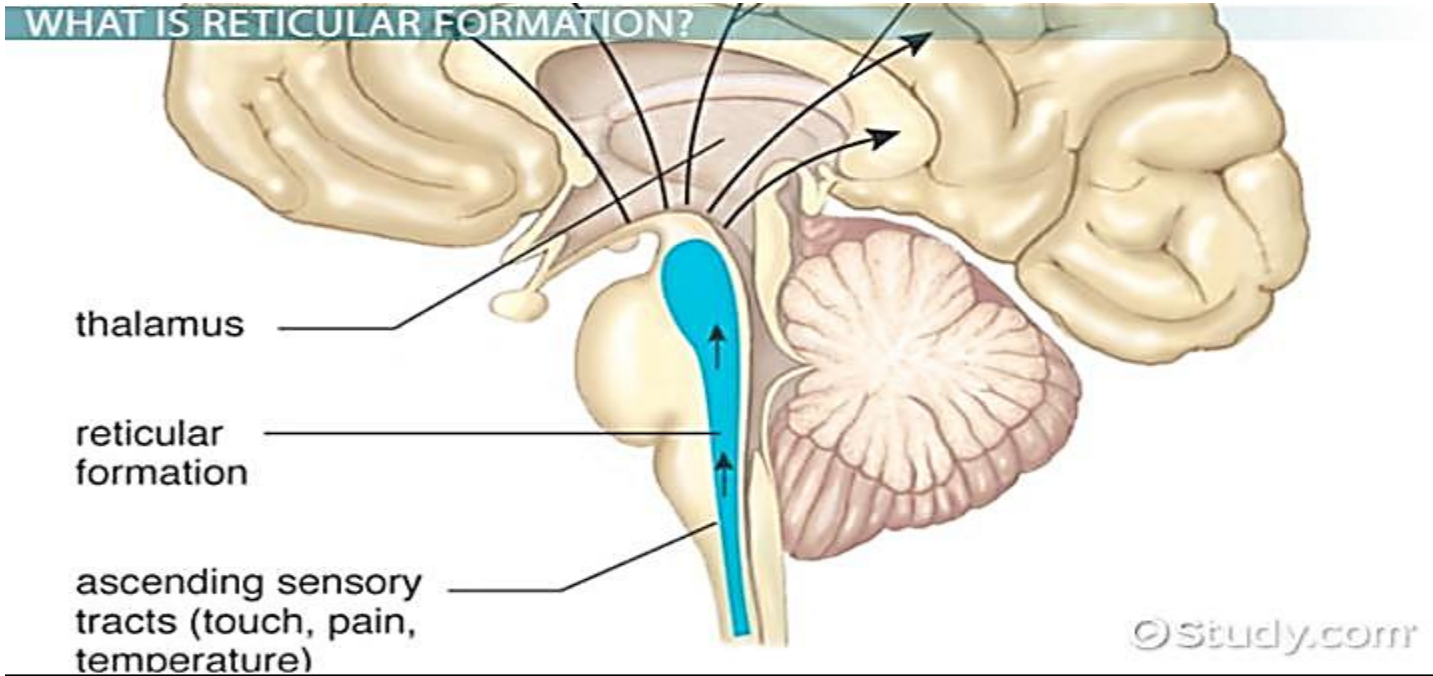
2023-2024

THE RETICULAR FORMATION

- This is a network of neurons located in the **brainstem**, extending upwards to the diencephalon and downwards to the upper part of the spinal cord, where it merges with its interneurons.
- Many nuclei and centers are present within its meshes (e.g. the respiratory & cardiac centers, the substantia nigra, and the red, vestibular and raphe nuclei).
- It is divided into sensory and motor parts.



The Sensory Part

- This consists of a large number of small neurons that have multiple interconnections with each other.
- It receives a rich afferent fibers from:
  - All ascending lemnisci.
  - The visual, auditory and olfactory nervous pathways.
  - The basal ganglia.
  - The cerebellum.
  - The cerebral cortex (corticofugal fibers).
  - The hypothalamus.
  - The vestibular apparatus.

The Motor Part

This consists of large neurons which receive signals from the sensory part, and their axons constitute the output (efferent fibers) from the reticular formation.

It contains facilitatory and inhibitory parts:

1. Facilitatory (excitatory; pontine) reticular formation: This is located in the pons and midbrain (especially the former). It has an inherent activity and the axons of its neurons divide into 2 branches:

(a) An ascending branch, which excites the cerebral cortex, and is called the reticular activating system (RAS) OR ascending reticular activating system (ARAS).

(b) A descending branch (ventral reticulospinal tract) which facilitates the spinal centers.

2. Inhibitory (medullary) reticular formation: This is located mainly in the medulla oblongata. It has no inherent activity and its axons descend as the lateral reticulospinal tract which inhibits the spinal centers.

Functions of Reticular Formation

1. Control of the level of consciousness via the ascending reticular activating system.
2. Regulation of the stretch reflex and muscle tone via the reticulospinal tract.
3. Pain inhibition by the raphe magnus nucleus.
4. Control of sleep by 2 specific centers.

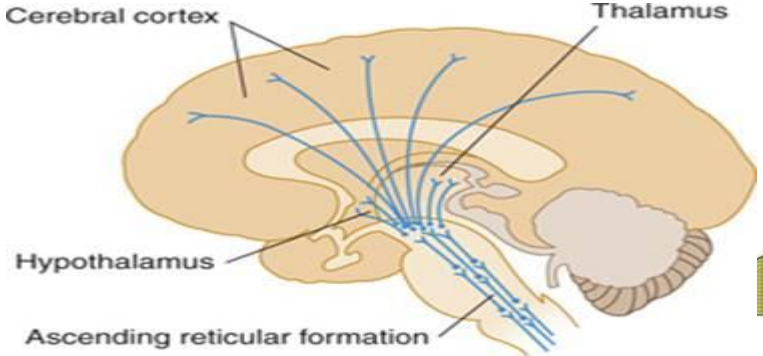
RETICULAR ACTIVATING SYSTEM (RAS)

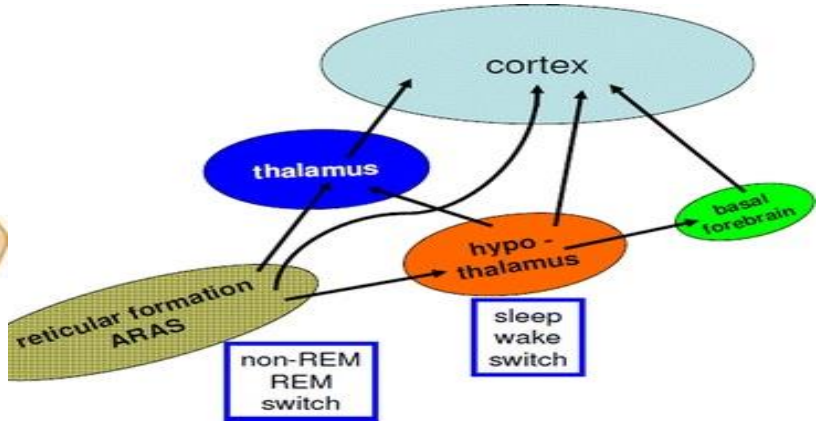
Definition:

- It is a **multi-neuronal polysynaptic system** of nerve fibers that **originates at the facilitatory reticular formation**.
- **Its fibers** extend upwards then **some project directly to the cerebral cortex**, while the **majority relay first at the nonspecific thalamic nuclei, from which other fibers arise and project diffusely to almost all parts of the cerebral cortex**. The latter pathway is called the **reticulo-thalamo-cortical pathway**.

Functions:

The **RAS controls the electric activity of the cerebral cortex**, and is concerned with **consciousness** and **production of the alert response**, so **reduction of its activity leads to sleep**.





Factors that affect the activity of RAS:

Factors that increase RAS activity:

1. Sensory signals (specially pain).
2. Signals from the cerebral cortex (via the corticofugal fibers) which increase alertness and resist the desire to sleep (e.g. during emotions and voluntary movements).
3. Analeptic drugs (e.g. catecholamines, amphetamine and caffeine).

Factors that decrease RAS activity:

1. Reduction of signals from either the sensory pathways or the cerebral cortex.
2. Stimulation of the sleep centers.
3. Extensive damage of the RAS (e.g. by tumors).
4. General anesthetic drugs: These drugs lead to unconsciousness through depressing the RAS activity. They inhibit the synaptic transmission between its neurons (by producing a state of hyperpolarization in these neurons).

ELECTRICAL ACTIVITY OF THE BRAIN

The brain has a marked electric activity and 2 types of potentials can be recorded: Evoked potentials and spontaneous potentials (EEG).

Evoked Cortical Potentials (EP)

- Definition: These are the potential changes that occur in the cerebral cortex after stimulation of a receptor.
- Recording:

The subject is anesthetized and the exploring electrode is applied over the excited cortical area.

- 2 types of these potentials are recorded:

A. Primary evoked potential.
B. Secondary evoked potential (diffuse secondary response).

(A) Primary evoked potential

- This consists of a +ve wave followed by a –ve wave, which are produced as a result of depolarization followed by hyperpolarization of the nerve cells.
- They are **localized** to the **brain area at which the sensory pathway terminates (the excited area)**(so recording of this potential has been used for **mapping the specific cortical sensory areas**).

(B) Secondary evoked potential (diffuse secondary response).

- This follows the primary potential and consists of a large and more prolonged +ve wave.
- It is not localized (appearing in **most areas of the cortex** at the same time), and is produced by afferent signals discharged to the cortex, most probably from the **nonspecific thalamic nuclei**.

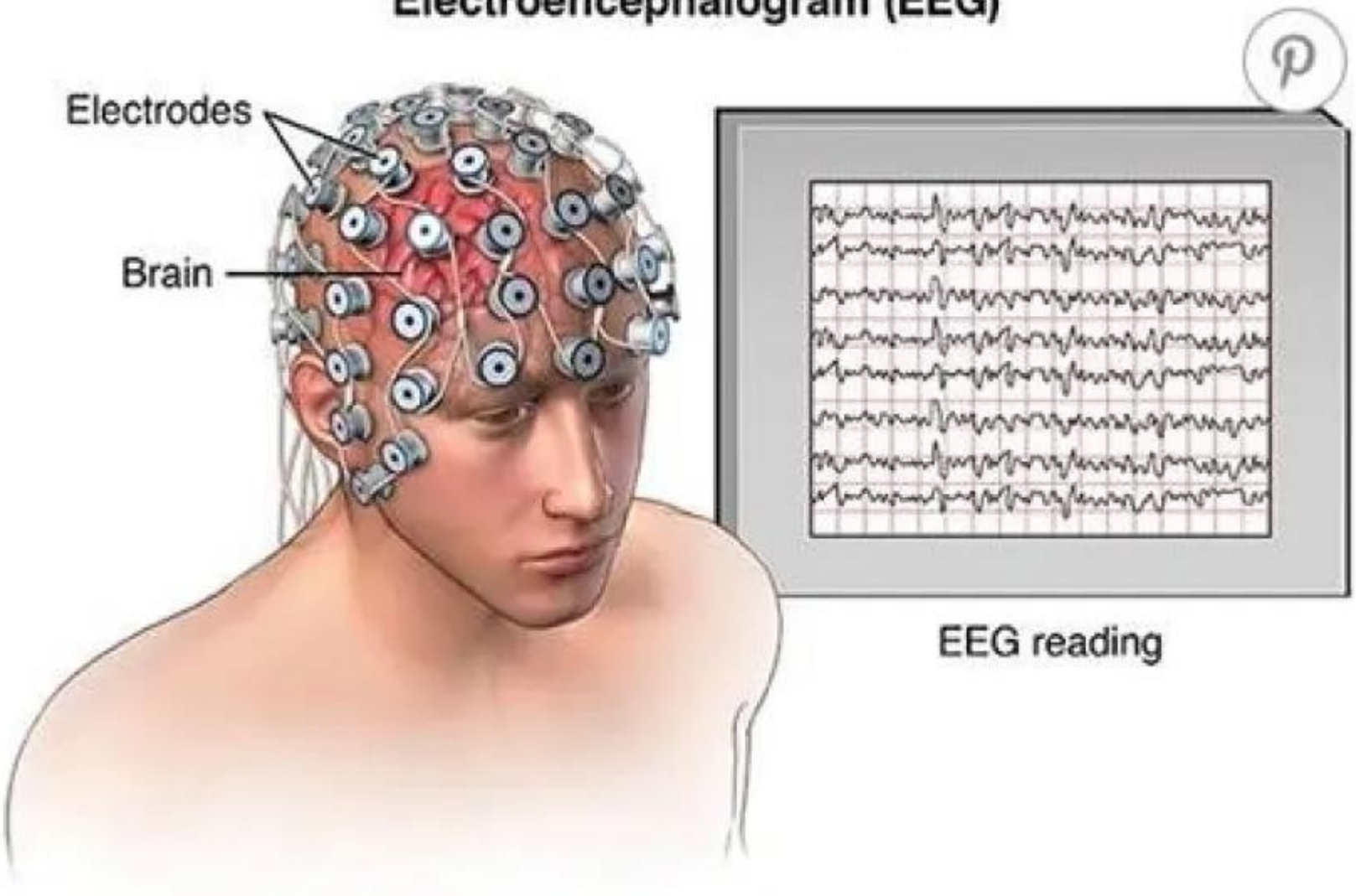
(2) Spontaneous Cortical Potentials
Electroencephalogram (EEG) OR Brain Waves

- **EEG is a record of the spontaneous brain electric activity in conscious subjects**.

- **Recording:**
  - The electrodes are applied on the scalp.
  - The room should be calm.
  - Comfortable temperature.
  - Complete physical and mental rest.

- Recording of EEG is a non-invasive technique for investigating the functions of brain.
- Recording of the human EEG showed 4 main types of waves:

Electroencephalogram (EEG)



Alpha waves:

- These waves are the dominant waves recorded in **conscious adults during rest, while they are relaxed and their eyes closed**.
- Their **voltage is about 50 μV**, and are most probably produced by activity of the nonspecific thalamic nuclei.
- The **frequency** of alpha rhythm is **8-13 Hz** (Hertz= cycles /second).
- It is most marked in the **occipital and parietal regions**.

Beta waves:

- These waves have the **lowest voltage (20 μV)**.
- They are recorded **in adults during brain activity with opened eyes and REM sleep**.
- The **frequency** of beta rhythm is **18-30 Hz**.
- It is most marked in the **frontal region**.

Theta waves:

- These waves have a **higher voltage than the alpha waves**.
- They are recorded in **children and in adults during light sleep**.
- The **frequency** of theta rhythm is **4-7 Hz**.
- It is most marked in the **parietal and temporal regions**.

Delta waves:

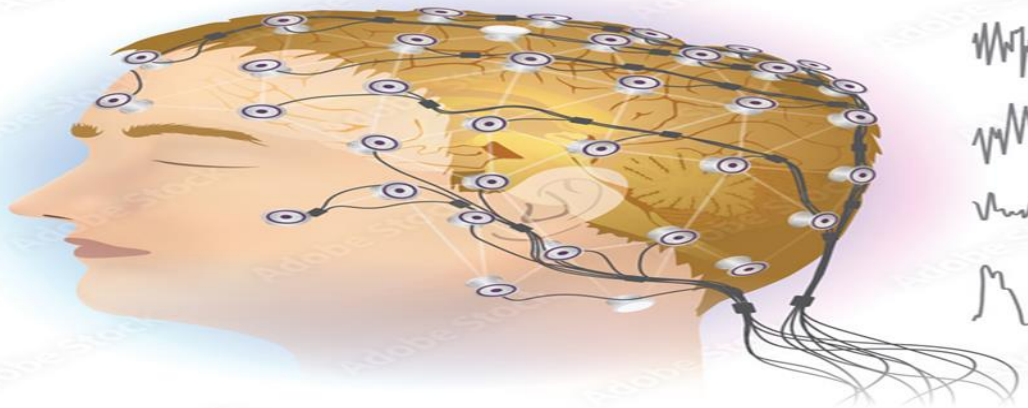
- These waves have the **highest voltage (100 μV)** and lowest **frequency (1-3 Hz)**.
- They are recorded in **infants and in adults during deep sleep**.
- They originate from the **cortical neurons themselves** (i.e. they are independent of the activity of the lower brain centers).

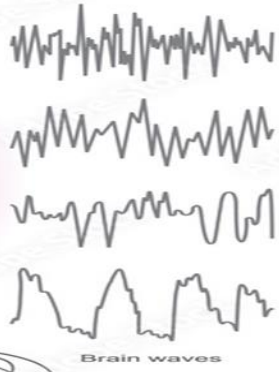
N.B. The frequency of waves is generally inversely proportionate to their amplitude (voltage).

	Alpha	Beta	Theta	Delta
1. Frequency	8-13 Hz	18-30 Hz	4-7 Hz	1-3 Hz
2. Amplitude	50 µV	20 µV	Higher than alpha	100 µV
3. Age and State of the person	Adult: Conscious (awake) Physical and mental rest (relaxed) Closed eyes	Adult: During brain activity Opened eyes REM sleep	Children Or in adults during light sleep	Infants Or in adult during deep sleep
4. Recorded at	Occipital-Parietal regions	Frontal region	Parietal-Temporal regions	

N.B. Other waves may be recorded in certain conditions e.g.
Gamma waves: Fastest (30-80 Hz, 10 µV) – during intense brain activity (cognitive function, memory & learning).

Electroencephalogram (EEG)





Beta 15-30 Hz
Awake, normal, alert consciousness

Alpha 9-14 Hz
Relaxed, calm, meditation, visualization

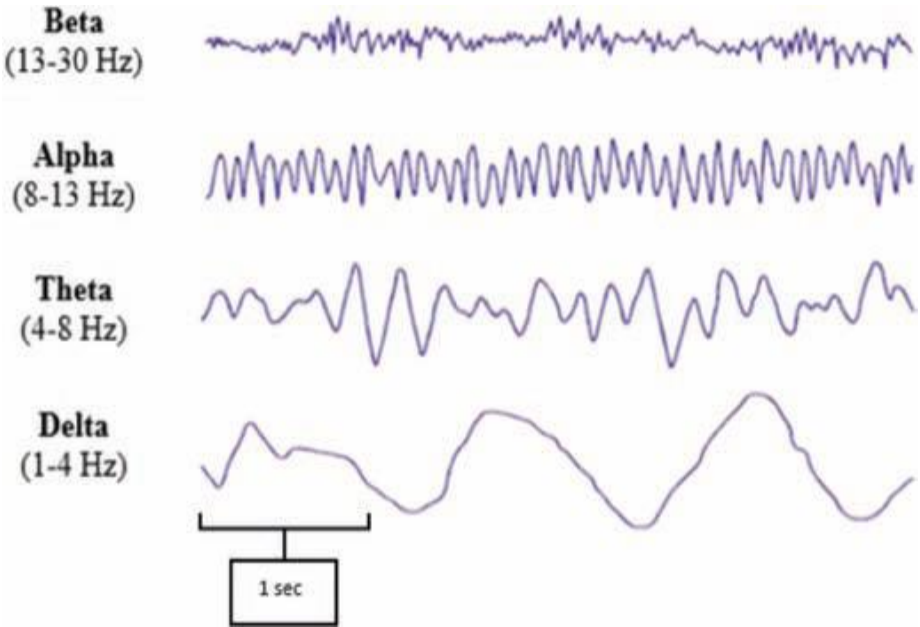
Theta 4-8 Hz
Deep Meditation, dreaming

Delta 1-3 Hz
Deep sleep

Brain waves

- **Sensory response to visual and light stimulation**
  Use of symbols, colors and light in test.

- **Sensory response to sound waves**
  Use of music and frequency sound waves test.



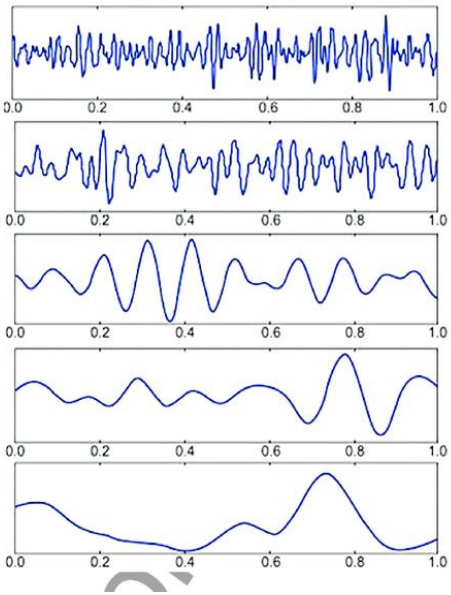
Gamma
Problem Solving, Concentration

Beta
Busy, Active Mind

Alpha
Reflective, Restful

Theta
Drowsiness

Delta
Sleep, Dreaming



EEG Variations

(1) Effect of age:

In young infants, **slow delta waves** are recorded.

During childhood, the **delta waves are replaced by theta waves**, then the **adult alpha rhythm** gradually appears **during adolescence**.

(2) Effect of sleep.

The arousal or alerting response

- This is an EEG response that occurs when the subject becomes alert (e.g. on opening his eyes or when solving a mathematical problem).
- The synchronized alpha rhythm is replaced by rapid low-voltage beta waves.
- It represents breaking up of the synchronized neuronal alpha activity, so it is also called **alpha block**.
- Such response is **reversible** (so if the eyes are closed again, the alpha rhythm is resumed).
- It is due to stimulation of the reticular activating system (RAS).

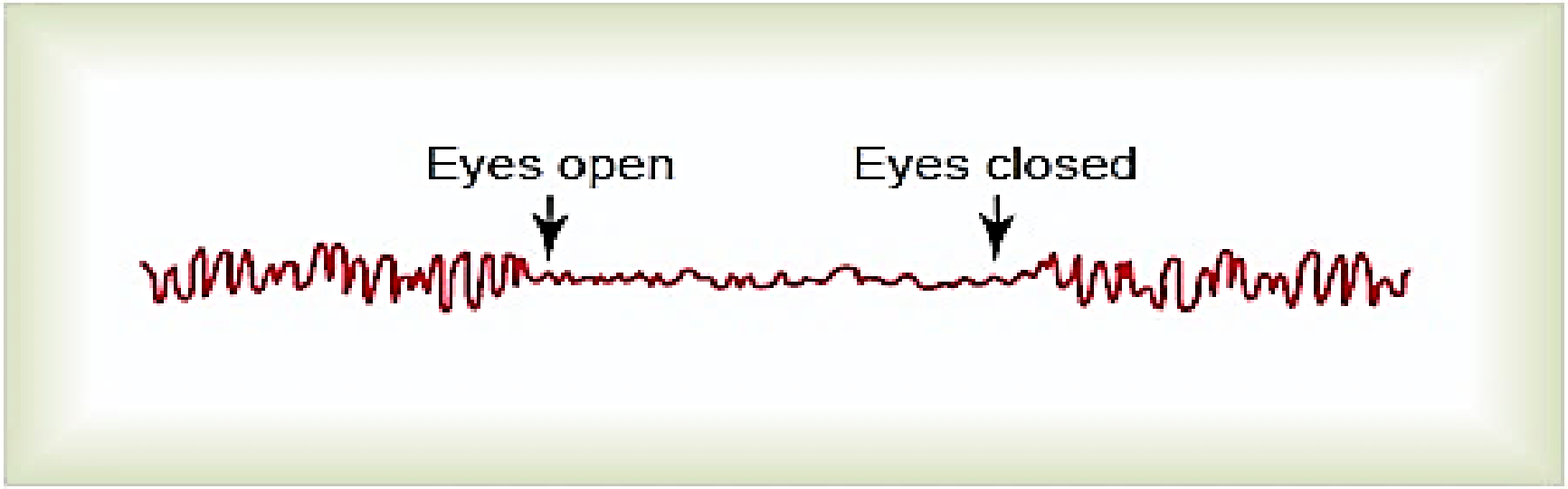


Figure 59–2

Replacement of the *alpha* rhythm by an asynchronous, low-voltage *beta* rhythm when the eyes are opened.

Clinical significance of the EEG

1. Localization of the sites of focal pathological processes in the brain e.g. the sites of tumors or fluid collection e.g. subdural hematoma.
2. It helps differential diagnosis of certain brain diseases, particularly grand mal and petit mal epilepsy (each causes characteristic EEG changes).
3. Diagnosis of sleep disorders.


THANK
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