Electroencephalogram (EEG)

■ INTRODUCTION

Electroencephalography is the study of electrical activities of brain. Electroencephalogram (EEG) is the graphical recording of electrical activities of brain. Electrical activity of the brain is complicated when compared to that of a single nerve fiber or neuron. It is due to the involvement of large number of neurons and synapses.

German psychiatrist **Hans Berger** was the first one to analyze the EEG waves systematically and hence the EEG waves are referred as **Berger waves.**

■ SIGNIFICANCE OF EEG

Electroencephalogram is useful in the diagnosis of neurological disorders and sleep disorders. EEG pattern is altered in the following neurological disorders:

1. **Epilepsy,** which occurs due to excessive discharge of impulses from cerebral cortex
2. **Disorders of midbrain** affecting ascending reticular activating system
3. **Subdural hematoma** during which there is collection of blood in subdural space over the cerebral cortex.

■ METHOD OF RECORDING EEG

Electroencephalograph is the instrument used to record EEG. The electrodes called **scalp electrodes** from the instrument are placed over unopened skull or over the brain after opening the skull or by piercing into brain. Electrodes are of two types, unipolar and bipolar electrodes. While using bipolar electrodes, both the terminals are placed in different parts of brain.

When unipolar electrodes are used, the active electrode is placed over cortex and the indifferent electrode is kept on some part of the body away from cortex.

■ WAVES OF EEG

Electrical activity recorded by EEG may have synchronized or desynchronized waves. **Synchronized waves** are the regular and invariant waves, whereas **desynchronized waves** are irregular and variant. In normal persons, EEG has three frequency bands (Fig. 159.1):

1. Alpha rhythm
2. Beta rhythm
3. Delta rhythm.

In addition to these three types of waves, EEG in children shows theta waves.

■ ALPHA RHYTHM

Alpha rhythm consists of rhythmical waves, which appear at a frequency of 8 to 12 waves/second with the amplitude of 50 μV. Alpha waves are **synchronized waves.**

Alpha rhythm is obtained in **inattentive brain** or **mind** as in drowsiness, light sleep or narcosis with closed eyes. It is abolished by visual stimuli or any other type of stimuli or by mental effort. So, it is diminished when eyes are opened.

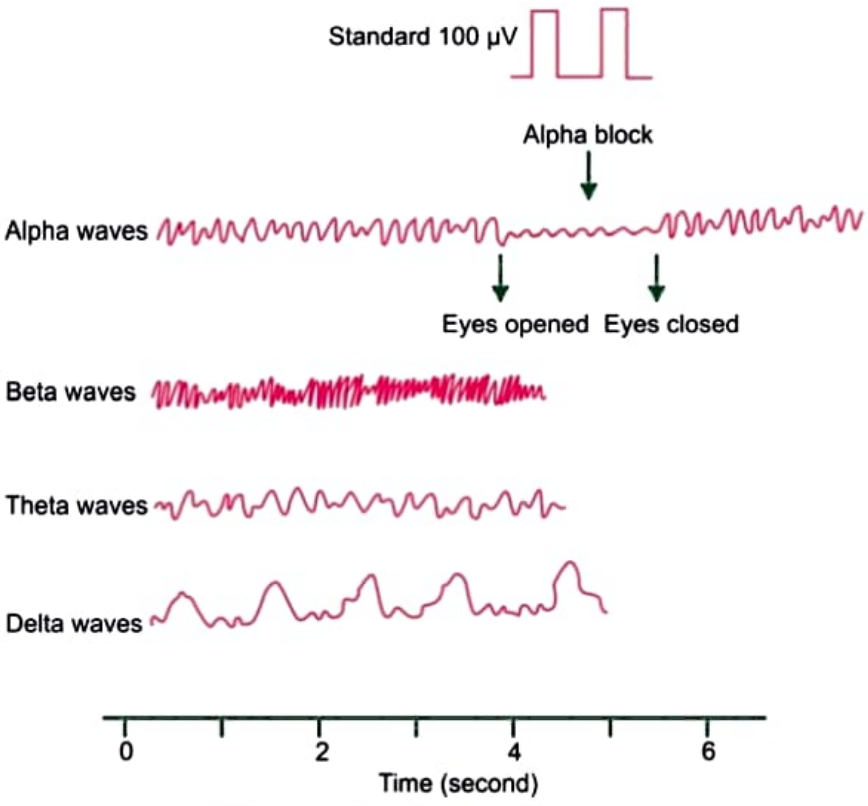

FIGURE 159.1: Waves of electroencephalogram

Waves of alpha rhythm are most marked in parieto-occipital area. Sometimes these waves appear in other areas also.

Alpha Block

Alpha block is the replacement of synchronized alpha waves in EEG by desynchronized and low voltage waves when the eyes are opened. The desynchronized waves do not have specific frequency. It occurs due to any form of sensory stimulation or mental concentration, such as solving arithmetic problems.

Desynchronization is the common term used for replacement of regular alpha waves with irregular low voltage waves. It is due to the loss of synchronized activity in neural elements that are responsible for regular wave pattern.

■ BETA RHYTHM

Beta rhythm includes high frequency waves of 15 to 60 per second but, the amplitude is low, i.e. 5 to 10 μV. Beta waves are **desynchronized waves.** Beta rhythm is recorded during mental activity or mental tension or arousal state. It is not affected by opening the eyes.

During higher mental activity or peak performance state like conscious activity, problem solving and fear, very high frequency waves of 30 to 100 per second appear. Some controversy exists in naming such waves. Often very high frequency waves are called **gamma rhythm.** However, many scientists consider these waves as beta rhythm.

■ DELTA RHYTHM

Delta rhythm includes waves with low frequency and high amplitude. These waves have the frequency of 1 to 5 per second with the amplitude of 20 to 200 μV. It is common in early childhood during waking hours. In adults, it appears mostly during **deep sleep.**

Presence of delta waves in adults during conditions other than sleep indicates the pathological process in brain like tumor, epilepsy, increased intracranial pressure and mental deficiency or depression. These waves are not affected by opening the eyes.

■ THETA WAVES

Theta waves are obtained generally in children below 5 years of age. These waves are of low frequency and low voltage waves. Frequency of theta waves is 4 to 8 per second and the amplitude is about 10 μV.

■ EEG DURING SLEEP

Changes in the EEG pattern during sleep are described in Chapter 160.

Physiology of Sleep

■ DEFINITION

Sleep is the natural periodic **state of rest for mind and body** with closed eyes characterized by partial or complete loss of consciousness. Loss of consciousness leads to decreased response to external stimuli and decreased body movements. Depth of sleep is not constant throughout the sleeping period. It varies in different stages of sleep.

■ SLEEP REQUIREMENT

Sleep requirement is not constant. However, average sleep requirement per day at different age groups is:

1. Newborn infants : 18 to 20 hours
2. Growing children : 12 to 14 hours
3. Adults : 7 to 9 hours
4. Old persons : 5 to 7 hours.

■ PHYSIOLOGICAL CHANGES DURING SLEEP

During sleep, most of the body functions are reduced to basal level. Following are important changes in the body during sleep:

■ 1. PLASMA VOLUME

Plasma volume decreases by about 10% during sleep.

■ 2. CARDIOVASCULAR SYSTEM

Heart Rate

During sleep, the heart rate reduces. It varies between 45 and 60 beats per minute.

Blood Pressure

Systolic pressure falls to about 90 to 110 mm Hg. Lowest level is reached about 4th hour of sleep and remains at this level till a short time before waking up. Then, the pressure commences to rise. If sleep is disturbed by exciting dreams, the pressure is elevated above 130 mm Hg.

■ 3. RESPIRATORY SYSTEM

Rate and force of respiration are decreased. Respiration becomes irregular and **Cheyne-Stokes type** of periodic breathing may develop.

■ 4. GASTROINTESTINAL TRACT

Salivary secretion decreases during sleep. Gastric secretion is not altered or may be increased slightly. Contraction of empty stomach is more vigorous.

■ 5. EXCRETORY SYSTEM

Formation of urine decreases and specific gravity of urine increases.

6. SWEAT SECRETION

Sweat secretion increases during sleep.

7. LACRIMAL SECRETION

Lacrimal secretion decreases during sleep.

8. MUSCLE TONE

Tone in all the muscles of body except ocular muscles decreases very much during sleep. It is called sleep paralysis.

9. REFLEXES

Certain reflexes particularly knee jerk, are abolished. **Babinski sign** becomes positive during deep sleep. Threshold for most of the reflexes increases. Pupils are constricted. Light reflex is retained. Eyeballs move up and down.

10. BRAIN

Brain is not inactive during sleep. There is a characteristic cycle of brain wave activity during sleep with irregular intervals of dreams. Electrical activity in the brain varies with stages of sleep (see below).

TYPES OF SLEEP

Sleep is of two types:

1. Rapid eye movement sleep or REM sleep
2. Non-rapid eye movement sleep, NREM sleep or non-REM sleep.

1. RAPID EYE MOVEMENT SLEEP – REM SLEEP

Rapid eye movement sleep is the type of sleep associated with rapid conjugate movements of the eyeballs, which occurs frequently. Though the eyeballs move, the sleep is deep. So, it is also called **paradoxical sleep.** It occupies about 20% to 30% of sleeping period. Functionally, REM sleep is very important because, it plays an important role in consolidation of memory. Dreams occur during this period.

2. NON-RAPID EYE MOVEMENT SLEEP – NREM OR NON-REM SLEEP

Non-rapid eye movement (NREM) sleep is the type of sleep without the movements of eyeballs. It is also called **slow-wave sleep.** Dreams do not occur in this type of sleep and it occupies about 70% to 80% of total sleeping period. Non-REM sleep is followed by REM sleep.

Differences between the two types of sleep are given in Table 160.1.

STAGES OF SLEEP AND EEG PATTERN

RAPID EYE MOVEMENT SLEEP

During REM sleep, electroencephalogram (EEG) shows irregular waves with high frequency and low amplitude. These waves are **desynchronized waves.**

NON-RAPID EYE MOVEMENT SLEEP

The NREM sleep is divided into four stages, based on the EEG pattern. During the stage of wakefulness, i.e. while lying down with closed eyes and relaxed mind, the **alpha waves** of EEG appear. When the person proceeds to drowsy state, the alpha waves diminish (Fig. 160.1).

Stage I: Stage of Drowsiness

Alpha waves are diminished and abolished. EEG shows only **low voltage fluctuations** and **infrequent delta waves.**

Stage II: Stage of Light Sleep

Stage II is characterized by **spindle bursts** at a frequency of 14 per second, superimposed by low voltage **delta waves.**

TABLE 160.1: Rapid eye movement (REM) sleep and non-rapid eye movement (NREM) sleep

Characteristics	REM sleep	Non-REM sleep
1. Rapid eye movement (REM)	Present	Absent
2. Dreams	Present	Absent
3. Muscle twitching	Present	Absent
4. Heart rate	Fluctuating	Stable
5. Blood pressure	Fluctuating	Stable
6. Respiration	Fluctuating	Stable
7. Body temperature	Fluctuating	Stable
8. Neurotransmitter	Noradrenaline	Serotonin

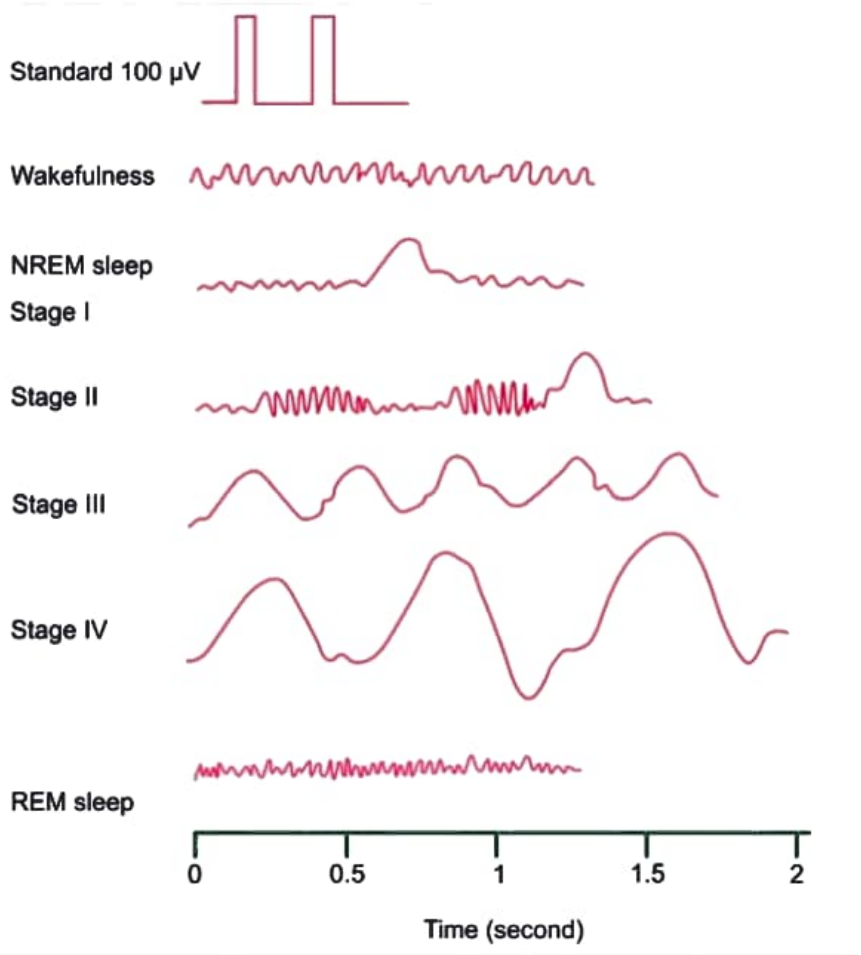

FIGURE 160.1: Electroencephalogram during wakefulness, different stages of NREM sleep and REM sleep. NREM = Non-rapid eye movement, REM = Rapid eye movement.

Stage III: Stage of Medium Sleep

During this stage, the spindle bursts disappear. Frequency of delta waves decreases to 1 or 2 per second and amplitude increases to about 100 μV.

State IV: Stage of Deep Sleep

Delta waves become more prominent with low frequency and high amplitude.

■ MECHANISM OF SLEEP

Sleep occurs due to the activity of some **sleep-inducing centers** in brain. Stimulation of these centers induces sleep. Damage of sleep centers results in sleeplessness or persistent wakefulness called **insomnia.**

■ SLEEP CENTERS

Complex pathways between the reticular formation of brainstem, diencephalon and cerebral cortex are involved in the onset and maintenance of sleep. However, two centers which induce sleep are located in brainstem:

1. Raphe nucleus
2. Locus ceruleus of pons.

Recently, many more areas that induce sleep are identified in the brain of animals. Inhibition of ascending reticular activating system also results in sleep.

1. *Role of Raphe Nucleus*

Raphe nucleus is situated in lower pons and medulla. Activation of this nucleus results in non-REM sleep. It is due to release of **serotonin** by the nerve fibers arising from this nucleus. Serotonin induces non-REM sleep.

2. *Role of Locus Ceruleus of Pons*

Activation of this center produces REM sleep. **Noradrenaline** released by the nerve fibers arising from locus ceruleus induces REM sleep.

Inhibition of Ascending Reticular Activating System

Ascending reticular activating system (ARAS) is responsible for wakefulness because of its afferent and efferent connections with cerebral cortex. Inhibition of ARAS induces sleep. Lesion of ARAS leads to permanent somnolence, i.e. coma.

■ APPLIED PHYSIOLOGY – SLEEP DISORDERS

■ 1. INSOMNIA

Insomnia is the inability to sleep or abnormal wakefulness. It is the most common sleep disorder. It occurs due to systemic illness or mental conditions such as psychiatric problems, alcoholic addiction and drug addiction.

■ 2. HYPERSOMNIA

Hypersomnia is the excess sleep or excess need to sleep. It occurs because of lesion in the floor of the third ventricle, brain tumors, encephalitis, chronic bronchitis and disease of muscles. Hypersomnia also occurs in endocrine disorders such as myxedema and diabetes insipidus.

■ 3. NARCOLEPSY AND CATAPLEXY

Narcolepsy is the sudden attack of **uncontrollable sleep.** Cataplexy is sudden **outburst of emotion.** Both the diseases are due to hypothalamic disorders. Refer Chapter 149 for details.

■ 4. SLEEP APNEA SYNDROME

Sleep apnea is the temporary stoppage of breathing repeatedly during sleep. Sleep apnea syndrome is the disorder that involves fluctuations in the rate and force of respiration during REM sleep with short apneic episode. Apnea is due to decreased stimulation of respiratory centers, arrest of diaphragmatic movements, airway obstruction (Chapter 127) or the combination of all these factors. When breathing stops, the resultant hypercapnia and hypoxia stimulate respiration.

Sleep apnea syndrome occurs in **obesity,** myxedema, enlargement of tonsil and lesion in brainstem. Common features of this syndrome are **loud snoring** (Chapter 127), restless movements, nocturnal insomnia, daytime sleepiness, morning headache and fatigue. In severe conditions, hypertension, right heart failure and stroke occur.

■ 5. NIGHTMARE

Nightmare is a condition during sleep that is characterized by a sense of extreme uneasiness or discomfort or by frightful dreams. Discomfort is felt as of some heavy weight on the stomach or chest or as uncontrolled movement of the body. After a period of extreme anxiety, the subject wakes with a troubled state of mind. It occurs mostly during REM sleep. **Nightmare** occurs due to improper food intake, digestive disorders or nervous disorders. It also occurs during drug withdrawal or alcohol withdrawal.

■ 6. NIGHT TERROR

Night terror is a disorder similar to nightmare. It is common in children. It is also called **pavor nocturnus** or **sleep terror.** The child awakes screaming in a state of fright and semiconsciousness. The child cannot recollect the attack in the morning. Nightmare occurs shortly after falling asleep and during non-REM sleep. There is no psychological disturbance.

■ 7. SOMNAMBULISM

Somnambulism is getting up from bed and walking in the state of sleep. It is also called **walking during sleep** or **sleep walking** (somnus = sleep; ambulare = to walk). It varies from just sitting up in the bed to walking around with eyes open and performing some major complex task. The episode lasts for few minutes to half an hour. It occurs during non-REM sleep. In children, it is associated with bedwetting or night terror without any psychological disturbance. However, in adults it is associated with psychoneurosis.

■ 8. NOCTURNAL ENURESIS

Nocturnal enuresis is the involuntary voiding of urine at bed. It is also called or **bedwetting.** It is common in children. Refer Chapter 57 for details.

■ 9. MOVEMENT DISORDERS DURING SLEEP

Movement disorders occur immediately after falling asleep. **Sleep start** or **hypnic jerk** is the common movement disorder during sleep. It is characterized by sudden jerks of arms or legs. Sleep start is a physiological form of clonus.

Other movement disorders are teeth grinding (bruxism), banging the head and restless moment of arms or legs.