NAME: OLAKADA FAVOUR ADAMBA
MATRIC NO.: 17/MHS01/254
COLLEGE: COLLEGE OF MEDICINE AND HEALTH SCIENCES
DEPARTMENT: MEDICINE AND SURGERY
COURSE TITLE: NEUROPHYSIOLOGY
COURSE CODE: PHS 305

QUESTION

1. Discuss the physiology of sleep.
2. Discuss the role of the basal ganglia in coordinating movement.

ANSWERS

1) PHYSIOLOGY OF SLEEP

Introduction

Sleep refers to a state of unconsciousness from which the individual can be aroused by sensory or other stimuli. In other words, sleep is the natural periodic state of rest for mind and body with closed eyes characterized by partial or complete loss of consciousness.When asleep, an individual is not aware of the environment and is unable to perform activities that require consciousness. During sleep, the stimulus pulse transfer becomes less frequent between the reticular formation and cerebral cortex.

Sleep-Wake Cycles

Sleep–wake cycles occur in a circadian rhythm, with a period of about 24 hours. The circadian periodicity is thought to be driven by the suprachiasmatic nucleus of the anterior hypothalamus, which receives input from the retina. A newborn infant has many cycles of sleep and wakefulness in 24 h, but after the age of 2 years a single sleep-wake cycle is established. In a normal adult, the sleep-wake cycle consists of 7–8 h of sleep and 16–17 h of wakefulness.

Types of Sleep

Sleep is of two types: non-REM (non-rapid eye movement) sleep and REM (rapid eye movement) sleep, which alternate in a sleep cycle.

- Rapid Eye Movement (REM) Sleep

  Rapid eye movement (REM) 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. This type of sleep is also called ‘fast wave (desynchronized) sleep’, or ‘paradoxical sleep’ or ‘dream sleep’. Functionally, REM sleep is very important because it plays an important role in consolidation of memory. In normal adults, the REM sleep follows non-REM sleep, while in adults entry into sleep occurs via REM sleep. About 25% of the entire sleep period is passed in REM sleep. REM sleep is characterized by eye movements, loss of muscle tone, pupillary constriction, and penile erection. Use of benzodiazepines and increasing age decrease the duration of REM sleep.

- Non-Rapid Eye Movement (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, because in this type of sleep brain waves are very slow. Dreams do not occur in this type of sleep. Non-REM sleep is a rest type of sleep which a person experiences during the first hour of sleep after having been kept awake for many hours. It occupies about 70% to 80% of the total sleeping period. Non-REM sleep is followed by REM sleep.

Stages of Sleep and EEG Pattern

- Rapid Eye Movement Sleep

  During REM sleep, electroencephalogram (EEG) shows irregular waves with high frequency and low amplitude. The EEG resembles that of a person who is awake or in Stage 1 non-REM sleep. These waves are desynchronized waves. It is usually more difficult to awake in REM sleep than in non-REM sleep.

- Non-Rapid Eye Movement Sleep

  The NREM sleep is divided into four stages, based on the EEG pattern. In these four stages, a person progresses from light to deep sleep. During the stage of wakefulness, i.e. while lying down with closed eyes and relaxed mind, the alpha waves of EEG appear.

  Stage I: Stage of Drowsiness

  Alpha waves are diminished and abolished. EEG shows only low voltage fluctuations and infrequent delta waves. There is still considerable sensitivity

to sensory stimuli. However, the mild to moderate stimuli are often unable to produce a full arousal.

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. Auditory stimuli during this phase readily evoke the K-complexes in the EEG. They also occur spontaneously during this stage. The K-complex consists of one or two high-voltage waves followed by a brief 14 Hz activity.

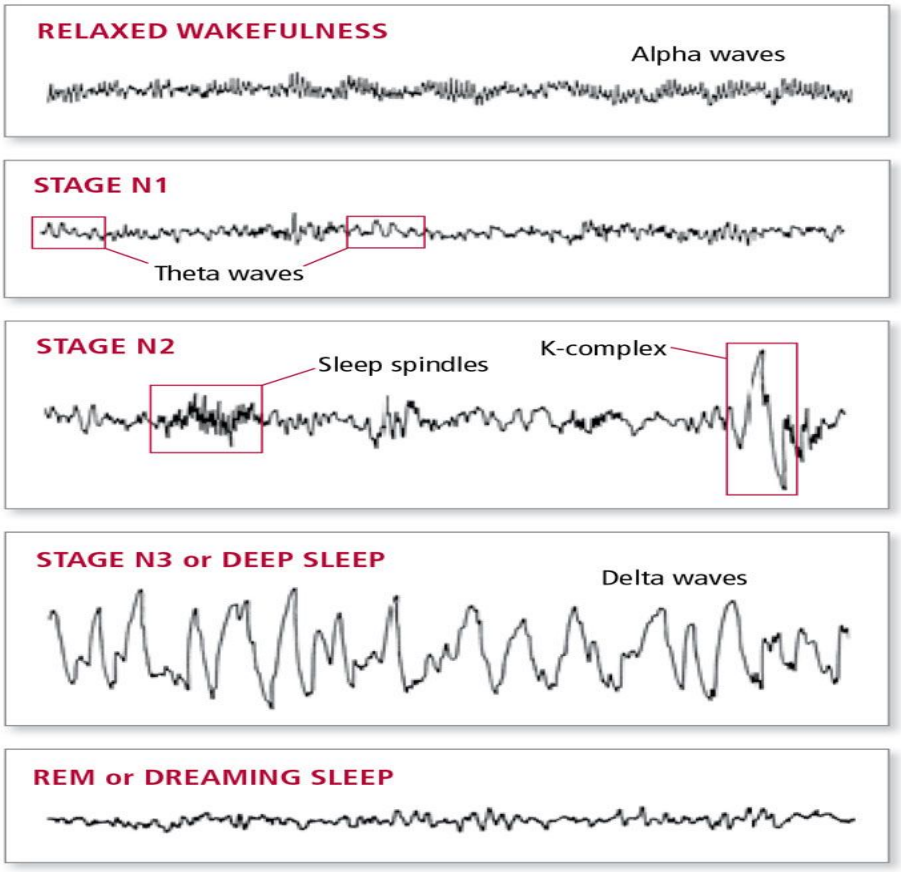
Stage III: Stage of Medium Sleep

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.

Stage IV: Stage of Deep Sleep

This stage produces EEG pattern dome-like very slow, large waves called δ waves (delta). Thus, the characteristic of deep sleep is a pattern of rhythmic slow waves, indicating marked synchronization.

Figure 1: EEG brain wave patterns during sleep



Brain waves change dramatically during the different stages of sleep.

Mechanism of Sleep

Sleep occurs due to the activity of some sleep-inducing centers in the 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 systems 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.
3. 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.

Chemical mediators of sleep

Neurotransmitters employed by the neurons forming the neural substrate of sleep include: serotonin, acetylcholine and noradrenaline. The substances that have been identified by an experiment on sleep-deprived animals as sleep-producing substances (S/S) are:

- Muramyl dipeptide, a chemical related to substances found in the bacterial cell walls,
- Interleukin-1, a cytokine that may mediate the effects of muramyl dipeptides as well as immune response,
- Adenosine,
- Delta sleep-inducing peptide, a substance isolated from the blood of sleeping rabbits,
- Prostaglandin D2 and
- Arginine vasotocin.

Physiological Significance of Sleep

Sleep is an indispensable phenomenon. Its physiological significance is highlighted.

1. **Sleep may serve as a period of body's rest and metabolic restoration** as evidenced by following physiological changes during non-REM sleep: Pulsatile release of growth hormone and gonadotropins from the pituitary and decrease in blood pressure, heart rate and respiration.
2. **Sleep is necessary for certain forms of learning.** In experimental animals, learning sessions do not improve performance until a period of SWS or SWS plus REM sleep has occurred. However, it is not known why sleep is necessary and there is as yet no clinical correlation to this experimental observation.
3. **REM sleep is necessary for mental well-being.** The correlation between dreaming and REM sleep indicates that the brain is highly active at this time. This may allow for the expression, through dreams, of concern in the subconscious and for long-term chemical and structural changes that the brain must undergo to make learning and memory possible.
4. **REM sleep plays an important role in homeostatic mechanisms.** It is evident from the observation that when the experimental animals are completely deprived of REM sleep for long periods, they lose weight in spite of increased caloric intake and finally die.

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 lesions 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: Narcolepsy is the sudden attack of uncontrollable sleep. It is a disease caused by hypothalamic disorders. As mentioned in the sleep cycle, in adults the sleep onset occurs with non-REM sleep, which is followed by REM sleep. However, in narcolepsy, REM sleep is entered directly from the waking states.
4. Sleep walking (somnambulism): Episodes of sleepwalking are more common in children than in adults and occur predominantly in males. These episodes may last for several minutes. Such individuals walk with their eyes open and avoid obstacles, but when awakened, they cannot recall the episode.
5. Bed-wetting (nocturnal enuresis): This is involuntary voiding of urine, occurs in some children during slow wave sleep.
6. Nightmares (pavor nocturnus or episodes of night terror): During a nightmare that occurs in slow wave sleep, an individual wakes up screaming and appears

terrified. However, no reason for acute anxiety is recalled. By contrast, terrifying dreams that occur during REM sleep are graphically remembered.

2) ROLE OF BASAL GANGLIA IN COORDINATING MOVEMENT

Basal ganglia are the scattered masses of gray matter submerged in the subcortical substance of the basal part of the cerebral hemisphere. Basal ganglia form part of the extrapyramidal system. The basal ganglia modulates thalamic outflow to the motor cortex to plan and execute smooth movements. Basal ganglia includes:

- Corpus striatum (amygdaloid body, and claustrum).
- Globus pallidus
- Subthalamic nucleus (body of Luys)
- Substantia nigra

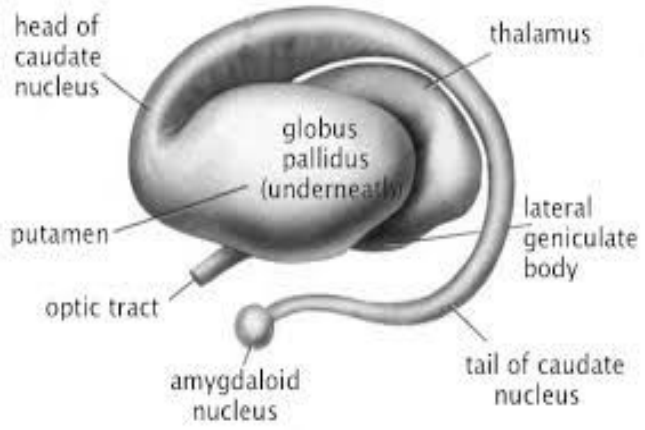


Fig 2. Diagram of Basal Ganglia

Basal ganglia control the voluntary movements which are initiated by the motor cortex. Role of basal ganglia in control of voluntary motor activity includes:

- Cognitive control of motor activity,
- Timing and scaling of intensity of movements and
- Subconscious execution of some movements.

Cognitive Control of Motor Activity

Most of the motor actions occur as a consequence of thoughts generated in mind. This process is known as cognitive control of motor activity. The cognitive control of motor activity is executed by the basal ganglia through the feedback loops (functional neuronal circuit). Neuronal circuits arise from three areas of the cerebral cortex:

a. Premotor area
b. Primary motor area
c. Supplementary motor area.

All these nerve fibers from the cerebral cortex reach the caudate nucleus. From here, the fibers go to putamen. Some of the fibers from the cerebral cortex go directly to

putamen also. Putamen sends fibers to globus pallidus. Fibers from here run towards the thalamus, subthalamic nucleus of Luys and substantia nigra. Subthalamic nuclei and substantia nigra are in turn projected into thalamus. Now, the fibers from thalamus are projected back into the primary motor area and other two motor areas, i.e. premotor area and supplementary motor area.

Timing and Scaling of Intensity of Movement

Two important capabilities of the brain in controlling movements are:

- Timing of movements, i.e. how rapidly the movements should be performed and
- Scaling of the intensity of movements, i.e. how large the movement should be.

In higher animals, the basal ganglia act as an important co-ordinating centre of the extrapyramidal system. In the absence of basal ganglia, the timing and scaling function becomes very poor.

Subconscious Execution of some Movements

Basal ganglia subconsciously execute some movements during the performance of trained motor activities, i.e. skilled activities. Examples of movements executed sub-consciously at the level of basal ganglia are:

- Swinging of arm while walking,
- Crude movement of facial expression that accompany emotions,
- Movements of limbs while swimming.

Control of clutch and brake while driving (constant attention is required during initial stages; however, they are carried out subconsciously by basal ganglia as they become routine). By subconscious control of activities, the basal ganglia relieve the cortex from routine acts so that the cortex can be free to plan its actions.
Cortical fibers reaching putamen are directly concerned with regulation of some subconscious movements, which take place during trained motor activities.

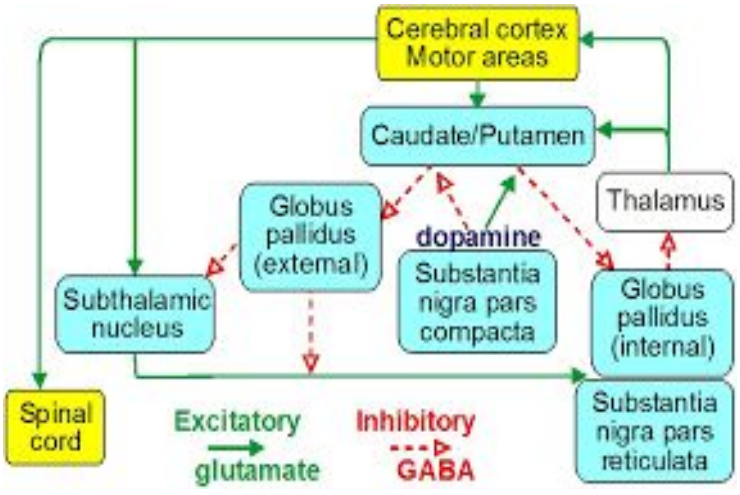


Fig 3. Diagram of Pathway of Basal Ganglia

Applied Physiology - Disorders of Basal Ganglia

1. Parkinson Disease: Parkinson disease is a slowly progressive degenerative disease of the nervous system associated with destruction of brain cells, which produce dopamine. It is also called parkinsonism. Parkinson disease occurs due to lack of dopamine caused by damage of basal ganglia. It is mostly due to the destruction of substantia nigra and the nigrostriatal pathway, which has dopaminergic fibers. Damage of basal ganglia usually occurs because of the following causes:
    a. Viral infection of brain like encephalitis
    b. Cerebral arteriosclerosis
    c. Injury to basal ganglia
    d. Destruction or removal of dopamine in basal ganglia. It occurs mostly due to long term treatment with antihypertensive drugs like reserpine. Parkinsonism due to the drugs is known as drug-induced parkinsonism.
    e. Unknown causes: Parkinsonism can occur because of the destruction of basal ganglia due to some unknown causes. This type of parkinsonism is called idiopathic parkinsonism.

2. Huntington Chorea
   Huntington disease is an inherited progressive neural disorder due to the degeneration of neurons secreting GABA in corpus striatum and substantia nigra. This disease starts mostly in middle age. It is characterized by chorea, hypotonia and dementia. In severe cases bilateral wasting of muscles occurs. It is otherwise called Huntington disease, chronic progressive chorea, degenerative chorea or hereditary chorea.