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PHYSIOLOGY OF SLEEP

Sleep is the natural periodic state of rest for mind and body with closed eyes characterized by partial or total 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 stage of sleep. Sleep requirement is not constant, however, average

sleep requirement per day at different age group is;
Newborn infants: 18-20 hours
Growing children: 12-14 hours
Adults: 7-9 hours
Old persons: 5-7 hours

Physiological changes during sleep

During sleep, most of the body functions are reduced to basal level. The following are some of the physiological changes in the body during sleep

1. Plasma volume: plasma volume decreases by about 10% during sleep
2. Cardiovascular system: during sleep, the heart rate reduces, it varies between 45 and 60 beats per minute.

Also, systolic pressure falls to about 90-110 mmHg. 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 130mmHg.

3. Respiratory system: rate and force of respiration are decreased. Respiration becomes irregular and Cheyne-stroke type of periodic breathing may develop.

4. Gastrointestinal tract: salivary secretion decreases during sleep. Gastric secretion is not altered or may be increased slightly. Concentration 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 sin becomes positive during sleep. Threshold for most 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.

TYPES OF SLEEP

Sleep is of two types

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

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

DIFFERENCES BETWEEN REM AND NREM SLEEP

CHARACTERISTICS	REM SLEEP	NON-REM SLEEP
Rapid	Present	Absent

eye movements		
Dreams	Present	Absent
Muscle twitching	Present	Absent
Heart rate	Fluctuating	Stable
Blood pressure	Fluctuating	Stable
Respiration	Fluctuating	Stable
Body temperature	Fluctuating	Stable
Neurotransmitter	Noradrenaline	Serotonin

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 patterns. During the stage of wakefulness, that is, 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.

Stage1: stage of drowsiness Alpha waves are diminished and abolished. EEG shows only **low voltage fluctuations** and **infrequent delta waves.**

Stage 2: stage of light sleep

Stage 2 is characterized by **spindle bursts** at a frequency of 14 per second, superimposed by low voltage **delta waves.**

Stage 3: 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 4: 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.**

<u>Sleep Centers</u>

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.

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.

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.

APPLIED PHYSIOLOGY (SLEEP DISORDERS)

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.

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.

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.

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 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**, restless movements, nocturnal insomnia, daytime sleepiness, morning headache and fatigue. In severe conditions, hypertension, right heart failure and stroke can occur.

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 semi consciousness. 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.

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.

ROLE OF BASAL GANGLIA IN COORDINATING MOVEMENTS

The basal ganglia (or basal nuclei) are a group of subcortical nuclei, of varied origin, in the brains, which are situated at the base of the forebrain and top of the midbrain. Basal ganglia are strongly interconnected with the cerebral cortex, thalamus, and brainstem, as well as several other brain areas. The basal ganglia are associated with a variety of functions, including control of voluntary motor movements, procedural learning, habit learning, eye movements, cognition, and emotion.

The basal ganglia are of major importance for normal brain function and behavior. Their dysfunction results in a wide range of neurological conditions including disorders of behavior control and movement, as well as cognitive deficits that are similar to those that result from damage to the prefrontal cortex. Those of behavior include Tourette syndrome, obsessive–

compulsive disorder, and addiction. Movement disorders include, most notably Parkinson's disease, which involves degeneration of the dopamine-producing cells in the substantia nigra, Huntington's disease, which primarily involves damage to the striatum, dystonia, and more rarely hemiballismus.

How does the basal ganglia work?

The separate nuclei of the basal ganglia all have extensive roles of their own in the brain, but they also are interconnected with one another to form a network that is thought to be involved in a variety of cognitive, emotional, and movement-related functions. The basal ganglia are best-known, however, for their role in movement. the basal ganglia act to facilitate desired movements and inhibit unwanted and/or competing movements.

To understand how this might work, think about the action of reaching out to pick up a pencil. First, consider what's happening in the moments before you extend your arm. Although it might seem like there would be very little movement-related activity going on in the brain at this point (because you are sitting still), your brain is actually constantly at work to inhibit unwanted movements (like jerking your hand involuntarily up in the air or suddenly turning your head to one side). The basal ganglia plays a critical role in this type of movement inhibition, as well as in the release of that inhibition when you do have a movement that you want to make (reaching for the pencil in this case). After the movement begins, it’s also important that muscles that would counteract the desired movement remain relaxed. When you extend your arm to reach for the pencil, for example, you don’t want the muscles that flex your arm (to move it back towards your body) to be activated at the same time. The basal ganglia are thought to help to inhibit these types of contradictory movements, allowing for a reaching movement that’s smooth and fluid.

The intricacies of how basal ganglia activity leads to the facilitation of movement are still a bit unclear, but one popular hypothesis suggests that there are different pathways in the basal ganglia that promote and inhibit movement, respectively. The direct/indirect model is centered around connections the basal ganglia (specifically the globus pallidus and substantia nigra) form with neurons in the thalamus. These thalamic neurons in turn project to the motor cortex (an area of the brain where many voluntary movements originate) and can stimulate movement via these connections. The basal ganglia, however, continuously inhibit the thalamic neurons, which stops them from communicating with the motor cortex—inhibiting movement in the process. According to the direct/ indirect model, when a movement is desired, a signal to initiate the movement is sent from the cortex to the basal ganglia, typically arriving at the caudate or putamen (which are referred to collectively as the striatum). Then, the signal follows a circuit in the basal ganglia known as the **direct pathway**, which leads to the silencing of neurons in the globus pallidus and substantia nigra. This frees the thalamus from the inhibitory effects of the basal ganglia and allows movement to occur. There is also a circuit within the basal ganglia called the **indirect pathway**, which involves the subthalamic nucleus and leads to the increased suppression of unwanted movements. It is thought that a balance between activity in these two pathways may facilitate smooth movement.