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QUESTION 1: Discuss the physiology of sleep

ANSWER: Sleep is the natural periodic state of rest for mind and body characterized by partial or complete loss of consciousness from which a person can be aroused by sensory or other stimuli. It is to be distinguished from coma, which is unconsciousness from which a person cannot be aroused. Loss of consciousness leads to decreased response to external stimuli and decreased body movements. Depth of sleep is not constant throughout the sleeping period as there are multiple stages of sleep, from feelings of drowsiness to very deep sleep.

Sleep requirement is not constant but average sleep requirement per day of different age groups include: 18 to 20 hours for newborn infants, 12to 14 hours for growing children, 7 to 9 hours for adults and 5 to 7 hours for old people.

Some important changes that occur during sleep are:

1. Plasma volume: it decreases about 10 percent during sleep
2. Cardiovascular system: the heart rate decreases to about 40 to 60 beats per minute while blood pressure falls to its lowest point at around the 4th hour of sleep but can rise during exciting dreams.
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 an empty stomach is more vigorous.
5. Excretory system: Formation of urine decreases and specific gravity of urine increases.
6. Sweat secretion: It increases during sleep.
7. Lacrimal secretion: It 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: It 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

Sleep researchers also divide sleep into two entirely different types of sleep that have different qualities, rapid eye movement sleep (REM) and non-rapid eye movement sleep (NREM) or slow-wave sleep.

**Rapid eye movement sleep-REM sleep**

Here, the eyes undergo rapid conjugate movements even though the person is till asleep. In a normal night of sleep, bouts of REM sleep lasting 5 to 30 minutes usually appear on average every 90 minutes in young adults and occupies about 25 percent of the sleep time in young adults. The movement of the eyeball signify brain activity so this type of sleep is called *paradoxical sleep or desynchronized sleep* because it is a paradox that a person can still be asleep despite the presence of marked activity in the brain.

When a person is extremely sleepy, each bout of REM sleep is short and may even be absent. As the person becomes more rested through the night, the durations of the REM bouts increase. Functionally, REM sleep is very important because, it plays an important role in consolidation of memory. Dreams occur during this period.

REM sleep has several important characteristics:

1. It is an active form of sleep usually associated with dreaming and active bodily muscle movements.

2. The person is even more difficult to arouse by sensory stimuli than during deep slow-wave sleep, and yet people usually awaken spontaneously in the morning during an episode of REM sleep.

3. Muscle tone throughout the body is exceedingly depressed, indicating strong inhibition of the spinal muscle control areas.

4. Heart rate and respiratory rate usually become irregular, which is characteristic of the dream state.

5. Despite the extreme inhibition of the peripheral muscles, irregular muscle movements occur in addition to the rapid movements of the eyes.

6. The brain is highly active in REM sleep, and overall brain metabolism may be increased as much as 20percent. An electroencephalogram (EEG) shows a pattern of brain waves similar to those that occur during wakefulness. This type of sleep is also called paradoxical sleep because it is a paradox that a person can still be asleep despite the presence of marked activity in the brain.

In summary, REM sleep is a type of sleep in which the brain is quite active. However, the person is not fully aware of his or her surroundings, and therefore he or she is truly asleep.

**Non-rapid eye movement sleep (NREM) or slow-wave sleep**

 This is the type of sleep without the movements of eyeballs. Dreams do not occur in this type of sleep and it occupies about 70% to 80% of total sleeping period. NREM sleep is followed by REM sleep. We can understand the characteristics of NREM sleep by remembering the last time we were kept awake for a long period and the deep sleep that occurred during the first hour after going to sleep. This sleep is exceedingly restful and is associated with decreases in both peripheral vascular tone and many other vegetative functions of the body. For instance, 10 to 30 percent decrease in blood pressure, respiratory rate, and basal metabolic rate. Although NREM sleep is frequently called “dreamless sleep,” dreams and sometimes even nightmares do occur during NREM sleep. The difference between the dreams that occur in NREM sleep and those that occur in REM sleep is that those of REM sleep are associated with more bodily muscle activity. Also, the dreams of NREM sleep are usually not remembered because consolidation of the dreams in memory does not occur.

Difference between REM sleep and NREM sleep

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|  | **Characteristics** | **REM** **sleep** | **NREM** **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 |

**STAGES OF SLEEP AND EEG PATTERN**

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

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 stage, the first stage, the alpha waves diminish.

Stage 1 (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): It 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 is caused by an active inhibitory process. An earlier theory of sleep was that the excitatory areas of the upper brain stem, the *ascending reticular activating system (ARAS)*, simply became fatigued during the waking day and became inactive as a result. An important experiment changed this thinking to the current view that sleep is caused by an *active inhibitory process*, because it was discovered that transecting the brain stem at the level of the midpons creates a brain cortex that never goes to sleep. In other words, a center located below the midpontile level of the brain stem appears to be required to cause sleep by inhibiting other parts of the brain. ARAS is responsible for wakefulness because of its afferent and efferent connections with the cerebral cortex. The inhibition caused by the active inhibitory process induces sleep. Lesion or tumor of ARAS leads to permanent somnolence, i.e. coma. Impact of head injury to ARAS can also result in coma.

Sleep also 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 are complex pathways between the reticular formation of brainstem, diencephalon and cerebral cortex. They 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.

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 OF SLEEP**

1. Insomnia: this 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: this 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. It also happens 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.
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 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 occur.
5. Nightmare: this 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: this 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.
7. Somnambulism: this 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: is the involuntary voiding of urine at bed. It is also called or bedwetting. It is common in children.
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.

QUESTION 2: Discuss the role of basal ganglia in coordinating movement

ANSWER: The basal ganglia is another accessory motor system that functions usually not by itself but in close association with the cerebral cortex and corticospinal motor control system. In fact, the basal ganglia receives most of their input signals from the cerebral cortex and also return almost all their output signals back to the cortex. On each side of the brain, these ganglia consist of the caudate nucleus, putamen, globus pallidus, substantia nigra, and subthalamic nucleus. They are located mainly lateral to and surrounding the thalamus, occupying a large portion of the interior regions of both cerebral hemispheres. Almost all motor and sensory nerve fibers connecting the cerebral cortex and spinal cord pass through the space that lies between the major masses of the basal ganglia, the caudate nucleus and the putamen. This space is called the internal capsule of the brain. It is important for our current discussion because of the intimate association between the basal ganglia and the corticospinal system for motor control.

The basal ganglia performs various functions involved in the coordination of movement by the body:

**CONTROL OF MOTOR ACTIVITY**

Regulation of voluntary movements

Movements during voluntary motor activity are initiated by cerebral cortex. However, these movements are *controlled* by basal ganglia, which are in close association with cerebral cortex. During lesions of basal ganglia, the control mechanism is lost and so the movements become inaccurate and awkward. Basal ganglia control the motor activities because of the nervous (neuronal) circuits between basal ganglia and other parts of the brain involved in motor activity.

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 cerebral cortex reach the caudate nucleus. From here, the fibers go to putamen. Some of the fibers from 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 nucleus and substantia nigra are in turn, projected into thalamus. Now, the fibers from thalamus are projected back into primary motor area and other two motor areas, i.e. premotor area and supplementary motor area.

Regulation of conscious movements

Fibers between cerebral cortex and caudate nucleus are concerned with regulation of conscious movements. This is the caudate circuit. This function of basal ganglia is also known as the cognitive control of activity. For example, when a stray dog barks at a man, immediately the person, understands the situation, turns away and starts running.

Regulation of subconscious movements

Cortical fibers reaching putamen are directly concerned with regulation of some subconscious movements, which take place during trained motor activities, i.e. skilled activities such as writing the learnt alphabet, paper cutting, nail hammering, etc.

**CONTROL OF REFLEX MUSCULAR ACTIVITY**

The basal ganglia are responsible for the coordination and integration of impulses for reflex activities such as visual and labyrinthine reflexes which are important in maintaining the posture. During lesion of basal ganglia, the postural movements, especially the visual and labyrinthine reflexes become abnormal. These abnormal movements are associated with rigidity. Rigidity is because of the loss of inhibitory influence from the cerebral cortex on spinal cord via basal ganglia.

**CONTROL OF AUTOMATIC ASSOCIATED MOVEMENTS**

The basal ganglia are responsible for the automatic associated movements. Examples are the swing of the arms while walking, appropriate facial expressions while talking or doing any work.

**RELEASE OF NEUROTRANSMITTERS**

The basal ganglia releases some neurotransmitters which execute their functions. These neurotransmitters include dopamine, gamma­aminobutyric acid (GABA), acetylcholine, substance P, enkephalins, noradrenaline, glutamic acid. The fibers that releases them and their action is shown in the table below;

|  |  |  |
| --- | --- | --- |
| **Neurotransmitter**  | **Released** **by** | **Action** |
| Dopamine | Fibers from substantia nigra to corpus striatum | Inhibition |
| Gamma aminobutyric acid | Intrinsic fibers of corpus striatum and substantia nigra | Inhibition |
| Acetylcholine | Fibers from cerebral cortex to caudate nucleus and putamen | Excitation |
| Substance P | Fibers from globus pallidus reaching substantia nigra | Excitation |
| Enkephalins | Fibers from globus pallidus reaching substantia nigra | Excitation |
| Noradrenaline | Fibers between basal ganglia and reticular formation | Excitation |
| Glutamic acid | Fibers from subthalamic nucleus to globus pallidus and substantia nigra | Excitation |

**APPLIED PHYSIOLOGY**

1. Parkinson’s disease: this is a slowly progressive degenerative disease of nervous system associated with destruction of brain cells, which produce dopamine. It 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. It is characterized by signs such aa speech problems, rigidity poverty of movements, gait, tremor, slowness of movement, dementia. It can be treated by dopamine injection.

1. Chorea: this is an abnormal involuntary movement. Chorea means rapid jerky movements. It mostly involves the limbs. It is due to the lesion in caudate nucleus and putamen.
2. Athetosis: this is another type of abnormal involuntary movement, which refers to slow rhythmic and twisting movements. It is because of the lesion in caudate nucleus and putamen.
3. Choreoathetosis: this is the condition characterized by aimless involuntary muscular movements. It is due to combined effects of chorea and athetosis.