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**NEUROPHYSIOLOGY**

Question 1: discuss the physiology of sleep.

**Answer**

Sleep is a naturally recurring state of mind and body, characterized by altered consciousness, relatively inhibited sensory activity, reduced muscle activity and inhibition of nearly all voluntary muscles during rapid eye movement (REM) sleep, and reduced interactions with surroundings.

It is distinguished from wakefulness by a decreased ability to react to stimuli, but more reactive than a coma or disorders of consciousness, with sleep displaying very different and active brain patterns.

There are two types of sleep:

1. non-rapid eye-movement (NREM) sleep
2. rapid eye-movement (REM) sleep.

NREM sleep is divided into stages 1, 2, 3, and 4, representing a continuum of relative depth. Each has unique characteristics including variations in brain wave patterns, eye movements, and muscle tone.

Sleep occurs in repeating periods, in which the body alternates between the two distinct modes: REM sleep and non-REM sleep. Although REM stands for "rapid eye movement", this mode of sleep has many other aspects, including virtual paralysis of the body.

The most pronounced physiological changes in sleep occur in the brain. The brain uses significantly less energy during sleep than it does when awake, especially during non-REM sleep. In areas with reduced activity, the brain restores its supply of adenosine triphosphate (ATP), the molecule used for short-term storage and transport of energy. In quiet waking, the brain is responsible for 20% of the body's energy use, thus this reduction has a noticeable effect on overall energy consumption.

Sleep increases the sensory threshold. In other words, sleeping persons perceive fewer stimuli, but can generally still respond to loud noises and other salient sensory events.

During slow-wave sleep, humans secrete bursts of growth hormone. All sleep, even during the day, is associated with secretion of prolactin.

Key physiological methods for monitoring and measuring changes during sleep include electroencephalography (EEG) of brain waves, electrooculography (EOG) of eye movements, and electromyography (EMG) of skeletal muscle activity. Simultaneous collection of these measurements is called polysomnography, and can be performed in a specialized sleep laboratory. Sleep researchers also use simplified electrocardiography (EKG) for cardiac activity and autography for motor movements.

As said earlier, sleep is divided into two broad types: non-rapid eye movement (non-REM or NREM) sleep and rapid eye movement (REM) sleep. Non-REM and REM sleep are so different that physiologists identify them as distinct behavioural states. Non-REM sleep occurs first and after a transitional period is called slow-wave sleep or deep sleep. During this phase, body temperature and heart rate fall, and the brain uses less energy. REM sleep, also known as paradoxical sleep, represents a smaller portion of total sleep time. It is the main occasion

for dreams (or nightmares), and is associated with desynchronized and fast brain waves, eye movements, loss of muscle tone, and suspension of homeostasis.

The sleep cycle of alternate NREM and REM sleep takes an average of 90 minutes, occurring 4–6 times in a good night's sleep.

Later into the night, the REM episodes become longer and non-REM sleep becomes shorter and lighter.

Non-REM sleep can be defined as stage 1, 2, 3 or 4. Stages 1 and 2 are often referred to as light sleep and stages 3 and 4 as deep sleep, slow wave sleep or delta sleep.

The whole period normally proceeds in the order: N1 → N2 → N3 → N2 → REM. REM sleep occurs as a person returns to stage 2 or 1 from a deep sleep. There is a greater amount of deep sleep (stage N3) earlier in the night, while the proportion of REM sleep increases in the two cycles just before natural awakening.

Awakening can mean the end of sleep, or simply a moment to survey the environment and readjust body position before falling back asleep. Sleepers typically awaken soon after the end of a REM phase or sometimes in the middle of REM. Internal circadian indicators, along with successful reduction of homeostatic sleep need, typically bring about awakening and the end of the sleep cycle. Awakening involves heightened electrical activation in the brain, beginning with the thalamus and spreading throughout the cortex.

During a night's sleep, a small amount of time is usually spent in a waking state. As measured by electroencephalography, young females are awake for 0–1% of the larger sleeping period; young males are awake for 0–2%. In adults, wakefulness increases, especially in later cycles. One study found 3% awake time in the first ninety-minute sleep cycle, 8% in the second, 10% in the third, 12% in the fourth, and 13–14% in the fifth. Most of this awake time occurred shortly after REM sleep.

Sleep is driven by three factors:

1. **Homeostatic drive:** The drive to fall asleep increases as the time since the previous episode of non-REM sleep increases (homeostatic drive). This drive reinforces the cyclic nature of sleep and wakefulness and is similar to other physiological needs. For example, the increased need to sleep with sleep deprivation is similar to increased hunger that occurs with increased lengths of food deprivation.

2. **Adaptive drive:** This includes a number of mechanisms which effect but are independent of the duration of wakefulness and the circadian rhythm. Mental stimulation prior to bedtime can make falling asleep difficult, particularly if there are worries or anxieties that cannot be resolved. The ability to relax the body (mentally and physically) affects whether one is able to initiate sleep. The level or lack of sensory inputs also influences our ability to fall asleep. A number of these sensory inputs include:

* **Pain and discomfort:** Awakening during the night is more common in individuals with chronic disease such as rheumatoid arthritis or multiple sclerosis. Pain is also associated with increased tossing and turnings that also result with increased awakenings during the night.
* **Temperature:** An ambient temperature of 18 °C is ideal for falling asleep and staying asleep.  Increased and decreased temperatures result in disrupted sleep.
* **Noise:** A noisy environment can impair sleep and increase arousal from sleep. The noise level that causes an individual to wake varies between people and also changes with age. A person is also more likely to wake up if the noise is significant to the person, the crying of an infant to its parents.
* **Light exposure:** Seasonal changes in the duration of daylight affect the sleep-wakefulness cycle. During sleep, 5-10% of light reaches the retina and light exposure can result in arousal from non-REM sleep. Light exposure during the day also increases alertness, motor function and mood, elevates body temperature and heart rate. A separate effect of light is on the circadian rhythm. This effect is mediated at a specific region in the brain called the suprachiasmatic nuclei (SCN) and suppresses melatonin levels.

3. **Circadian rhythm:** Circadian rhythms occur in 24 hour cycles. The circadian rhythm prompts sleep at night and also to small extent between 2 and 4 pm. Usually the sleep, temperature and hormonal circadian rhythms are synchronised so that all of these factors act together to drive a state of sleep or wakefulness.

The circadian rhythm is generated by a “**biological clock**” whose activity is modulated by various external stimuli. These external cues ensure that the internal clock is in sync with the external environment.

Special cells within the retina of the eye provide the input to the SCN. The SCN in turn influences melatonin secretion from the pineal gland. Melatonin is synthesised from tryptophan. Melatonin production can be increased by an increased oral intake of tryptophan and vitamin B6 (a co-enzyme in tryptophan metabolism) such as by consuming carbohydrates, milk, bananas, figs and peanuts, so consuming these can help an individual to fall asleep. Melatonin secretion is increased by selective serotonin reuptake inhibitors (anti-depressants) and antipsychotics. Melatonin release is inhibited by caffeine, beta-blockers, benzodiazepines and non-steroidal anti-inflammatories, and their consumption can make it more difficult to sleep.

Regimented times for going to bed, going to sleep, waking and getting up are important for reinforcing circadian rhythm. The most important of these is the time of waking because it helps to ensure that the homeostatic drive to sleep is strong.

Other physiological changes that occur during sleep include:

1. Cardiovascular: Changes in blood pressure and heart rate occur during sleep and are primarily determined by autonomic nervous system activity. For instance, brief increases in blood pressure and heart rate occur with K-complexes, arousals, and large body movements.

2. Sympathetic-nerve activity: Sympathetic-nerve activity decreases as NREM sleep deepens; however, there is a burst of sympathetic-nerve activity during NREM sleep due to the brief increase in blood pressure and heart rate that follows K-complexes. Compared to wakefulness, there is a rise in activity during REM sleep.

3. Respiratory: Ventilation and respiratory flow change during sleep and become increasingly faster and more erratic, specifically during REM sleep.

Ventilation data during REM sleep are somewhat unclear, but they suggest that hypoventilation (deficient ventilation of the lungs that results in reduction in the oxygen content or increase in the carbon dioxide content of the blood or both) occurs in a similar way as during NREM sleep. Several factors contribute to hypoventilation during NREM, and possibly REM, sleep such as reduced pharyngeal muscle tone. Further, during REM sleep, there is reduced rib cage movement and increased upper airway resistance due to the loss of tone in the intercostals and upper airway muscles

4. Renal: There is a decreased excretion of sodium, potassium, chloride, and calcium during sleep that allows for more concentrated and reduced urine flow. The changes that occur during sleep in renal function are complex and include changes in renal blood flow, glomerular filtration, hormone secretion, and sympathetic neural stimulation .

5. Endocrine: Endocrine functions such as growth hormone, thyroid hormone, and melatonin secretion are influenced by sleep. Growth hormone secretion typically takes place during the first few hours after sleep onset and generally occurs during SWS, while thyroid hormone secretion takes place in the late evening. Melatonin, which induces sleepiness, likely by reducing an alerting effect from the suprachiasmatic nucleus, is influenced by the light-dark cycle and is suppressed by light.

Question 2: discuss the role of basal ganglia in coordinating movement

**Answer**

The **basal ganglia** (or **basal nuclei**) are a group of subcortical nuclei, of varied origin, in the brains of vertebrates, including humans, which are situated at the base of the forebrain and top of the midbrain. There are some differences in the basal ganglia of primates. 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.

In order to understand the functions of the basal ganglia, we must mention the **extrapyramidal system**. This system is the part of the brain and brain stem that participates in motor control except for the corticospinal (pyramid) system. It includes:

1. Basal ganglia and their pathways

2. Portions of the cerebral cortex that give projections to the basal ganglia

3. Parts of the cerebellum that give projections to the basal ganglia

4. Parts of the reticular formation that are connected to the basal ganglia and cerebral cortex

5. Thalamus nuclei associated with the basal ganglia and reticular formation.

The role of the **extrapyramidal system** is to control automatic movements, skeletal muscle tone, and maintenance of postural reflexes.

The basal ganglia exert their role in motor control through constant interaction with the c**erebral cortex** and the corticospinal pathway. They get information mainly from the cerebral cortex and send out information.

Almost all the motor and sensory nerve fibres that connect the cerebral cortex to the spinal cord pass between the major masses of the basal ganglia (**nucleus caudatus** and **putamen**) and are called the internal brain capsule.

The connections of the motor cortex, the thalamus and the joint circuits of the brain stem and **cerebellum** are very important. Namely, the main circuit of the **basal ganglia system** involves a huge number of connections between the basal ganglia themselves, as well as numerous entry and exit pathways between the motor regions of the brain and the basal ganglia.

The most prominent functions of the

basal ganglia include:

1. Represents the accessory motor system. Mediates between neocortical motor centers and the "elderly" motor areas of the brainstem Selects the purposeful and desired motor activity and suppresses unwanted movements.

2. Acts by modifying ongoing neural activity in motor projections

3. Delivers an inhibitory role in motor control

4. Inhibits muscle tone (balance of excitatory and inbound input signals according to PMN terminating on skeletal muscle)

5. Monitor and adjust slow and continuous contractions (equilibrium, body position, etc.)

6. Regulates attention and individual cognitive processes

7. Participates in motor planning and learning

8. Assisting the cerebral cortex in making subconscious, learned movements

9. Temporal pattern of movement and gradation of the intensity of movement

One of the major roles of the basal ganglia is to participate in the control of complex patterns of **motor activity** such as:**letter writing**, cutting paper with scissors, throwing a ball into a basket, adding the ball in football, many aspects of vocalization, controlled eye movements, or literally all our other skilled movements.

Cognitive control of motor activity in which the **nucleus caudatus** plays a major role is another important function of the basal ganglia. Likewise, planning which movement patterns will be used together, or in what order in order to achieve a complex goal, is another role of the basal ganglia.