17/MHS01/302

MEDICINE AND SURGERY

MEDICINE AND HEALTH SCIENCE

NEUROPHYSIOLOGY ASSIGNMENT

QUESTION 1: DISCUSS THE PHYSIOLOGY OF SLEEP

ANSWER

Sleep is defined as unconsciousness from which the person can be aroused by sensory or other stimuli. It is to be distinguished from coma, which is unconsciousness from which the person cannot be aroused. There are multiple stages of sleep, from very light sleep to very deep sleep; sleep researchers also divide sleep into two entirely different types of sleep that have different qualities, as follows.

1. Slow-Wave Sleep: This sleep is exceedingly restful and is associated with decrease in both peripheral vascular tone and many other vegetative functions of the body. For instance, there are 10 to 30 per cent decreases in blood pressure, respiratory rate, and basal metabolic rate. Although slow-wave sleep is frequently called "dreamless sleep," dreams and sometimes even nightmares do occur during slow-wave sleep. The difference between the dreams that occur in slow-wave sleep and those that occur in REM sleep is that those of REM sleep are associated with more bodily muscle activity, and the dreams of slow-wave sleep usually are not remembered.
2. Rapid Eye Movement REM sleep (Paradoxical Sleep, Desynchronized Sleep): In a normal night of sleep, bouts of REM sleep lasting 5 to 30 minutes usually appear on the average every 90 minutes. When the person is extremely sleepy, each bout of REM sleep is short, and it may even be absent. Conversely, as the person becomes more rested through the night, the durations of the REM bouts increase. There are several important characteristics of REM sleep:
    - It is usually associated with active dreaming and active bodily muscle movements.
    - 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.
    - Muscle tone throughout the body is exceedingly depressed, indicating strong inhibition of the spinal muscle control areas.
    - Heart rate and respiratory rate usually become irregular, which is characteristic of the dream state.
    - Despite the extreme inhibition of the peripheral muscles, irregular muscle movements do occur. These are in addition to the rapid movements of the eyes.
    - The brain is highly active in REM sleep, and overall brain metabolism may be increased as much as 20 per cent.

In summary, REM sleep is a type of sleep in which the brain is quite active. However, the brain activity is not channeled in the proper direction for the person to be fully aware of his or her surroundings, and therefore the person is truly asleep.

Neuronal Centers, Neurohumoral Substances, and Mechanisms That Can Cause Sleep (A Possible Specific Role for Serotonin): Stimulation of several specific areas of the brain can produce sleep with characteristics near those of natural sleep. Some of these areas are the following:

1. The most conspicuous stimulation area for causing almost natural sleep is the raphe nuclei in the lower half of the pons and in the medulla. These nuclei are a thin sheet of special neurons located in the midline. Nerve fibers from these nuclei spread locally in the brain stem reticular formation and also upward into the thalamus, hypothalamus, most areas of the limbic system, and even the neocortex of the cerebrum. In addition, fibers extend downward into the spinal cord, terminating in the posterior horns where they can inhibit incoming sensory signals, including pain. It is also known that many nerve endings of fibers from these raphe neurons secrete serotonin. When a drug that blocks the formation of serotonin is administered to an animal, the animal often cannot sleep for the next several days. Therefore, it has been assumed that serotonin is a transmitter substance associated with production of sleep.
2. Stimulation of some areas in the nucleus of the tractus solitarius can also cause sleep. This nucleus is the termination in the medulla and pons for visceral sensory signals entering by way of the vagus and glossopharyngeal nerves.
3. Stimulation of several regions in the diencephalon can also promote sleep, including
   - The rostral part of the hypothalamus, mainly in the suprachiasmal area, and
   - An occasional area in the diffuse nuclei of the thalamus.

Cycle between Sleep and Wakefulness: When the sleep centers are not activated, the mesencephalic and upper pontile reticular activating nuclei are released from inhibition, which allows the reticular activating nuclei to become spontaneously active. This in turn excites both the cerebral cortex and the peripheral nervous system, both of which send numerous positive feedback signals back to the same reticular activating nuclei to activate them still further. Therefore, once wakefulness begins, it has a natural tendency to sustain itself because of all this positive feedback activity. Then, after the brain remains activated for many hours, even the neurons themselves in the activating system presumably become fatigued. Consequently, the positive feedback cycle between the mesencephalic reticular nuclei and the cerebral cortex fades, and the sleep-promoting effects of the sleep centers take over, leading to rapid transition from wakefulness back to sleep. This overall theory could explain the rapid transitions from sleep to wakefulness and from wakefulness to sleep. It could also explain arousal, the insomnia that occurs when a person's mind becomes preoccupied with a thought, and the wakefulness that is produced by bodily physical activity.

PHYSIOLOGIC EFFECTS OF SLEEP

Sleep causes two major types of physiologic effects: first, effects on the nervous system itself, and second, effects on other functional systems of the body. The nervous system effects seem to be by far the more important because any person who has a transected spinal cord in the neck (and therefore has no sleep wakefulness cycle below the transection) shows no harmful effects in the body beneath the level of transection that can be attributed directly to a sleep wakefulness cycle. Lack of sleep certainly does, however, affect the functions of the central nervous system. Prolonged wakefulness is often associated with progressive malfunction of the thought processes and sometimes even causes abnormal behavioral activities. Sleep in multiple ways restores both normal levels of brain activity and normal "balance" among the different functions of the central nervous system. This might be likened to the "rezeroing" of electronic analog computers after prolonged use, because computers of this type gradually lose their "baseline" of operation; it is reasonable to assume that the same effect occurs in the central nervous system because overuse of some brain areas during wakefulness could easily throw these areas out of balance with the remainder of the nervous system.

QUESTION 2: DISSCUSS THE ROLE OF BASAL GAANGLIA IN COORDINATING MOVEMENT

ANSWER

BASAL GANGLIA AND THEIR MOTOR FUNCTIONS

The basal ganglia, like the cerebellum, constitute 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 receive most of their input signals from the cerebral cortex itself 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. Note also that 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 because of the intimate association between the basal ganglia and the corticospinal system for motor control.

Function of the Basal Ganglia in Executing Patterns of Motor Activity (The Putamen Circuit)

One of the principal roles of the basal ganglia in motor control is to function in association with the corticospinal system to control complex patterns of motor activity. An example is the writing of letters of the alphabet. When there is serious damage to the basal ganglia, the cortical system of motor control can no longer provide these patterns. Instead, one's writing becomes crude, as if one were learning for the first time how to write. Other patterns that require the basal ganglia are cutting paper with scissors, hammering nails, shooting a basketball through a hoop, passing a football, throwing a baseball, the movements of shoveling dirt, most aspects of vocalization, controlled movements of the eyes, and virtually any other of our skilled movements, most of them performed subconsciously.

Role of the Basal Ganglia for Cognitive Control of Sequences of Motor Patterns (The Caudate Circuit)

The term cognition means the thinking processes of the brain, using both sensory input to the brain plus information already stored in memory. Most of our motor actions occur as a consequence of thoughts generated in the mind, a process called cognitive control of motor activity. The caudate nucleus plays a major role in this cognitive control of motor activity. The neural connections between the caudate nucleus and the corticospinal motor control system, are somewhat different from those of the putamen circuit. Part of the reason for this is that the caudate nucleus, extends into all lobes of the cerebrum, beginning anteriorly in the frontal lobes, then passing posteriorly through the parietal and occipital lobes, and finally curving forward again like the letter “C” into the temporal lobes. Furthermore, the caudate nucleus receives large amounts of its input from the association areas of the cerebral cortex overlying the caudate nucleus, mainly areas that also integrate the different types of sensory and motor information into usable thought patterns. After the signals pass from the cerebral cortex to the caudate nucleus, they are next transmitted to the internal globus pallidus, then to the relay nuclei of the ventroanterior and ventrolateral thalamus, and finally back to the prefrontal, premotor, and supplementary motor areas of the cerebral cortex, but with almost none of the returning signals passing directly to the primary motor cortex. Instead, the returning signals go to those accessory motor regions in the premotor and supplementary motor areas that are concerned with putting together sequential patterns of movement lasting 5 or more seconds instead of exciting individual muscle movements. A good example of this would be a person seeing a lion approach and then responding instantaneously and automatically by:

- Turning away from the lion
- beginning to run, and
- Even attempting to climb a tree.

Without the cognitive functions, the person might not have the instinctive knowledge, without thinking for too long a time, to respond quickly and appropriately. Thus, cognitive control of motor activity determines subconsciously, and within seconds, which patterns of movement will be used together to achieve a complex goal that might itself last for many seconds.

Function of the Basal Ganglia to Change the Timing and to Scale the Intensity of Movements

Two important capabilities of the brain in controlling movement are:

- To determine how rapidly the movement is to be performed and
- To control how large the movement will be.

For instance, a person may write the letter “a” slowly or rapidly. Also, he or she may write a small “a” on a piece of paper or a large “a” on a chalkboard. Regardless of the choice, the proportional characteristics of the letter remain nearly the same. In patients with severe lesions of the basal ganglia, these timing and scaling functions are poor; in fact, sometimes they are nonexistent. Here again, the basal ganglia do not function alone; they function in close association with the cerebral cortex. One especially important cortical area is the posterior parietal cortex, which is the locus of the spatial coordinates for motor control of all parts of the body as well as for the relation of the body and its parts to all its surroundings. A person lacking a left posterior parietal cortex might draw the face of another human being, providing proper proportions for the right side of the face but almost ignoring the left side (which is in his or her right field of vision). Also, such a person will try always to avoid using his or her right arm, right hand, or other portions of his or her right body for the performance of tasks, almost not knowing that these parts of his or her body exist. Because the caudate circuit of the basal ganglia system functions mainly with association areas of the cerebral cortex such as the posterior parietal cortex, presumably the timing and scaling of movements are functions of this caudate cognitive motor control circuit.