QUESTION 1: PHYSIOLOGY OF SLEEP

Sleep is the natural periodic state of rest for mind and body with closed eyes characterized by partial or complete loss of consciousness.

Sleep requirements

New born infants: 18 to 20 hours; Growing children: 12 to 14 hours; Adults: 7 to 9 hours; Old persons: 5 to 7 hours

Physiological changes during sleep

1. Plasma volume decreases by about 10% during sleep.
2. Heart rate reduces. It varies between 45 and 60 beats per minute.
3. Systolic pressure falls to about 90 to 110 mm Hg.
4. Rate and force of respiration are decreased.
5. Salivary secretion decreases during sleep. Gastric secretion is not altered. Contraction of empty stomach is more vigorous
6. Formation of urine decreases and specific gravity of urine increases.
7. Sweat secretion increases during sleep.
8. Lacrimal secretion decreases during sleep.
9. Tone in all the muscles of body except ocular muscles decreases very much during sleep.
10. Certain reflexes particularly knee jerk, are abolished. Threshold for most of the reflexes increases. Pupils are constricted.
11. Brain is not inactive during sleep. There is a characteristic cycle of brain wave activity during sleep with irregular intervals of dreams.

Types of sleep

1. Rapid eye movement sleep or REM
2. Non-rapid eye movement sleep or NREM
3. Rapid eye movement sleep or REM:this is associated with rapid conjugate movements of the eyeballs, which occurs frequently. Though the eyeballs move, the sleep is deep. So, it is also called paradoxical sleep. It occupies about 20% to 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.
4. Non-rapid eye movement sleep or NREM: this is the type of sleep without the movement of the eyeballs. Also called slow-wave sleep. Dreams do not occur hear. It occupies about 70% to 80% of total sleeping period. Non-REM sleep is followed by REM sleep.

Stages of sleep and EEG pattern

1. Rapid eye movement sleep:during REM sleep,electroencephalogram (EEG) shows desynchronized waves. I.e an irregular waves with high frequency and low amplitude.
2. Non-REM eye movement sleep: this is divided into four stages, based on the EEG pattern. During the stage of wakefulness, the alpha waves of EEG appear. When the person proceeds to drowsy state, 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: stage 2 is characterised 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 100uv

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 centres in brain. Stimulation of these centres results in sleeplessness or persistent wakefulness called insomnia.

Applied physiology-sleep disorders

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, alcohol 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 tumours, encephalitis, chronic bronchitis and disease of muscles. Hypersomnia also occurs in endocrine disorders such as myxoedema 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. Nightmare: this is a condition during sleep that is characterised by a sense of extreme uneasiness or discomfort or by frightful dreams. 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.
5. 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.
6. Nocturnal enuresis: this is the involuntary voiding of urine at bed. It is also called bedwetting. It is common in children.

QUESTION 2: THE BASAL GANGLIA AND ITS ROLE IN MOVEMENT

1. Regulation of voluntary movement: 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 circuits between basal ganglia and other parts of the brain involved in motor activity. Neuronal circuits arise from three areas of the cerebral cortex:
* Premotor area
* Primary motor area
* Supplementary motor area

All these nerve fibres from cerebral cortex reach the caudate nucleus. From here, the fibres go to putamen. Some of the fibres from cerebral cortex go directly to putamen also. Putamen sends fibres to Globus pallidus. Fibres from here run towards the thalamus, subthalamic nucleus of Luys and substantia nigra are in turn, projected into thalamus. Now, the fibres from thalamus are projected back into primary motor area and other two motor areas, i.e. premotor area and supplementary motor area.

1. Regulation of conscious movements:fibres between cerebral cortex and caudate nucleus are concerned with regulation of conscious movements. This function of basal ganglia is also known as cognitive control of activity. For example, when a stray dog barks at a man, immediately the person, understands the situation, turns away and start running.
2. Regulation of subconscious movements:cortical fibres 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.

The basal ganglia are a collection of subcortical structures consisting of several connected nuclei located in the brain. They are called the caudate nucleus, putamen, globus pallidus, subthalamic nucleus, and substantia nigra (the last two are only functionally connected and related to this system).Three major pathways emerge from the basal ganglia, which project onto various structures of the brain, communicating with them. They are called the **direct** (excitatory), **indirect** (inhibitory) and **hyperdirect** (inhibitory) pathways. Their activity is modulated by D1 and D2 dopamine receptors contained in the substantia nigra, pars compacta.

DIRECT PATHWAY

The direct pathway starts from the cortex and projects to the **striatum** (caudate nucleus and putamen) with excitatory glutamatergic (glu) neurons. The neurons from the striatum, which are inhibitory GABAergic, send their axons to the medial (internal) globus pallidus and substantia nigra, pars reticulata (SNr).

The neurons from the internal globus pallidus and SNr send their axons to the **thalamus**, and they are also inhibitory. The fibers that travel from the pallidum to the thalamus, form two white matter fascicles called ansa lenticularis and lenticular fasciculus, that fuse into one pathway called thalamic fasciculus just before they enter the thalamus. From the thalamus, excitatory pathways go to the **cortex** (prefrontal, premotor and supplementary cortex) where they affect the planning of the movement by synapsing with the neurons of the corticospinal and corticobulbar tracts in the brainstem and spinal cord.

This entire system functions on the principle of **positive feedback**. Since the two of the inhibitory synapses are serially connected, that means that the first inhibitory neuron (striatum) suppresses the activity of the second inhibitory neuron (globus pallidus). The result of this is a reduction of the inhibitory influence that the globus pallidus has over the thalamus, so-called **disinhibition of the thalamus**, which is equivalent to the excitation of the motor cortex. So the final function of the direct pathway of the basal ganglia is to excite the motor cortex or to increase the motor activity.

INDIRECT PATHWAY

This pathway begins (like the direct pathway) from the cortex, projecting to the **striatum**. Instead of sending axons directly to the GPi and SNr, they project to the external globus pallidus.

The neurons from the GPe send inhibitory fibers to the **subthalamic nucleus** instead of sending directly to the thalamus (hence its name “indirect”). From the subthalamic nucleus, neurons send their axons to the GPi/SNr and then continue as the direct pathway with GABAergic inhibitory neurons to the thalamus and glutamate excitatory efferents to the cortex.

So, functionally, the striatum inhibits the external globus pallidus, and that causes **disinhibition of the subthalamus**. For that reason, the neurons of the subthalamus become more active, and they excite the internal segment of the globus pallidus which in the end, inhibits the thalamic nuclei. The final result of this pathway is a decreased activity of the cortical motor neurons and consequential **suppression** of the extemporaneous movement.