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MEDICINE AND SURGERY

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1. PHYSIOLOGY OF SLEEP

Sleep can be defined as “an active state of unconsciousness produced by the body where the brain is in a relative state of rest and is reactive primarily to internal stimulus. Sleep is characterized by:

1. Low physical activity levels
2. Reduced sensory awareness

Sleep is also regulated by the circadian rhythm and homeostatic mechanisms. Furthermore, certain brain activity patterns, as well as the different phases of sleep can be visualized using *Electroencephalography(EEG).* Multiple areas in the brain work together to control sleep-wake cycles. Some of these areas include:

* The Thalamus
* The Hypothalamus - Contains the Suprachiasmatic nucleus (SCN) - the body's biological clock, and in conjunction with the thalamus it regulates slow-wave sleep.
* The Pons - Important in the regulation of rapid eye movement(REM) sleep

During sleep, several endocrine glands secrete and regulate hormones such as:

* **Melatonin** - Involved in the regulation of biological rhythms and the immune system
* **Follicle-Stimulating hormone (FSH)** -secreted by the pituitary gland and key in regulating the reproductive system
* **Luteinizing hormone (LH)** - Secreted by the pituitary gland and key in regulating the reproductive system.
* **Growth hormone** - Secreted by the pituitary gland and has a role in physical growth and maturation.

**SLEEP REGULATION**

Sleep is regulated by two systems, the circadian rhythm and sleep/wake homeostasis. The circadian rhythm synchronizes biological rhythms, including sleep, over a cycle of 24 hours. Sleep/wake homeostasis describes the body’s internal neurophysiologic drive toward either sleep or waking. Homeostasis refers to principles of equilibrium or balance and the body is driven towards a balance between sleep and wakefulness i.e. a neurophysiological drive to sleep is evident after long periods of wakefulness and there is a neurophysiological drive to wakefulness after long periods of sleep.

**FUNCTIONS OF SLEEP**

Several theories have been proposed to explain the function of sleep and why it is necessary. These theories include the restorative theory of sleep, the cognitive theory of sleep; the energy conservation theory of sleep and the adaptive theory of sleep.

* 1. **RESTORATIVE THEORY**

This theory supports the notion that sleep is necessary to revitalize and restore the physiological processes that help in rejuvenating the body and mind. With this theory, it is postulated that Non-Rapid Eye- Movement (NREM) sleep is important for restoring physiological functions and Rapid Eye Movement (REM) sleep is important in the restoration of mental functions.

Findings of many biological functions occurring primarily during sleep support the restorative theory of sleep. Some of these functions include:

1. Muscle repair
2. Cell repair
3. Tissue growth
4. Protein synthesis
5. Release of many of the important hormones for growth

Sleep therefore allows for the body to repair and replete several cellular components that are needed for physiological functions and that become depleted during the day. This supports the concept of allowing our patients to get sufficient rest after surgeries in order to promote efficient recovery processes.

* 1. **COGNITIVE FUNCTION THEORY**

Sleep is important for cognitive function and memory formation. Studies on sleep deprivation show disruption in cognition and also indicate memory deficits. These disruptions lead to the following:

1. Impairment in the attention-maintaining ability
2. Impairments in decision making
3. Difficulty recalling long-term memories

These types of disruptions are also positively correlated to the amount of sleep deprivation, the impairments become more severe as the sleep deprivation time increases.

* 1. **ENERGY CONSERVATION THEORY**

Sleep has been implicated as a means of energy conservation. The energy conservation theory suggests that the main function of sleep is to reduce energy demand during a part of the day and night. The fact that the body has a decreased metabolism of up to 10% during the sleep supports this theory. Body temperature and calorie demand drop during sleep and increase when we are awake, again supporting the hypothesis that sleep plays an important role in helping to conserve energy resources.

* 1. **ADAPTIVE THEORY**

The adaptive theory is also referred to as the *evolutionary theory of sleep or the inactivity* *theory*. It is one of the earliest theories that explain the function of sleep. This theory suggests that sleep is a behaviour which enhances our overall survival. It has been suggested that human beings evolved at a faster rate compared to other species due to our focus on getting rest. This theory suggests that all species have adapted to sleep during periods of time when wakefulness will put them more at risk of danger. Similar to hunger and thirst, sleepiness may represent an underlying physiological need which is only satisfied by sleeping and it’s integral to survive of individual.

**SLEEP STAGES**

Sleep can be divided into two sleep states or types and there is a sequential rotation between these two sleep states several times (5 to 6 times) during a night. These rotations are generally between 90 to 100 minutes per cycle. These two major phases of sleep are:

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

The increasingly longer and deeper REM stages generally occur during the latter part of the sleep cycle. There is no sleep stage division of REM, but NREM sleep consists out of three or four main subdivisions. Rechtschaffen and Kales published standardised criteria for the staging of sleep in 1968. Non-rapid eye movement (NREM) sleep is subdivided into three stages (N1, N2 and N3) of increasing sleep depth.

**NREM Sleep Stage 1 (N1)**

* Transitional phase between wakefulness and sleep (the period during which we drift off to sleep)
* Shallow stage of sleep
* Reduced respiration rate
* Reduced heartbeat
* Brain wave activity (EEG)
* Associated with alpha and theta waves
* Earlier in N1 – alpha waves, low frequency (8-13 Hz), high amplitude patterns of electrical activity (waves) that become synchronized.
* This brain wave activity pattern is like someone who is very relaxed, but awake. Further on in stage N1 – increase theta wave activity. Theta waves – lower frequency (4 -7 Hz), higher amplitude brain waves
* Easy to wake someone from stage 1
* Lasts around 5 -10 minutes

**NREM Sleep Stage 2 (N2)**

* The body goes into a deep relaxation state
* The onset of sleep
* Drop in body temperature
* Heart rate slows down
* The brain produces sleep spindles
* People are less aware of their surroundings
* Lasts around 20 minutes
* Brain wave activity: Theta waves still dominant, but interrupted by sleep spindles (rapid burst of higher frequency brain waves – these may be important for learning and memory). K-complexes also during this stage (very high amplitude pattern of brain activity that may occur in response to environmental stimuli – may serve as a bridge to higher levels of arousal in response to what is going on in our environments). Sleep spindles and K-complexes help to distinguish between NREM N1 and N2.

**NREM Sleep Stage 3 (N3)**

* Revised combination of previous stage 3 and 4 according to Rechtschaffen and Kales
* Also known as slow-wave sleep (SWS)
* Muscles relax
* Blood pressure drops
* Breathing rate drops
* The deepest sleep occurs
* People are less responsive
* Noises and activity in the surrounding environment may fail to generate a response
* The transitional period between light sleep and very deep sleep
* Brainwaves: low frequency (up to 4Hz), high amplitude delta waves

2) THE ROLE OF THE BASAL GANGLIA IN COORDINATING MOVEMENT

The direct/indirect popular hypothesis 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 *stratum*). 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 activities in these two pathways may facilitate smooth movement.

CASES WHERE THE BASAL GANGLIA HAVE BEEN DAMAGED

In **PARKINSON’S DISEASE**, for example, [***dopaminergic***](http://www.neuroscientificallychallenged.com/glossary/dopaminergic) neurons of the [*substantia nigra*](http://www.neuroscientificallychallenged.com/glossary/substantia-nigra) degenerate. When this happens, the ability of the basal ganglia to inhibit contradictory movements is affected. This may cause individuals with Parkinson's disease to have difficulty initiating movements, resulting in some of the symptoms associated with Parkinson's disease like rigidity and slow movement.

**HUNTINGTON DISEASE**, degeneration of basal ganglia circuits causes the inhibitory capabilities of the basal ganglia to be diminished. This may lead to the excessive activation of movement-related circuits, causing the jerky and writhing involuntary movements seen in Huntington's disease.

**HEMIBALLISM:** Hemiballism (from the Greek “to throw”) is used to describe hyperkinetic, involuntary, forceful movements of the ipsilateral arm and leg. Commonly, a lesion in the contralateral subthalamic nuclei causes hemiballism.

**TOURETTE SYNDROME:** Tourette syndrome has been shown to have a significant neurological basal ganglia component which manifests as sudden, repetitive uncontrolled movements and vocalizations, called “tics.” These tics have been associated with dysfunction of the GABAergic projections from the striatum, leading to a relative increase in dopaminergic activity much like in hemiballism and Huntington’s disease.