**(Slide 1) Lecture 19**

**Physiology of higher nervous activity. Part 3**

**(Slide 2)** Lecture plan:

1. Definition of attention, sensation and perception.

2. General questions of the physiology of learning and memory.

3. Learning as Formation and Deformation inside the Brain/

4. Localization of Learning Processes and Memory.

5. Memory Systems.

6. The Different Types of Memory.

7. The Process of Learning inside the Brain.

8. Mechanisms that shape and regulate sleep.

9. Theories of sleep.

10. Sleep Stages.

**Definition of attention, sensation and perception**

**(Slide 3)** Forms of mental activity are sensations, perceptions, feelings (emotions), thinking, attention, ideas, will.

**(Slide 4)** **Attention is** a state of active wakefulness, characterized by readiness to respond to a stimulus and is expressed in the direction of mental activity towards a specific object. The appearance of attention is due to the activation of nervous processes that contribute to the transition from one level of wakefulness to another, higher one; a very strong degree of activation disrupts the process of attention. There are two types of attention - involuntary and voluntary (volitional). Involuntary attention is an innate process that is carried out when a certain stimulus acts on the body due to its inherent characteristics and is perceived by a person without any effort on his part. In the process of social activity, a person acquires the ability to control his attention; attention that obeys the will of a person is called volitional (arbitrary).

**(Slide 5)** The leading role in voluntary attention belongs to the frontal lobes. Intellectual attention is considered to be the highest form of volitional attention. Thus, attention is a product of social development, expressed in the purposeful mobilization of a person's mental activity. The appearance of attention is the beginning of exploratory behavior, adaptive conscious activity of the organism, selection of the necessary information. In physiological terms, attention is based on the orienting reflex. This reflex disappears with repetition, which indicates the role of the cerebral cortex and that the orienting reflex has some features of learning (extinction) characteristic of conditioned reflexes. To understand the mechanism of attention, the concept of the dominant is used (A.A. Ukhtomsky).

**(Slide 6)** Sensation is a form of direct reflection in the human mind of individual properties of objects and phenomena of reality that currently affect the human senses. Often sensations give a spatial representation (light source, tactile sensations). Every sensation has quality, strength and duration. Depending on the quality of the stimulus, visual, auditory, etc. sensations are distinguished.

**(Slide 7)** Perception (Latin perceptio - perception) is an active process of holistic (sensory-figurative) reflection of objects and phenomena of the outside world, arising from the direct impact of the stimulus on the receptors of sensory systems. Perception does not necessarily reflect all the properties of an object. Perceived and taken into account are usually those details without which the perceived as a whole cannot be distinguished from the totality of similar objects. Therefore, perception is selective. Each person perceives what interests him.

**(Slide 8)** The central link of perception is the identification of an object, a phenomenon. This process is based on complex systems of temporary connections. The object and phenomena act on receptors, information from them reaches the corresponding cortical zones, then in the associative zones of the cortex, the incoming information is compared (compared) with the images stored in the memory, and it is recognized. In a person, it can be reflected in speech, i.e. become aware, leading to the emergence of the concept. Thus, perception develops at the final stage as a conscious process.

**(Slide 9) Video\_Sensation & Perception\_ Top-Down & Bottom-Up Processing**

**Physiology of Learning and Memory**

**(Slide 10)** The word learning is originally related to ‘teaching somebody’ and ‘trick’. Furthermore, learning is also etymologically related to ‘tracing something’. The conclusion is that learning is a process to acquire new knowledge. Learning is the precondition for the brain to store experiences and to use those experiences in our actions to gain benefits and prevent damage.

**(Slide 11)** Learning processes during the first 6 months of a baby’s life hold great significance for the development of the nervous system. Environmental stimuli and experiences also play a role in this process since they lead to the formation of new synapses and the improvement of already existing synaptic connections. The ability of the brain to form and improve these connections are referred to as neuroplasticity, whether they are based on physiological or neuroanatomical conditions.

**(Slide 12)** Most brain cells are already formed during pregnancy. However, an infant’s nerve cells still cannot communicate at the time of birth, since they are not yet connected. These connections are developed during the 1st 3 years of life. This process takes place by developing dendrites, which enable cells to absorb information. Moreover, synaptic connections, which are responsible for relaying information, are formed. The extent of these connections is far greater than what is required, which makes it easy to adjust later if needed.

**(Slide 13)** Babies react strongly to stimuli, which is also an important indication that a learning process is being carried out. Besides, these stimuli are necessary for the brain to develop, meaning that an environment with few stimuli hinders the development of babies.

**(Slide 14)** During this development stage, the ability to differentiate faces and vocal sounds are better developed than in adults, which enables the baby to distinguish between familiar people and strangers. After imprinting their personal surroundings, the baby loses a certain amount of flexibility concerning their mental abilities. However, learning processes become more specific. This development takes place during the first 6 months of life.

**(Slide 15)** The brain uses neurons to communicate and, to a large extent, manage itself. However, the development of neurons and the resulting brain capacities depend on environmental and sensory stimuli. The brain works in connection with the spinal cord to send and receive information via the neurons. The brain processes all perceptions, which are also connected. For this process, the brain uses already stored experiences. However, most perceptions are suppressed. The brain differentiates perceptions that must be processed during the learning process according to:

* Relevance
* Value of new knowledge
* Significance
* Meaningfulness

**(Slide 16)** Cognition and emotions play a major role in the process of learning. Sensations are used as somatic markers, which influence processing, storage, and memory. Learning also includes the strengthening of the most used neuronal pathways, so they can be used longer and above all faster.

**Learning as Formation and Deformation inside the Brain**

**(Slide 17)** The process of learning starts with processing external influences. Learning leads to changes in the brain that can be classified into 4 categories: expanding, tuning, reconstructing, and pruning.

**(Slide 18)** Expanding means to improve the number and strength of neuronal connections by developing a network of already existing information. Tuning describes the process of creating new connections. During the process of reconstructing, relearning takes place. In this time-consuming and exhausting process, preexisting learning achievements (motor patterns and routine processes) are replaced by new ones that are better suited for the respective task. Pruning describes the regression of neuronal potential, which is used little or not at all. During this process, connections can be changed in such a way that they cannot be activated anymore.

**(Slide 19)** Learning is differentiated into:

1. Intentional learning
2. Individual learning
3. Collective learning
4. Physical learning
5. Social learning

**(Slide 20)** Humans need social interactions, and this also applies to the brain. Mirror neurons inside the brain are responsible for the development of the required cognitive orientation pattern. Physical activity is important for brain performance as well, and this particularly applies in the 1st years of life.

**(Slide 21)** Motor learning is located in the neurons of the cerebellum and basal ganglia. The declarative memory is located in the medial temporal lobe. A lesion of the hippocampus leads to anterograde amnesia, meaning that new information cannot be stored anymore.

**Memory Systems**

**(Slide 22)** The procedural memory is in the striatum and uses the pathway of the neocortex. Associative learning takes place inside the amygdala for emotional processes and in the cerebellum for motor processes. Non-associative learning occurs in the form of habituation and sensitization (both via reflex circuits).

**(Slide 23)** The Hebbian theory explains how the connection between certain neurons can be strengthened. If an axon of neuron A is located close enough to neuron B so that neuron B can be stimulated by neuron Repeatedly or continuously, the efficiency of neuron A for the stimulation by neuron B is increased by growth processes or changes in metabolism in both or 1 of the 2 neurons. This means that experience-related changes in the nervous systems depend on certain conditions.

**(Slide 24)** The Papez circuit is important for the development of memory. The circuit is located in the center of the limbic system. The limbic system is located above the brain stem and exists in all mammals. It has a vital role in social behavior, solicitude, love, fear, and learning by imitation.

**(Slide 25)** The Papez circuit is a chain of neurons, named after its discoverer, James Papez. Research on the tasks of the Papez circuit for memory performance is still ongoing. However, the assumption that the circuit controls anger and rage is already outdated since it has been discovered that the circuit is even more complex than Papez thought.

**(Slide 26)** These days, it is assumed that the Papez circuit serves the storage of memories by transferring information from the primary memory (short-term memory) to the secondary memory (long-term memory) or the tertiary memory (an independent part of the long-term memory). The Papez circuit proceeds as follows: hippocampus → fornix → mammillary body inside the hypothalamus (corpora mammillaria) → cingulate cortex → hippocampus

**(Slide 27)** **The Different Types of Memory**

**Video\_Memory Systems \_ Psychology**

**(Slide 28)** The specialist term for mind and memory is called the mnestic function. Some things are easier to remember than other things. For example, important things are easier to remember than events that hold no meaning, and positive experiences are easier to remember than neutral experiences. Moreover, the process of remembering is easier in a prevailing positive mood, which also means that remembering things is more difficult in a state of fatigue or grief.

**(Slide 29)** Encoding is the process of transferring sensory information into a construct which is then stored in our memory system. Working memory stores information for immediate use as part of mental activity (i.e. learning or problem solving). It is thought to include phonological loop, visuospatial sketchpad, central executive, and episodic buffer. It allows for manipulation and organization of information vs. short-term memory.

**(Slide 30)** Sensory memory (ultra-short-term memory). The ultra-short-term memory receives stimuli from sensory organs in the form of neuronal excitation. This process has a duration of less than 1 second, and the perception can take place via the eyes or ears. The ultra-short-term memory via the eye is also referred to as iconic memory, and via the ears, echoic memory (and it perishes just as fast). Only stimuli that reach the short-term memory remain because the ultra-short-term memory has no storage capabilities.

**(Slide 31)** Short-term memory (primary memory). Memories in the primary memory (short-term memory) are available as long as we occupy ourselves with them. If that process is interrupted, the memory is lost too. Memories that begin in the primary memory can be available permanently, but only if they are transferred to long-term memory. It is assumed that short-term memory is a transit for experiences into long-term memory.

**(Slide 32)** The hippocampus, located in the cerebral cortex, is involved in the process of transmitting information from the **primary memory** to the long-term memory. The hippocampus is thought to be involved in this process because when lesions appear in the hippocampus, only the short-term memory remains intact. Another term for primary memory is ‘labile memory’ since it is very unstable. One distraction is enough to forget the perceived or heard information. Calcium has a major role in these processes.

**(Slide 33)** **Video\_** **Memory and the Hippocampus.**

**(Slide 34)** Long-term memory. For storing memories in long-term memory, repetition is particularly important. This concept is easily understandable when one considers the high amount of repetition required to learn new movement patterns, e.g., when learning a new sport.

**(Slide 35)** Semantic networks and spreading networks. Information is stored in our long-term memory as an organized network. Individual ideas or hubs are called nodes (i.e. cities on a map). Nodes are connected by links or associations (i.e. roads between cities). The strength of the association is related to how frequently and deeply the connection is made. Processing material in different ways leads to the establishment of multiple connections. Nodes are only activated once they reach a response threshold. The response threshold is reached by the summation of input signals from multiple nodes. Activation of a node leads to the stimulation of neighboring connecting nodes. The activation of a few nodes can lead to a pattern of activation within the network that spreads inward (known as spreading activation).

**The Process of Learning inside the Brain**

**(Slide 36)** The hippocampus also plays an important role in the process of learning. There exists a connection between nerve cells and the neuronal mechanism, which is assumed to be the physiologic substrate of learning. This physiologic substrate consists of continuous electrophysiologic, morphologic, and molecular changes of nerve cells. For information to be available long-term, long-term potentiation (LTP) is necessary. Long-term potentiation facilitates the stimulation of afferent axons over a period of weeks as well as a stronger calcium influx. Everything stored in the long-term memory is available during one’s entire life. The processes of the long-term memory take place under the influence of the neurotransmitter glutamate (glutamic acid).

**Physiology of Sleep**

**(Slide 37) Video\_What happens when we sleep**

**(Slide 38)** Sleep is an important part of our daily routine. It is estimated that we spend about a third of our time sleeping. Quality sleep is just as important for good health as proper nutrition and physical activity. Sleep is important to many brain functions, we need sleep to learn effectively and it has been shown that a lack of sleep affects our concentration levels negatively. Evidence also shows that sleep affects almost every type of tissue and system in the body and that a chronic lack of sleep can increase the risk for non-communicable diseases such as hypertension, diabetes, cardiovascular disease and obesity. Sleep is vital to good health!

**(Slide 39)** 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 characterised by:

* low physical activity levels
* reduced sensory awareness

**(Slide 40)** 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 visualised using electroencephalography (EEG).

**(Slide 41)** Multiple areas in the brain work together to control sleep-wake cycles. Some of these areas include the:

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

**(Slide 42)** 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
* Luteinising 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

**(Slide 43)** Sleep is regulated by two systems, the circadian rhythm and sleep/wake homeostasis. The circadian rhythm synchronises 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.

**(Slide 44)** 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.

**(Slide 45) Video\_Functions of Sleep**

**(Slide 46) Restorative Theory**. This theory supports the notion that sleep is necessary to revitalise 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 sleep is important in the restoration of mental functions.

**(Slide 47)** Findings of many biological functions occurring primarily during sleep support the restorative theory of sleep. Some of these functions include:

* Muscle repair
* Cell repair
* Tissue growth
* Protein synthesis
* Release of many of the important hormones for growth

**(Slide 48)** 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.

**(Slide 49) 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:

* Impairment in the attention-maintaining ability
* Impairments in decision making
* Difficulty recalling long-term memories

**(Slide 50)** 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. It has also been shown that slow-wave sleep (NREM N3) after learning a new task has the ability to improve resultant performance on that task. Stickgold (2005) also showed that slow-wave sleep is vital for effective memory formation. It is therefore not the best idea to stay up all night studying for a test, as it may not be effective and may even be counterproductive.

**(Slide 51) 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.

**(Slide 52) 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 eg that sleep is an adaptive behavior to keep us away from night and darkness when predator species enjoy advantage in vision and stealth. 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 individuals.

**(Slide 53) 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:

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

The increasingly longer and deeper REM stages generally occur during the latter part of the sleep cycle.

**(Slide 54)** There is no sleep stage division of REM. NREM sleep consists out of three or four main subdivisions. Rechtschaffen and Kales published standardised criteria for the staging of sleep in 1968. The American Academy of Sleep medicine revised these criteria and published the revised version in 2007. Main change: combining of stage three and four into a single-stage – defined now as slow-wave sleep or deep sleep (for the purpose of this page, reference will be made to the American Academy of Sleep classification). Polysomnography is used to identify and categorise the different sleep states. Non-rapid eye movement (NREM) sleep is subdivided into three stages (N1, N2 and N3) of increasing sleep depth.

**(Slide 55)**

Questions that we will analyze for a lesson on this topic:

1. Definition of attention, sensation and perception.

2. General questions of the physiology of learning and memory.

3. Learning as Formation and Deformation inside the Brain/

4. Localization of Learning Processes and Memory.

5. Memory Systems.

6. The Different Types of Memory.

7. The Process of Learning inside the Brain.

8. Mechanisms that shape and regulate sleep.

9. Theories of sleep.

10. Sleep Stages.

Finish for today

The full lecture is at the indicated website.

**Thank you for attention**