Lecture 38

The Cranial Nerves

Plan of the Lecture

1. Cranial Nerve Pathways
2. Cranial Nerve Classification
3. Cranial Nerve Survey
4. Composition, Function, Origin, Termination, Cranial, Passage, Effect of Damage, Clinical Test of I, II, III, IV, V, VI, VII, IX, X, XI, XII cranial nerves

LEARNING OUTCOMES

1. List the 12 cranial nerves by name and number;
2. Identify where each cranial nerve originates and terminates in the model and picture;
3. State the functions of each cranial nerve.

To be functional, the brain must communicate with the rest of the body. Most of its input and output travels by way of the spinal cord, but it also communicates by way of 12 pairs of cranial nerves.

These arise primarily from the base of the brain, exit the cranium through its foramina, and lead to muscles and sense organs located mainly in the head and neck. The cranial nerves are numbered I to XII starting with the most rostral pair. Each nerve also has a descriptive name such as optic nerve and vagus nerve.

Most motor fibers of the cranial nerves begin in the nuclei of the brainstem and lead to glands and muscles. The sensory fibers begin in receptors located mainly in the head and neck and lead mainly to the brainstem. These include the special senses such as vision and hearing, as well as general senses such as touch and proprioception.

Sensory fibers for proprioception begin in the muscles innervated by motor fibers of the cranial nerves, but they often travel to the brain in a different nerve than the one that supplies the motor innervation.

Most cranial nerves carry fibers between the brainstem and ipsilateral receptors and effectors. Thus, a lesion in one side of the brainstem causes a sensory or motor deficit on the same side of the head. This contrasts with lesions of the motor and somatosensory cortex of the cerebrum, which, as we saw earlier, cause sensory and motor deficits on the contralateral side of the body. The exceptions are the optic nerve (II), where half the fibers decussate to the opposite side of the brain, and the trochlear nerve (IV), in which all efferent fibers lead to a muscle of the contralateral eye.

Cranial nerves are traditionally classified as sensory (I, II, VIII), motor (III, IV, VI, XI, XII), or mixed (V, VII, IX, X). In reality, only cranial nerves I and II (for smell and vision) are purely sensory, whereas all of the rest contain both afferent and efferent fibers and are therefore mixed nerves. Those traditionally classified as motor not only stimulate muscle contractions but also contain sensory fibers of proprioception, which provide the brain with feedback for controlling muscle action and make one aware of such things as the position of the tongue and orientation of the head. Cranial nerve VIII, concerned with hearing and equilibrium, is traditionally classified as sensory, but it also has motor fibers that return signals to the inner ear and tune it to sharpen the sense of hearing. The nerves traditionally classified as mixed have sensory functions quite unrelated to their motor functions. For example, the facial nerve (VII) has a sensory role in taste and a motor role in controlling facial expressions.

Check yourself! The questions for self-control

1. Names and numbers of the 12 pairs of cranial nerves, and their relationships to the brainstem and skull foramina
2. Which cranial nerves are purely sensory, which are mixed, which have traditionally been regarded as motor, and why it is not entirely accurate to simply call them motor nerves
3. For each cranial nerve, its location, functions, origin, termination, passage through the skull
4. Effects of damage to each cranial nerve, and clinical methods of testing for damage

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Anne M Gilroy, Brian R MacPherson, Lawrence M Ross, Michael Schuenke, Erik Schulte, Udo Schumacher - Atlas of Anatomy (2012, Thieme) - libgen.lc
3. Sagar Dugani, Jeffrey E. Alfonsi, Anne M. R. Agur, Arthur F. Dalley - Clinical Anatomy Cases: An Integrated Approach with Physical Examination and Medical Imaging (2016, Wolters Kluwer)
4. Stefan Silbernagl, Agamemnon Despopoulos - Color Atlas of Physiology (Thieme, 2009)

Lecture 39

General Properties and anatomy of the Autonomic Nervous System

Plan of the Lecture

1. Introduction
2. Visceral Reflexes
3. Divisions of the Autonomic Nervous System
4. Autonomic Output Pathways
5. Anatomy of the Autonomic Nervous System

LEARNING OUTCOMES

1. Explain how the autonomic and somatic nervous systems differ in form and function;
2. Explain how the two divisions of the autonomic nervous system differ in general function.
3. Identify the anatomical components and nerve pathways of the sympathetic and parasympathetic divisions;
4. discuss the relationship of the adrenal glands to the sympathetic nervous system;
5. describe the enteric nervous system of the digestive tract and explain its significance.

The autonomic nervous system (ANS) can be defined as a motor nervous system that controls glands, cardiac muscle, and smooth muscle. It is also called the visceral motor division to distinguish it from the somatic motor division that controls the skeletal muscles. The primary targets of the ANS are organs of the thoracic and abdominal cavities, such as the heart, lungs, digestive tract, and urinary tract, but it also innervates some structures of the body wall, including cutaneous blood vessels, sweat glands, and piloerector muscles.

The word autonomic literally means “self-governed.” It refers to the fact that the ANS usually carries out its actions without one’s conscious intent, awareness, or ability to control it at will. It is for this reason that autonomic responses are used as a basis for polygraph (“lie detector”) tests. Visceral effectors do not depend on the autonomic nervous system to function, but only to adjust their activity to the body’s changing needs. The heart, for example, goes on beating even if all nerves to it are severed, but the ANS adjusts the heart rate for such conditions as rest or exercise.

The ANS works through visceral reflexes, which regulate such primitive

functions as blood pressure, heart rate, body temperature, digestion, and many others. In short, the ANS quietly manages a myriad of unconscious processes responsible for our homeostasis; these are not specifically human but among our most basic animal functions. Many drug therapies are based on manipulation of autonomic functions.

The ANS has components in both the central and peripheral nervous systems. In the CNS, there are autonomic control centers in the hypothalamus and other regions of the brainstem, and motor neurons in the spinal cord. PNS components include motor neurons in the ganglia and nerve fibers in the cranial and spinal nerves you have already studied. The autonomic pathway to a target organ differs significantly from somatic motor pathways. In somatic pathways, a motor neuron in the brainstem or spinal cord issues an axon that reaches all the way to a skeletal muscle. In autonomic pathways, the signal must travel across two neurons to get to the target cells, and it must cross a synapse where these neurons meet in an autonomic ganglion. The first neuron, called the preganglionic neuron, has a soma in the brainstem or spinal cord; its axon terminates in a ganglion outside the CNS.

It synapses there with a postganglionic neuron whose axon extends the rest of the way to the target cells. The axons of these neurons are called the pre- and postganglionic fibers.

The ANS has two subdivisions: sympathetic and parasympathetic. The sympathetic division adapts the body in many ways for physical activity—it increases alertness, heart rate, blood pressure and flow, blood glucose concentration, and pulmonary airflow. Extreme sympathetic responses are often called the “fight-or-flight” reaction because they come into play when an animal must attack, defend itself, or flee from danger. In our own lives, this reaction occurs in many situations involving arousal, competition, stress, danger, anger, or fear—ranging from a game of chess to defending oneself from an attacker. Ordinarily, however, the sympathetic division has more subtle effects that we notice barely, if at all.

The parasympathetic division, by comparison, has a calming effect on many body functions. It is associated with reduced energy expenditure and normal bodily maintenance, including such functions as digestion and waste elimination. This is sometimes called the “resting-and-digesting” state.

This doesn’t mean that the body alternates between states where one division or the other is active and the opposite system is turned off. Normally both divisions are active simultaneously, but the balance between them shifts with the body’s changing needs. Neither division has universally excitatory or calming effects. The sympathetic division, for example, excites the heart but inhibits digestive and urinary functions, while the parasympathetic division has the opposite effects.

All efferent, preganglionic fibers of the sympathetic division arise from the thoracic and first two lumbar segments of the spinal cord. These fibers travel a short distance to ganglia that lie alongside the vertebral column. Here, some of the fibers turn and travel up or down to higher and lower ganglia, unitingthe ganglia into a string called the sympathetic chain. The chain extends upward into the cervical region and downward to the sacral and coccygeal levels.

Usually, the preganglionic nerve fiber synapses with a postganglionic neuron somewhere in the sympathetic chain. Some of the fibers pass through the chain without synapsing, however, and go to ganglia wrapped around the abdominal aorta, the large artery on the posterior abdominal wall. From either the sympathetic chain or these ganglia, postganglionic nerve fibers then complete the path to the target organs. The general pattern in the sympathetic division is to have short preganglionic fibers and long postganglionic ones.

Most preganglionic fibers branch before reaching their synapses. Typically, each preganglionic neuron synapses with 10 to 20 postganglionic neurons. This means that a localized output from the spinal cord can branch out and reach several target organs at once, such as the eyes, sweat glands, heart, and lungs, creating multiple effects of the fight-or-flight response (pupillary dilation, sweating, faster heart rate, and increased airflow).

Another component of the sympathetic division is found in the adrenal glands, which lie superior to the kidneys. The inner core of each gland, the adrenal medulla, is essentially a sympathetic ganglion. Preganglionic fibers penetrate through the cortex and terminate on cells of the medulla, which secrete epinephrine (adrenaline) and norepinephrine (noradrenaline) into the blood. These hormones accentuate the effects of the sympathetic division.

Check yourself! The questions for self-control

1. The fundamental function and effectors of the autonomic nervous system (ANS)
2. Why this system is called autonomic; how it differs from the somatic motor system
3. The fundamental, contrasting functions of the sympathetic and parasympathetic divisions of the ANS
4. Why it cannot be said that at any given moment, either the sympathetic or the parasympathetic division is active; the meaning of autonomic tone
5. Basic anatomical components of the ANS
6. How autonomic efferent pathways differ from somatic efferent pathways; the meanings of preganglionic and postganglionic fibers
7. Origin of the sympathetic preganglionic fibers and the routes they take to the sympathetic chain ganglia

8. Anatomy of the sympathetic chain; the number of ganglia at its various levels; and the body regions supplied by nerve fibers issuing from each group of ganglia
9. The gray and white communicating rami that connect the sympathetic ganglia to the spinal nerves; the reason they are named sympathetic nerve fibers take through these rami
10. Differences between the spinal nerve route, sympathetic nerve route, and splanchnic nerve route by which fibers leave the sympathetic chain
11. Various places in which a sympathetic preganglionic fiber may synapse with a postganglionic neuron
12. Locations of the celiac, superior mesenteric, and inferior mesenteric ganglia; the collective name for them; and the varied meanings of the expression solar plexus
13. The degree and significance of neural divergence in the sympathetic nervous system, and the effect of this on target organ stimulation
14. Why the adrenal medulla can be considered part of the sympathetic nervous system; what products it secretes when stimulated
15. Names and numbers of the cranial and spinal nerves that carry preganglionic fibers of the parasympathetic nervous system; which nerve carries the largest percentage of parasympathetic fibers
16. The path of the vagus nerve, and the names and locations of the plexuses and trunks to which it gives rise
17. Where, in general, terminal ganglia of the parasympathetic division are found, and therefore where the postganglionic fibers begin
18. The location and functions of the enteric nervous system

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Anne M Gilroy, Brian R MacPherson, Lawrence M Ross, Michael Schuenke, Erik Schulte, Udo Schumacher - Atlas of Anatomy (2012, Thieme) - libgen.lc
3. Sagar Dugani, Jeffrey E. Alfonsi, Anne M. R. Agur, Arthur F. Dalley - Clinical Anatomy Cases: An Integrated Approach with Physical Examination and Medical Imaging (2016, Wolters Kluwer)
4. Stefan Silbernagl, Agamemnon Despopoulos - Color Atlas of Physiology (Thieme, 2009)

Lecture 41

Autonomic Effects on Target Organs.

Plan of the Lecture

1. Neurotransmitters and Their Receptors
2. Dual Innervation
3. Control Without Dual Innervation
4. Autonomic Output Pathways
5. Anatomy of the Autonomic Nervous System

LEARNING OUTCOMES

1. name the neurotransmitters employed at different synapses of the ANS;
2. name the receptors for these neurotransmitters and explain how they relate to autonomic effects;
3. explain how the ANS controls many target organs through dual innervation;
4. explain how control is exerted in the absence of dual innervation.

The sympathetic division accelerates the heartbeat, for example, and the parasympathetic division slows it down; the sympathetic division inhibits digestion and the parasympathetic division stimulates it. The key to such contrasting effects, and to many drug actions, depends on differences in the neurotransmitters employed by the two divisions and in the types of neurotransmitter receptors found in the target cells. A single neurotransmitter can excite some organs and inhibit others because of differences in the type of receptor those organs have for it.

The two main neurotransmitters employed in the ANS are acetylcholine (ACh) and norepinephrine (NE). A cholinergic31 nerve fiber or receptor is one that, respectively, secretes or binds ACh. An adrenergic nerve fiber or receptor secretes or binds NE; it is named for an older synonym for NE, adrenaline.

All preganglionic fibers of the ANS are cholinergic; they release ACh to stimulate the postganglionic neurons. Parasympathetic postganglionic fibers also are cholinergic, whereas most sympathetic postganglionic fibers are adrenergic.

Many organs receive both sympathetic and parasympathetic input. In the eye, for example, the iris receives fibers of both types. Sympathetic fibers dilate the pupil, a well-known sympathetic effect, whereas parasympathetic fibers constrict it. When the two divisions of the ANS have opposite effects on the same organ, they are said to have antagonistic effects.

In other cases, the two divisions have cooperative effects. Saliva, for example,

consists of a watery solution of digestive enzymes plus slippery mucus that makes food easier to swallow. Sympathetic fibers stimulate mucus secretion, and parasympathetic fibers stimulate enzyme secretion.
It is not always necessary to have dual innervation, however, for the ANS to produce opposite effects on an organ. Most blood vessels, for example, receive only sympathetic nerves. When the nerves increase their firing rate, they constrict the vessels, which raises the blood pressure. When the nerves decrease their firing rate, they allow the blood vessels to relax and dilate, which lowers the blood pressure. In some cases, such as sudden emotional shock, the sympathetic firing rate decreases so much that the blood pressure falls too low and a person faints.

Check yourself! The questions for self-control

1. Why the autonomic effect on a target cell depends on both the neurotransmitter released and the type of receptor on the target cell
2. The difference between cholinergic and adrenergic fibers and where each can be found in the ANS
3. What nicotinic and muscarinic receptors have in common, how they differ, and where they occur in the ANS
4. What α- and β-adrenergic receptors have in common, how they differ, and where they occur in the ANS
5. Neurotransmitter stability and how it relates to the duration of sympathetic versus parasympathetic effects
6. The variety of neurotransmitters and neuromodulators employed by them
7. Autonomic control of certain organs by dual innervation, and examples of antagonistic and cooperative effects on an organ
8. How the ANS can regulate organs that lack dual innervation

Recommended readings:

5. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
6. Anne M Gilroy, Brian R MacPherson, Lawrence M Ross, Michael Schuenke, Erik Schulte, Udo Schumacher - Atlas of Anatomy (2012, Thieme) - libgen.lc
7. Sagar Dugani, Jeffrey E. Alfonsi, Anne M. R. Agur, Arthur F. Dalley - Clinical Anatomy Cases: An Integrated Approach with Physical Examination and Medical Imaging (2016, Wolters Kluwer)

Lecture 42

Central Control of Autonomic Function.

Plan of the Lecture

1. Cerebral cortex
2. Hypothalamus.
3. Midbrain, pons, and medulla oblongata.
4. Spinal cord

LEARNING OUTCOMES

1. describe how the autonomic nervous system is influenced by the central nervous system.

Even though autonomic means “self-governed,” the ANS is not an independent nervous system. All of its output originates in the CNS, and it is strongly influenced by the cerebral cortex, hypothalamus, limbic system, medulla oblongata, and spinal cord. Consequently, our emotions affect such autonomic functions as blood pressure, heart rate, digestion, and sexual function. Other autonomic responses originate in the brainstem or are at least influenced by it, such as thermoregulation, salivation, digestive secretion, bladder and bowel control, and pupillary light reflexes.

The spinal cord also contains integrating centers for such autonomic reflexes as defecation, urination, erection, and ejaculation. Fortunately, the brain is able to inhibit defecation and urination consciously, but when injuries sever the spinal cord from the brain, the autonomic spinal reflexes alone control the elimination of urine and feces. The lack of voluntary control over these functions is called urinary or fecal incontinence. Erection and ejaculation can occur through autonomic spinal reflexes alone even in men with spinal cord injuries who cannot feel the associated sensations.

Check yourself! The questions for self-control

1. Examples of the influence of the cerebral cortex, hypothalamus, midbrain, pons, medulla oblongata, and spinal cord on the autonomic nervous system, and their involvement in autonomic effects.

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Anne M Gilroy, Brian R MacPherson, Lawrence M Ross, Michael Schuenke, Erik Schulte, Udo Schumacher - Atlas of Anatomy (2012, Thieme) - libgen.lc
3. Sagar Dugani, Jeffrey E. Alfonsi, Anne M. R. Agur, Arthur F. Dalley - Clinical Anatomy Cases: An Integrated Approach with Physical Examination and Medical Imaging (2016, Wolters Kluwer)

Lecture 43

Properties and Types of Sensory Receptors The General Senses;

Plan of the Lecture

1. General Properties of Receptors
2. Classification of Receptors
3. Unencapsulated Nerve Endings.
4. Encapsulated Nerve Endings
5. Somatosensory Projection Pathways
6. Pain

LEARNING OUTCOMES

7. Define receptor and sense organ; list the four kinds of information obtained from sensory receptors, and describe how the nervous system encodes each type; outline three ways of classifying receptors.
8. List several types of somatosensory receptors;
9. Describe the projection pathways for the general senses; explain the mechanisms of pain and the spinal blocking of pain signals;
10. Explain how taste and smell receptors are stimulated; identify in the picture;
11. Describe the receptors and projection pathways for these two senses.

A sensory receptor is any structure specialized to detect a stimulus. Some receptors are simple, bare nerve endings, such as the receptors for heat and pain, while others are true sense organs. A sense organ is a structure composed of nervous tissue along with muscular, epithelial, or connective tissues that enhance the organ's response to a certain type of stimulus. Sense organs can be as complex as the eye and ear or as microscopic and simple as a dendrite wrapped in a little connective tissue.

Sensory signals to the brain sometimes produce a sensation—the subjective awareness of a stimulus. However, most sensory signals delivered to the CNS produce no conscious sensation at all. Some are filtered out in the brainstem before reaching the cerebral cortex, a valuable function that keeps us from being distracted by innumerable unimportant stimuli detected by the sense organs. Other nerve signals concern functions that do not require our conscious attention, such as monitoring blood pressure and pH.

Sensory receptors provide the CNS with four kinds of information about a

stimulus— type, location, intensity, and duration There are multiple ways of classifying the senses and receptors. The general senses are distributed over much or all of the body—in the skin, muscles, tendons, joints, and viscera. They include the senses of touch, pressure, pain, heat and cold, stretch, and others. The special senses are limited to the head and employ receptors that are innervated by the cranial nerves. They include taste, smell, hearing, equilibrium, and vision.

Check yourself! The questions for self-control

1. The definition of receptor and the range of complexity in sensory receptors
2. The definition of sensory transduction and the relationship of neural action potentials to that concept
3. The production and role of the receptor potential in sensory transduction
4. Four kinds of stimulus information transmitted by sensory receptors
5. Five categories of receptors classified by stimulus modality
6. Three categories of receptors classified by origin of their stimuli
7. Differences between general (somatosensory) and special senses

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Anne M Gilroy, Brian R MacPherson, Lawrence M Ross, Michael Schuenke, Erik Schulte, Udo Schumacher - Atlas of Anatomy (2012, Thieme) - libgen.lc
3. Sagar Dugani, Jeffrey E. Alfonsi, Anne M. R. Agur, Arthur F. Dalley - Clinical Anatomy Cases: An Integrated Approach with Physical Examination and Medical Imaging (2016, Wolters Kluwer)

Lecture 44

The Chemical Senses. Taste and Smell

Plan of the Lecture

1. Gustation—The Sense of Taste
2. Olfaction—The Sense of Smell

LEARNING OUTCOMES

1. Describe the receptor cells for taste and smell and identify their anatomical locations;
2. Identify the five primary taste sensations and the chemicals that produce them;
3. Discuss factors other than taste that contribute to the flavor of food;
4. Identify the brain regions that process gustatory and olfactory information.

Gustation begins with the chemical stimulation of sensory cells clustered in about 4,000 taste buds. Most of these are on the tongue, but some occur inside the cheeks and on the palate, pharynx, and epiglottis, especially in infants and children. The visible bumps on the tongue are not taste buds but various types of lingual papillae, including vallate, foliate, fungiform, and filiform types. Most of our taste buds are in 7 to 12 circular vallate papillae that form a V at the rear of the tongue.

The spiky filiform papillae (responsible for the roughness of a cat's tongue) have no taste buds in humans but are employed in perception of food texture, or what food technologists call mouthfeel.

Olfaction, the sense of smell, is a response to airborne chemicals (odorants). These are detected by a patch of sensory epithelium called the olfactory mucosa in the roof of the nasal cavity. The mucosa measures about 5 cm and consists of 10 to 20 million olfactory cells, nonsensory supporting cells and basal cells, and mucus-secreting olfactory glands. Olfactory cells are true neurons, unlike taste cells. They have a swollen tip bearing 10 to 20 cilia called olfactory hairs, a bulbous body containing the nucleus, and a basal end that tapers to a thin axon leading to the brain. Being the only neurons directly exposed to the external environment, they live only about 60 days and are continually replaced by dividing basal cells.

Check yourself! The questions for self-control

1. Structure and locations of the taste buds
2. Types, locations, and functions of lingual papillae
3. Five primary taste sensations, and sensations other than taste that play a part in flavor
4. Mechanisms by which sugars, salts, alkaloids, acids, and glutamate excite taste cells
5. Which nerves carry taste signals, what routes they take to the brain, and what brain centers receive gustatory input
6. Structure and location of the olfactory mucosa and its receptor cells
7. How odor molecules excite olfactory cells
8. Which cranial nerve carries olfactory signals to the brain, and the route and point of termination of its nerve fibers
9. Sensory routes from the olfactory bulbs to the temporal lobes, insula, orbitofrontal cortex, hippocampus, amygdala, and hypothalamus
10. How the cerebral cortex influences olfactory bulb function and one's perception of smell

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Anne M Gilroy, Brian R MacPherson, Lawrence M Ross, Michael Schuenke, Erik Schulte, Udo Schumacher - Atlas of Anatomy (2012, Thieme) - libgen.lc
3. Sagar Dugani, Jeffrey E. Alfonsi, Anne M. R. Agur, Arthur F. Dalley - Clinical Anatomy Cases: An Integrated Approach with Physical Examination and Medical Imaging (2016, Wolters Kluwer)

Lecture 45

Eye and Vision.

Plan of the Lecture

1. Light and Vision
2. Accessory Structures of the Orbit
3. Anatomy of the Eye
4. Formation of an Image
5. Light and Dark Adaptation
6. The Dual Visual System
7. Color Vision
8. Stereoscopic Vision
9. The Visual Projection Pathway

LEARNING OUTCOMES

1. Describe and identify the anatomy of the eye and its accessory structures in the picture and in the model;
2. Discuss the structure of the retina and its receptor cells;
3. Explain how the optical system of the eye creates an image on the retina;
4. Discuss how the retina converts this image to nerve signals;
5. Explain why different types of receptor cells and neural circuits are required for day and night vision;
6. Describe the mechanism of color vision; and trace the visual projection pathways in the brain.

The eyes are classified as photoreceptors, organs specialized to detect light. Vision, a step beyond mere photoreception, is the ability to form a recognizable image of an object that emits or reflects light. It begins with focusing light on a membrane called the retina, the site of our sensory cells for vision. Here, the light creates a chemical reaction that leads to the generation of a nerve signal. The brain must receive and interpret this nerve signal for the process of vision to be complete.

The eyeball occupies a bony socket called the orbit. This general area of the face is the orbital region. It contains structures that protect and aid the eye The eyeball itself is a sphere about 24 mm (1 in.) in diameter. It is composed of three tissue layers that form the wall of the eye, optical components that admit and focus light, and neural components that absorb light and generate a nerve signal The outer fibrous layer is composed of the opaque white sclera (“white of the eye”) over most of the eye surface, and the transparent cornea over the

anterior central region. Only the cornea admits light into the eye.
2. The middle vascular layer consists of three regions:
· The iris, an adjustable diaphragm that admits light through its central opening, the pupil. The iris contains pigment cells with variable amounts of melanin. If melanin is abundant, the eye color ranges from hazel to brown or black. If melanin is scanty, light reflects from a more posterior layer of the iris and gives it a blue, green, or gray color.
· The ciliary body, a thick ring of muscular tissue that encircles and supports the iris and lens and adjusts lens shape for focusing.
· The choroid, a deeply pigmented layer, rich in blood vessels, that underlies and nourishes the retina.
3. The inner neural layer consists of the retina and the beginning of the optic nerve.
The visual process begins when light rays enter the eye, focus on the retina, and produce a tiny inverted image. The pupil dilates or constricts to determine how much light enters the eye. Dilation is achieved by the pupillary dilator, a system of contractile cells in the iris that radiate from the pupil like the spokes of a wheel.
These cells respond to the sympathetic nervous system and dilate the pupil when light intensity falls, when we look from a nearby to a more distant object, or when the body is in a general state of sympathetic arousal. Constriction is achieved by a circle of smooth muscle in the iris called the pupillary constrictor, innervated by the parasympathetic nervous system. Pupillary constriction occurs when light intensity rises and when we shift our focus to a relatively close object.
The responses to light are called photopupillary reflexes.
Image formation depends on refraction, the bending of light rays. Light travels at different speeds through media such as air, water, and glass. When light rays strike a denser medium at a 90° angle, they merely slow down; but if they strike at an oblique angle, like the curved off-center areas of the cornea, they also bend. In vision, the greatest amount of refraction, and therefore most focusing, occurs at the air–cornea interface. The lens contributes additional refraction and fine-tunes the focusing process begun by the cornea. The aqueous humor and vitreous body have relatively little effect. An important difference between the cornea and lens is that the curvature of the cornea is fixed, and therefore so is the amount of refraction occurring at the air–cornea interface. The curvature of the lens, however, can be adjusted moment by moment.
Sensory transduction, the conversion of light energy into nerve signals, occurs in the retina. To understand the process, we must begin with the retina's cellular layout. Its outermost layer is a dark pigment epithelium that absorbs excess light. Facing this is a layer of receptor cells called rods and cones, which are

packed with visual pigments (rhodopsin in rods and photopsin in cones) to absorb light and begin the process of sensory transduction.

A human retina contains about 130 million rods and 6.5 million cones. These two receptor cells are concerned with distinctly different aspects of vision. All rods contain identical rhodopsin molecules. As a result, they all respond to light in the same way and have no basis for distinguishing colors (different wavelengths of light) from each other; essentially, rods produce visual sensations of shades of gray (monochromatic, or black-and-white, vision). Furthermore, they are active only in dim light, producing night (scotopic) vision and grainy, low-resolution images.

Once nerve signals are generated in the retina, where do they go? The two optic nerves enter the cranial cavity, converge, and form an X called the optic chiasm. Here, half of the nerve fibers from each eye cross over to the opposite side of the brain.

The right cerebral hemisphere thus receives input from the medial (nasal) side of the left eye and the lateral side of the right eye. The left cerebral hemisphere receives the medial fibers from the right eye and lateral fibers from the left. Consequently, the right brain sees things on the left side of the body, the left brain sees things on the right side of the body, and the two overlap in the middle. Recall that the right brain controls most voluntary motor responses on the left side of the body, and vice versa, so each cerebral hemisphere visually monitors the side of the body where it exercises its primary motor control.

Check yourself! The questions for self-control

1. Why can’t we see wavelengths of 350 nm or 750 nm?
2. Why are light rays bent (refracted) more by the cornea than by the lens?
3. List as many structural and functional differences between rods and cones as you can.
4. Explain how the absorption of a photon of light leads to excitation of an optic nerve fiber.
5. Discuss the duplicity theory of vision, summarizing the advantage of having separate types of retinal photoreceptor cells and neural circuits for photopic and scotopic vision.

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Anne M Gilroy, Brian R MacPherson, Lawrence M Ross, Michael

Schuenke, Erik Schulte, Udo Schumacher - Atlas of Anatomy (2012, Thieme) - libgen.lc
3. Sagar Dugani, Jeffrey E. Alfonsi, Anne M. R. Agur, Arthur F. Dalley - Clinical Anatomy Cases: An Integrated Approach with Physical Examination and Medical Imaging (2016, Wolters Kluwer)

Lecture 46

Hearing and Equilibrium

Plan of the Lecture

1. The Nature of Sound
2. Anatomy of the Ear
3. The Physiology of Hearing
4. Equilibrium
5. Light and Dark Adaptation
6. The Dual Visual System
7. Color Vision
8. Stereoscopic Vision
9. The Visual Projection Pathway

LEARNING OUTCOMES

1. Identify the properties of sound waves that account for pitch and loudness;
2. Describe the gross and microscopic anatomy of the ear;
3. Identify and find the structure of the ears in the model;
4. Explain how the ear converts vibrations to nerve signals and discriminates between sounds of different intensity and pitch;
5. Explain how the vestibular apparatus enables the brain to interpret the body's position and movements;
6. Describe the pathways taken by auditory and vestibular signals to the brain.

The ear serves two very different human senses—equilibrium and hearing. The first of these was the original evolutionary function of the ear. Its role in hearing emerged only as vertebrates colonized land and benefited from sensitivity to airborne vibrations.

This was when animals evolved the outer and middle ears, including an eardrum (tympanic membrane), and a new inner-ear structure, the cochlea, specialized for hearing. As you will soon see, however, the cochlea and organs of balance work by surprisingly similar means—the movement of inner-ear fluids and gelatinous membranes relative to a type of sensory cells called hair cells. The ears are mechanoreceptors—organs that generate nerve signals in response to physical distortion of the plasma membranes of receptor cells. Touch, pressure, and some of our other senses also fall in this category.

The ear consists of three sections called the outer, middle, and inner ear.

The outer ear collects sound waves; the middle ear relays them to the inner ear and has devices for protecting the ear from loud sounds; and the inner ear contains devices for converting vibrations and body movements into nerve signals.

Equilibrium is the sense of body position, movement, and balance. There are two forms of equilibrium for which we have different (but functionally overlapping) inner-ear structures: (1) Static equilibrium, the sense of orientation of the head in space (whether it is erect or tilted in any direction), is served by the saccule and utricle. (2) Dynamic equilibrium, the sense of movement and acceleration, is also served by the saccule and utricle as well as by the semicircular ducts.

The saccule11 and utricle12 are pouches immediately medial to the middle ear. Each is filled with endolymph and contains a patch of epithelium called a macula, composed of sensory hair cells and nonsensory supporting cells. A hair cell is a columnar to pear-shaped cell with hairlike microvilli called stereocilia on its apical surface. Overlying the macula is a layer of gel called the otolithic membrane, containing granules of protein and calcium carbonate called otoliths. The otoliths give the membrane added weight and inertia, which enhances its ability to stimulate the hair cells when the body moves.

Hearing is the awareness of sound, waves of molecular motion created by vibrating objects. The outer and middle ear are concerned with collecting airborne sound waves and transferring vibration to the inner ear. In the inner ear, only the cochlea is concerned with hearing. Named for its coiled snail-like shape, this structure converts vibrations to nerve signals.

The cochlea is a fleshy tube that coils around a screwlike bony core. A vertical section through the cochlea cuts the coil at each turn, as shown in figure 10.11. The tube is divided into a triangular space called the cochlear duct, filled with endolymph, and two larger spaces called scalae (SCALE-ee) above and below it, filled with perilymph. A thin membrane separates the upper scala from the cochlear duct and a thicker basilar membrane forms the floor of the cochlear duct, separating it from the lower scala. The basilar membrane is a platform for the sensory cells of the cochlea.

Nerve fibers from the basilar membrane feed into the cochlear nerve, which then becomes part of the already-discussed vestibulocochlear nerve leading to the pons. The pons sends signals back to the cochlea for tuning by the outer hair cells, and back to the middle ear for the reflexes of the stapedius and tensor tympani muscles. It also compares input from the right and left ears to give us a sense of binaural18 hearing, the ability to localize sounds in space. The signals for hearing ascend to the inferior colliculi of the midbrain, which further aid in binaural hearing and in processing fluctuations in pitch. Finally, signals ascend farther to be relayed through the thalamus to the primary auditory cortex in the

temporal lobe of the cerebrum, which is where we become consciously aware of the sound.

Check yourself! The questions for self-control

1. What physical properties of sound waves correspond to the sensations of loudness and pitch?
2. What are the benefits of having auditory ossicles and muscles in the middle ear?
3. Explain how vibration of the tympanic membrane ultimately produces fluctuations of membrane voltage in a cochlear hair cell.
4. How does the brain recognize the difference between the musical notes high C and middle C? Between a loud sound and a soft one?
5. How does the function of the semicircular ducts differ from the function of the saccule and utricle?
6. How is sensory transduction in the semicircular ducts similar to that in the saccule and utricle?

Recommended readings:

1. Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2. Anne M Gilroy, Brian R MacPherson, Lawrence M Ross, Michael Schuenke, Erik Schulte, Udo Schumacher - Atlas of Anatomy (2012, Thieme) - libgen.lc
3. Sagar Dugani, Jeffrey E. Alfonsi, Anne M. R. Agur, Arthur F. Dalley - Clinical Anatomy Cases: An Integrated Approach with Physical Examination and Medical Imaging (2016, Wolters Kluwer)

Lecture 6
The laws of geometric optics

Plan of the Lecture

1. The modern ideas about the nature of light. The wavelength range of visible light.
2. Optical system of a microscope, building an image of an object.
3. The formula for enlarging an optical microscope.
4. The maximum (marginal) and useful increase.
5. The eye, as an organ of vision.
6. Methods of obtaining polarized light.

Learning outcomes:

- learn the physical basics that allow to obtain the images in optical and electronic microscope, their possibilities;
- understand the biophysics of the eyesight, consider an eye as centric optical system.
- obtain the images in optical microscope and its characteristics.

Geometrical optics is based on three basic laws:

- **The law of rectilinear propagation (transmission**). In a region of constant refractive index *n*, light travels in a straight line.
- **The law of reflection.** When a ray of light is reflected at an interface dividing two optical media, the reflected ray remains within the plane of incidence, and the angle of reflection θ_r equals the angle of incidence θ_i. The plane of incidence is the plane containing the incident ray and the surface normal at the point of incidence.
- Mathematically, the law of reflection is very simple: $\theta_r = \theta_i$
- ***The laws of refraction****: The incident and the refracted ray are in the same plane perpendicular to the interface, conducted at the point of falling, the ratio of the sine of the angle of incidence (sin i) to the sine of the angle of refraction (sin r is equal to the velocity of light propagation in the first medium (V_1) , to a second speed (V_2)* :

$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2} = n_{21}$$

Microscopy is the technique used to view objects that cannot be seen by the naked eye. The range can be anything between mm and nm. There are 3 main microscopic techniques that are used; Optical microscopy, Scanning probe microscopy and Electron microscopy.

Optical microscopy

Otherwise known as light microscopy, it involves the use-age of visible light and one or more lens to produce an enlarged image of an object that is placed in the focal plane of the lens. This can either branch off into transmission, where the beam of light passes through the sample or reflection where the beam reflects off the sample surface, i.e reflected light microscope. There are many applications to Optical microscopy such as in nanophysics and biotechnology but in medicine it is mostly known as being used in diagnosis when we are dealing with tissues or tests on free cells known as a smear test.

There are a wide variety of subdivisions of optical microscopy. These include bright field, dark field, oblique illumination, fluorescence, phase contrast, confocal, deconvolution, differential interference contrast and dispersion staining microscopy, to name a few.

Optical microscopy has several drawbacks; firstly, the technique works at its best only with darker objects, or ones that refract effectively. Secondly, image clarity is often reduced from interfering light outside of the focal plane. And thirdly, the resolution is severely limited by diffraction.

A general biological microscope mainly consists of an objective lens, ocular lens, lens tube, stage, and reflector. An object placed on the stage is magnified through the objective lens. When the target is focused, a magnified image can be observed through the ocular lens.

The degree of penetration into the microworld, the study of the microworld depends on the ability to consider the size of microobjects. Modern optical microscopes make it possible to obtain large magnifications with high resolution. However, optical microscopy has reached the limit of its capabilities due to phenomena caused by the wave nature of light (diffraction, interference). A fundamental limitation lies in the impossibility of obtaining by means of electromagnetic radiation an image of an object smaller in size than the wavelength of this radiation. The optical system of a microscope consists of a system of short-focus lenses: an objective and an eyepiece, and gives an enlarged, imaginary, and inverse image observed by the eye under normal accommodation conditions. The main characteristic of the microscope is the magnification defined by the formula:

$$\gamma = \frac{LS}{f_{eyepiece} f_{objective}}.$$

The magnification of the microscope is numerically equal to the product of the linear increase in the lens and the angular increase in the eyepiece $\gamma_{м} = \gamma_{об} \cdot \gamma_{eyepiece}$

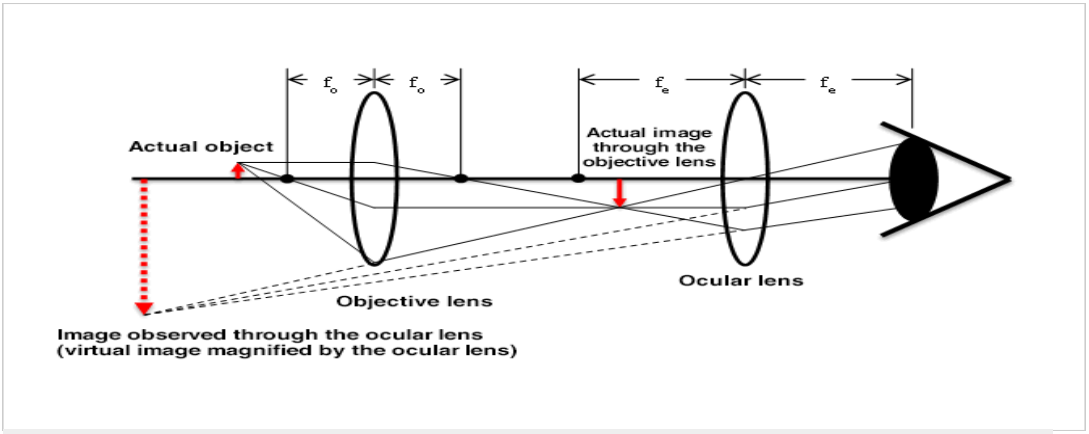

Figure: Principle that enables magnified observation with a biological microscope

Limits of optical magnification

Optical enlargement reaches its barriers at a factor of 1000-1200. The wavelength of light is the limiting criteria. The reason is, that in this range, a light beam is simply bigger than the observed object. From this point on, a microscope can´t generate useful pictures.

However, in practice, microscopes with magnifications in excess of 1500-2000 are not used, since the possibility of distinguishing small details of an object in a microscope is limited. This limitation is caused by the influence of light diffraction occurring in the structure of the object under consideration. In this regard, the concept of resolution and resolution of the microscope is introduced. The normal eye at a distance of best vision distinguishes a fine structure consisting of lines and dots, provided that they are at a distance of at least 0.07 mm. The quality of the microscope is determined not only by magnification, but also by resolution. The resolution limit is the smallest distance between two points of an object when these points are distinguishable, i.e. are perceived under a microscope not merging with each other. Resolution is the ability of a microscope to give a separate image of the small details of an object. An optical microscope makes it possible to distinguish between structures up to 0.25 microns. Resolution is the reciprocal of the resolution limit. From the theoretical course it is known that the limit of resolution of a microscope is determined by the formula

$$Z = \frac{\lambda}{2n \sin U}$$

When illuminating an object with white light, the wavelength is considered equal to 0.555 microns, since the eye is most sensitive to it. Thus, a useful microscope enlargement is usually in the range 500 A <G <1000 A. A further improvement of the microscope is the use of an immersion lens. This is the name of a lens in which the space between the observed object and the lens is filled with a transparent liquid, with a refractive index close to glass n (1.45-1.65). With an immersion lens, the brightness of the image is significantly increased first (due to the fact that when immersed, the light from the object to the lens passes through an optically homogeneous medium and does not cause reflection loss), the value A = nsinU for an immersion lens is called *a numerical aperture* for a dry lens (A = sinU), is indicated on its frame along with the increase. The maximum aperture angle can be of the order of 70, then for a dry lens the numerical aperture is $A = \sin 70^0 = 0.94$, for immersion aperture at n = 1.5 A = 1.5 • 0.94 = 1.4

When illuminating an object with white light, we can assume that $\lambda = 0.555$ microns (the wavelength to which the eye is most sensitive), then the resolution limit for a dry microscope Z = 0.5, for immersion lens Z = 0.2 microns. In order for these objects to be distinguishable by the eye as well, the magnification of the microscope must be no less than the value determined by the ratio of the resolution limits of the eye and the microscope.

Eye as an optical system. The eye is an adaptive optical system comprising of a cornea and a lens. Unlike most optical systems, the crystalline lens of the eye changes its shape to focus light from objects OVER A great RANGE OF distances on the retina. After entering into the eye through the cornea, light is refracted by the cornea and lens. Accommodation is the process by which the shape of the lens can be altered to change its power when the eye needs to focus at different distances. The iris is controlling the amount of light rays enter into its opening which is called pupil by it's aperture stop mechanism. This aperture stop is a very important component of an optical system, affecting a wide range of optical processes. Subsequently the light beam projected to the inner layer of the eye, the Retina , which is an extension of the central nervous system The image on the retina is inverted - like a camera and is connected to the brain by the optic nerve.

Myopia. This defect is also called nearsightedness, and it refers to impaired vision where a person sees clearly near objects, but distant objects are blurred. The defect is caused by the elongation of the eyeball or excessive curvature of the cornea. The defect can be corrected by a divergent lens which refocuses the image on the retina.

Hypermetropia. The defect is also known as farsightedness, it is the opposite of shortsightedness and it is a defect in vision where a person sees near objects with blurred vision, but distant objects are clearly visible. The defect occurs when the eyeball is too short or when the focal length is too great. The problem is corrected by using a converging lens of the required focal length.

Astigmatism. This eye defect occurs when the rays of light do not converge to a single focal point on the retina, either in front or behind. The problem is caused by an irregular curvature of the cornea. The condition is corrected by using a special spherical cylindrical lens.

Special types of microscopy

- ***A stereoscopic binocular microscope*** is designed to obtain a three-dimensional image of an object. It consists of two separate microscopic systems, provides a small increase (up to 100); used in the assembly of electronic miniature components, surgical operations.
- ***A luminescent microscope*** illuminates the sample with ultraviolet or blue light. Absorbing this radiation, the sample emits visible luminescence light. LM are used in medicine for diagnosis.
- ***A dark field microscope*** is used to obtain images of transparent living objects (especially living cells). Using special devices, part of the light passing through the microscope is phase-shifted by half the wavelength, thereby achieving image contrast.
- ***An interference microscope*** - uses the phenomenon of interference. Each beam entering the microscope bifurcates. One of the rays obtained is directed through the observed particle, and the second past it (along the additional optical branch of the microscope). In the ocular part of the microscope, both beams are again connected and interfere with each other. This produces colored images that provide very valuable information in the study of living objects.

The questions for self - control:

1. The phenomena of light refraction. Refractive index.
3. What is called an optically homogeneous medium.
4. What conditions are necessary to reflect the light from the transparent medium.
5. The resolution of the microscope, the limit of resolution.
6. Electron microscope, elements of electronic optics.
7. Diopter system of the eye.
8. The device of the gastroscopy, endoscope
9. Device and use of the refractometer.
10. The phenomenon of total reflection.
11. Physical principles of fiber optics.

Recommended readings:

1.Suzanne A.K. Introduction to physics in modern medicine. USA: Taylor@Francis Group,2009. 422 pages.
2. An Introduction by Roland Glaser. Biophysics. Second edition. Springer.2012
3. Patrick F.Dillon. Biophysics. Cambridge University Press. 2012
4. Daniel Goldfarb. Biophysics DeMystified. 2011 by the McGraw-Hill Company. USA
5. Philip Nelson. Biological Physics. 2004.
6. The German OF, Hoffman Y.F. Handbook of nuclear physics .- Kiev, 1975.

Lecture 3 (H1)
Lymphoid System

LECTURE OUTLINE

- General features of the Lymphoid System.
- Cells of the Lymphoid System. Lymphoid nodules.
- Thymus.
- Lymph nodes.
- Spleen

LEARNING OUTCOMES

1. define the distinguishing features of the lymphoid organs.
2. define the names, locations, functions of the cells, tissues, organs of the lymphoid system.
3. recognize the cells, tissues, organs of the thymus in micrographs.
4. recognize the cells, tissues, organs of the lymph nodes in micrographs.
5. recognize the cells, tissues, organs of the spleen in micrographs.

The organs of immunogenesis have a reticular stroma of the connective tissue, or reticular epithelium, and perform three functions: 1) formation of blood cells, 2) blood or lymph depot, 3) protection (as the result of phagocytosis and the formation of immune cells). There are central and peripheral organs. Central organs are red bone marrow and thymus; they contain stem cells and continuously form blood cells. The peripheral organs are spleen, lymph nodes and lymphoid formations of the mucous membranes. They do not contain stem cells but they form mature lymphocytes and plasmocytes when an antigen appears in the body. Thymus (thymus gland, T) is responsible for the cellular immunity. It performs 2 functions: 1) hematopoietic – it forms T-helpers and T-suppressors; 2)endocrine – thymic stromal cells secrete thymic hormones. When the thymus is removed, the immune system is suppressed, an infection spreads rapidly, but a transplanted tissue does not die off. The thymus develops from the ectoderm of the pharyngeal section of the gut at the 4–5th week. At the 7th week it is populated by lymphocytes. The thymus is covered with the connective tissue capsule and consists of lobes separated by the septa of interlobular connective tissue. Each lobe has a dark cortex and a light medulla. The stroma is composed of the squamous reticular epithelium. Its basal layer lies under the lobular capsule and the surface layers, in the center of the lobe. The epithelial cells with large processes are called oxyphils. The stromal epithelium secretes hormones: thymosins into the blood and thymopoietin into the thymic tissue. They activate the reproduction of lymphocytes and functions of mature lymphocytes. T-lymphocytes are called thymocytes. They lie between the stromal epithelial cells. Lymph nodes develop from mesenchyme during the 3rd month; they begin myelopoiesis. From the 4th month B-lymphocytes move into the nodes, form dark cortex and bright medulla. Then T-lymphocytes move into the nodes, myelopoiesis decreases, lymphopoiesis increases. A lymph node is bean-shaped, d=0,5–1 cm, located along the lymph vessels, covered with the connective tissue capsule, the trabeculae depart from it. There is a network of reticulum between lymph nodes. Lymphoid cells and macrophages are placed in the network hinges. Spleen performs

five functions: 1) hematopoietic, 2) immune protection, 3)blood depot, 4) hemolytic, 5) absorbing iron from erythrocytes. At the 5th week of development the mesenchyme of the dorsal mesentery forms the spleen germ from the reticular tissue. Then at the 12th week macrophages and B-lymphocytes appear in the germ; they group and form follicles of the white pulp. By the 6th month the red pulp is formed between them. By the 5th month all blood cells have been formed in the spleen. After birth only lymphopoiesis takes place. The spleen is covered with the mesothelium and has a connective tissue capsule and trabeculae with smooth muscle cells. It is a support-contractile apparatus through which the deposited blood is expelled into the general circulation. Between the trabeculae the stroma from the reticular tissue is placed. The stroma with lymphoid cells and erythrocytes forms the white and red pulp.

Questions for self-control:

1. What are the functions of the reticular stroma of haemopoietic organs?
2. What are the central and peripheral organs of haemopoiesis and immunogenesis?
3. What cells are formed in the red bone marrow?
4. What cells are formed in the thymus?
5. Name the T- and B-dependent zones in the peripheral haemopoietic organs.
6. What spleen functions do you know?
7. What zones has the spleen follicle?

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1.Leslie P. Gartner: Color Atlas and Text of Histology. - 7th Edition. - Wolters Kluwer, 2017.
2. Victor P. Eroschenko, Atlas of Histology with Functional Correlations 13th Edition, LWW, 2017

Lecture 6 (H2)
Histology of Digestive System

LECTURE OUTLINE

- General features of the Digestive Tract.
- Pharynx.
- Esophagus.
- Stomach.
- Small intestine.
- Large intestine.

LEARNING OUTCOMES

1. describe the structure of the pharynx.
2. compare the digestive tract organs in terms of the 4 layers comprising their walls and relate any structural variations to differences in organ function.
3. define distinguishing regional structure of each digestive tract organ.
4. recognize the organ in a micrograph of any part of the digestive tract.

The digestive tract consists of 3 sections: anterior, middle and posterior. The anterior section consists of the oral cavity with teeth, tongue and salivary glands, gullet and esophagus. The oral cavity takes food and crushes it with teeth. The saliva moistens it and digests simple carbohydrates. The tongue determines the taste. The oral mucosa partially absorbs. The middle section consists of the stomach, small and large intestines, liver and pancreas. Its function is the chemical digestion, the absorption of products of digestion and bowel movement. The posterior section consists of the caudal (final) rectum. It eliminates the undigested residue. Despite different functions, the structure of the digestive tract has common features. The wall of the tract consists of 4 tunics: mucosa, submucosa, muscle and the outer tunica (serosa or adventitia). The mucosa consists of 3 plates: epithelial lining, an underlying lamina propria of loose connective tissue and muscular mucosa of a smooth muscle layer. In different organs of the digestive tract the mucosa has different characteristics and topography. In the anterior region it is smooth, in the stomach it forms gastric pits, and in the intestine it forms intestinal villi and crypts, fixed submucosa. Mucosa and submucosa form folds. The villi, crypts and folds increase the overall absorption surface of the intestine up to 40-50 m, and the epithelial microvilli increase it even by a factor of 30–40. Pharynx. It consists of 3 parts: nasopharynx carrying only air, oropharynx The wall of the esophagus consists of 4 tunics: the mucosa, the submucosa, the muscular and the outer tunics – adventitia at the upper and middle parts of the esophagus, serosa in the low part. The mucous membrane consists of the *stratified squamous non-keratinized epithelium and lamina propria* with papillae. At the point of natural narrowing of the esophagus the lamina propria has cardiac glands. The stomach glands are simple tubular glands. The tubular glandular unit has a body and a fundus. A short terminal duct, which called «the neck», opens into the gastric pits. The glands secrete acidic gastric juice, pepsin, its enzymes work in acidic medium. There are three types of glands: 1) fundic (in the body and fundus of the stomach), 2) cardiac (in the region where the esophagus enters the stomach), 3)pyloric (at the junction of the stomach and the intestine). The small intestine consists of 3 parts: the duodenum (30 cm), the jejunum and the ileum. In the duodenum the digestive processes are completed, in all three parts of the small intestine the nutrients (products of digestion) are absorbed by the epithelial cells. These functions determine two organ specificities of the small intestine structure: 1 – the presence of duodenal digestive glands in the duodenal

submucosa, 2 – special structures of the mucosa maximizing the absorbing surface. There are 3 types of the special structures: 1) the border epithelium structure which contains the border cells having the *brush border composed of 1,5–3 thousand microvilli* on the apical surface; 2) the *intestinal villi and crypts* which are permanent structures formed by all three layers of the mucosa and fixed by the submucosa; 3) *circular folds* which are formed of mucosa and submucosa; they do not straighten out when the intestine is filled. The large intestine (or colon) has the following regions: the short cecum, with the ileocecal valve and appendix, the colon (ascending, transverse, descending and sigmoid), and the rectum.

Questions for self-control:

1. What sections of digestive tract do you know?
2. What types of digestion do you know?
3. What tunics does the wall of the digestive tract consist of?
4. What embryonic germs of the oral cavity organs do you know?
5. What is the structure of the taste organ?
6. What tunics does the wall of the esophagus consist of?
7. What are the functions of the stomach?
8. What cells compose the fundic glands of the stomach?
9. What endocrine cells of the stomach do you know?
10. Name the mucosa structures maximizing the absorption surface.
11. Describe the histophysiology of absorption.
12. What are the structural features of the large intestine?

REFERENCES

1.Leslie P. Gartner: Color Atlas and Text of Histology. - 7th Edition. - Wolters Kluwer, 2017.
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Lecture 9 (H3)
Histology of Digestive System 2
Gland associated with the Digestive Tract.

LECTURE OUTLINE

1. General features of the Gland associated with the Digestive Tract.
   - Components of the system
   - Exocrine and endocrine functions
   - Glandular subunits
2. Salivary glands
3. Liver
4. Pancreas

LEARNING OUTCOMES

1. define the accessory glands of the digestive tract by their ducts and describe their roles in digestion
2. compare mucous and serous secretory cells in terms of their structure, secretions.
3. relate pancreatic acinar cell ultrastructure to its function.
4. relate the hepatocyte's complex ultrastructure to its function.
5. recognize the digestive glands in a micrograph.

The salivary glands open between the tongue papillae into grooves. The mixed protein-mucous glands are at the tip of the tongue, the protein glands are in the tongue body, the mucous glands are near the tongue root. The salivary glands are complex branched alveolar and alveolar-tubular glands; they open into the oral cavity. There are three pairs of them: the parotid, submandibular, sublingual glands. Liver is a mixed gland: its exocrine function is secretion of bile into the digestive tract; the humoral function is secretion of glucose, proteins and vitamins into blood. The liver recovers well (20% within 10 days). Hepatic lobule is a structural and functional part of the liver. It has the form of a 6-sided truncated cone, the diameter is 1,5 mm, and the height is 2 mm. In the interlobular septae the interlobular artery, the vein and the bile duct pass. They form the hepatic triads, a lymphatic vessel often passes with them. In humans the interlobular septae are thin, but in cirrhosis they grow abnormally, occlude the vessels, the nutrition of hepatocytes gets disturbed, necrosis develops. In the lobules hepatocytes form anastomosing radial plates. Each plate consists of two hepatocyte cords lying tightly and connected with desmosomes and in the form of the lock. From outside the plates are entwisted by the reticular fibers. Three types of cells lie on them: reticulo-endothelial, Kupffer cells and pit-cells («natural killers», or large granular lymphocytes). They line the sinusoidal capillaries which have no basement membrane. They also extend between the plates and merge into the central vein. Between sinusoids and hepatocytes Disse spaces are located. They are filled with the basic substance. The microvilli of hepatocytes and Kupffer cell processes penetrate in these spaces, where there are small lipocytes. These cells deposit fat-soluble vitamins and synthesize the reticular fibers. Inside the plate the cellular cytolemma of adjacent hepatocyte cords invaginate into the cytoplasm and form the wall of bile capillaries. Their lumen is separated from the intercellular gaps by the tight junction. The pancreas is covered with a dense connective tissue capsule and serosa. From the capsule septa extend to cover larger vessels and ducts

and to divide the parenchyma into lobules. It develops from the primary colon endoderm. The exocrine part is 97 % of the pancreas, it is a complicated diverged alveolar-tubular gland formed with a single layer of epithelium, and it produces pancreatic juice digesting everything. Glandular units are called acini. Acinus is composed of one layer of acinar cells – serocytes; they are polarized and coneshaped. The basophilic basal pole of these cells, called the homogeneous zone, contains a nucleus, GrEPR and basal striation. The apical acidophilic zymogen zone contains zymogen granules. Zymogen is a precursor of enzymes activated in the lumen of the duodenum. First the secretion enters the intracellular secretory capillaries formed by the cytolemma invagination of adjacent serocytes. Then the secretion passes into the acinus lumen, and then – into the short intercalated duct lined with simple squamous epithelium. From there the secretion passes into the interacinous intralobular ducts, then into the interlobular ducts, and then into the main pancreatic duct. Large ducts have mucosa with prismatic epithelium and crypts that produce mucus. The main pancreatic duct has the sphincter and the mucosa forms valves for the contents of the intestine not to flow into the pancreas.

Questions for self-control:

1. What salivary glands do you know?
2. Describe salivary glands classification.
3. What liver functions do you know?
4. Name the structural and functional part of the liver.
5. Describe the liver circulation.
6. What parts of the pancreas do you know?
7. What is the endocrine part of the pancreas?
8. What is the exocrine part of the pancreas?

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1.Leslie P. Gartner: Color Atlas and Text of Histology. - 7th Edition. - Wolters Kluwer, 2017.
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Lecture 12 (H4)
ENDOCRINE SYSTEM. HYPOTHALAMUS. PITUITARY GLAND.
THYROID AND PARATHYROID GLANDS. ADRENAL GLAND.

LECTURE OUTLINE

1. The general morphofunctional characteristic of the endocrine system.
2. Endocrine glands classification.
3. Major divisions of the pituitary, location of the pituitary, its embryonic origins.
4. Cell types found in each division of the pituitary and indications of characteristic staining properties.
5. Hormones produced by the pituitary, indicating for each one the division and cell type responsible for its production as well as its target site.
6. Hypothalamus nuclei. Peculiarities of the neurosecretory cells.
7. Description of role of the hypothalamus in controlling pituitary function.
8. Location, shape, and embryonic origin of the thyroid gland.
9. Role of the pituitary gland and hypothalamus in the regulation of thyroid follicular activity.
10. Comparison of parenchymal cell types of the parathyroids (chief cells and oxyphil cells) in light and electron microscopes.
11. Distinguish between the cortex and medulla of the adrenals in terms of their histologic structure, function, location, and embryonic origin.

LEARNING OUTCOMES

1. Interpret the general morphofunctional characteristic of the endocrine system.
2. Describe the location of the pituitary, its embryonic origins.
3. Identify the major divisions of the pituitary and their descriptions.
4. Recognise cell types found in each division of the pituitary and indications of characteristic staining properties.
5. Explane hormones produced by the pituitary, indicating for each one the division and cell type responsible for its production as well as its target site.
6. Identify pinealocytes and neuroglial cells.
7. Recognise structure, function, location, and embryonic origin of the C or parafollicular cells.
8. Describe the thyroid follicles, follicular cells, basement membrane, colloid, capillaries of the thyroid gland.
9. Compare the parenchymal cell types of the parathyroids (chief cells and oxyphil cells) in light microscope.
10. Layers of the adrenal cortex in terms of each layer's histologic structure, the hormones secreted, and the layer's location.

All the processes of human and animal activity are regulated by the nervous and endocrine systems. In performing their functions they are so closely connected that, as a matter of fact, present the united whole neuroendocrine regulating system. Endocrine glands are the sites of synthesis and secretion of substances known as hormones, which are disseminated throughout the body by the bloodstream where they act on specific target organs. Commonly with the nervous system, hormones coordinate and integrate the functions of all the physiological systems. The endocrine system regulates body functions under the control of the nervous system. It secretes hormones. Each of them changes the function of specific cells or metabolism. The hormones, peptides and steroids, are produced in small portions and rapidly destroyed in tissues. Peptides do not penetrate into the cell and act via membrane

receptors. Steroids are liposoluble, they enter into the cell and act through nuclear receptors. Hormones are produced by endocrine cells or glands. Endocrine glands are ductless, so the secretion is released directly into the blood or lymph. The endocrine system is divided into the central and peripheral parts. The **central part** includes hypothalamus, pituitary and pineal gland. They are connected with the nervous system, receive from it the information about the body needs and regulate the operation of the **peripheral endocrine system**. It operates on the internal organs and includes: 1 – glands having only the endocrine function (adrenal glands, thyroid, parathyroid glands); 2 – mixed function organs (placenta, pancreas and sex glands), 3 – diffuse endocrine system of individual cells in various organs. According to the origin, these cells are divided into two groups. 1 – endocrinocytes of the nonnervous origin, they secrete the peptide and steroid hormones and depend on the pituitary; there is a lot of them in the urogenital system. 2 – neuroendocrine APUDcells, they are able to absorb and decarboxylate the precursors of amines, they are developed from neuroblasts and depend only on the nervous system; they secrete biologically active amines (histamine, serotonin, A, NA) and peptide hormones (gastrin, bombesin, somatostatin). They include secretory neurons of the hypothalamus, C-cells of the thyroid gland, adrenal chromaffin cells, enterochromaffin cells of the gastrointestinal tract, the secretory cardiomyocytes, labrocytes, and others. The endocrine glands are constructed from the epithelial trabeculae. According to the structure, they are divided into 3 types: reticular, trabecular and follicular.

Questions for self-control:

1. What organs refer to the central part of the endocrine system?
2. What organs refer to the peripheral parts of the endocrine system?
3. What hypothalamus nucleus do you know? Name its hormones.
4. Name the adenohypophysis hormones.
5. What zones does the adrenal cortex consist of?
6. What steroid hormones do you know?
7. Name the hormones of the thyroid and parathyroid glands.

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Lecture 15 (H5)
Histology of REPRODUCTIVE SYSTEM.

LECTURE OUTLINE

- Spermatogenesis and structural peculiarities of the spermatogenetic cells at different stages of their development.
- Ovogenesis (main stages and their morphofunctional characteristics).
- Comparison of the stages of the ovogenesis and spermatogenesis.

LEARNING OUTCOMES

1. Know the development, microscopic structure and function of the male reproductive glands, stages and biologic essence of spermatogenesis.
2. Interpret the spermatogenesis and structural peculiarities of the spermatogenetic cells at different stages of their development.
3. Explain the ovogenesis (main stages and their morphofunctional characteristics).
4. Comparison of the stages of the ovogenesis and spermatogenesis.

Knowledge of the histophysiology of the reproductive system is a necessity for many medical specialists: endocrinologists, urologists who diagnosing testis diseases, must search for changes in both functions of male sexual glands. Only such an approach will provide making a correct diagnosis and proper treatment of patients. The reproductive system develops with the urinal system in parallel and consists of gonads and accessory organs. The gonads in men are testes, in women ovaries. In the gonads reproductive cells are formed and sexual hormones are produced. Additional organs in men are the accessory glands, excretory genital ducts and supporting sexual organs. Additional organs in women are the uterine tubes, uterus, vagina and vulva. The development undergoes 3 stages: 1 – laying of the indifferent genital germ, 2 – sexual differentiation of the genital germ, 3 – development and maturation of sex (reproductive) cells. Stage 1. Laying of the indifferent genital germ occurs indifferently at 1 month of development, i.e., it happens in the same way both in males and in females. From the mesonephros (Wolff's duct), parallel to it, the paramesonephros (Muller's duct) splits. On the medial surface of the mesonephros the celomic epithelium grows and forms two genital ridges – the germs of gonads. The primary reproductive cells (gonoblasts) migrate into these ridges. They are laid in the blood islets of the yolk sac wall from the mesenchyme. Gonoblasts are large and round cells, with plenty of glycogen and RNA. From the epithelium of genital ridges the genital cords with gonoblasts grow into the mesonephros. Stage 2. Sexual differentiation of the genital germ begins at the 2nd month of development and is determined with the presence or absence of Y-chromosome that encodes the gene of the peptide hormone Inhibin-1. In boys at 6 weeks of development the epithelial cells of the genital ridges and cords begin to produce hormone Inhibin-1, that inhibits the cell proliferation of Muller's duct and mesenchyme at the base of the mesonephros. As a result, Wolff's duct is preserved and differentiates into the appendage of the testis and excretory genital ducts. Muller's duct is reduced, leaving only the upper and lower parts developing into the vestigial organs – Morgan's vial and the prostate (male) utricle. At 3 months of development the prostate gland (prostata) is laid around the male utricle as an outgrowth of the epithelium of the proximal part of the urethra. In girls sexual differentiation of the genital germ begins later: at 7–8 weeks of development. Y-chromosome is absent, so Inhibin-1 is not produced. The mesenchyme at the base of the mesonephros grows intensely and forms the mesovarium, from which the ovarian medulla will develop. The growing mesenchyme eliminates the ends of the genital cords and tubules of the mesonephros and separates the mesonephros from the genital germ. Afterwards the

mesonephros is reduced, and Muller's duct continues to differentiate: the upper part forms the fallopian (uterine) tubes, the ends of which turn into the funnels (infundibulum) with fimbriae. The distal ends of these tubes thicken and grow together forming the uterus and vagina. At incomplete fusion of Muller's ducts the pathology of development appears: a two-horned uterus, a double uterus or a double vagina.

Questions for self-control:

1. What are the stages of development of the reproductive system?
2. Name the spermatogenesis periods.
3. What features of oogenesis do you know?

4. REFERENCES

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Lecture 18 (H6)
Histology of MALE REPRODUCTIVE SYSTEM

LECTURE OUTLINE

- Structure and function of the testis seminiferous tubules, microscopic and ultramicroscopic structure of the Sertoli cells.
- Structure and significance of the haemotesticular barrier.
- Morphofunctional characteristic of Leyding cells.
- Structure of the wall of the tubuli recti, the rete testis and the mediastinum testis.
- Structure of the wall of the ductus efferents and the ductus epididimus.
- Morphology of the ductus deferents, the ductus ejaculatorius and the urine.
- General structure and function of the prostate gland.

LEARNING OUTCOMES

1. Describe the general structure and function of the testis.
2. Recognise structure and function of the testis seminiferous tubules, microscopic and ultramicroscopic structure of the Sertoli cells.
3. Identify structure and significance of the haemotesticular barrier.
4. Explain morphofunctional characteristic of Leyding cells.
5. Know features of the wall structure of different portions of the spermatic excretory ducts and prostate gland, to be able to recognize them.
6. Recognise the structure of the wall of the tubuli recti, the rete testis and the mediastinum testis.
7. Interpret the structure of the wall of the ductus efferents and the ductus epididimus.
8. Identify the morphology of the ductus deferents, the ductus ejaculatorius and the urine.
9. Recognise the general structure and function of the prostate gland.
10. Recognise the structure of the paraurethral gland of the prostate.
11. Identify the seminal vesicles and bulbourethral glands, their fine structure.

In boys the genital ridges differentiate into testes. Inside the genital ridge the mesenchyme grows between the genital cords. Then it grows from inside under its epithelium and forms a layer of a dense connective tissue which differentiates into the testis capsule – the tunica albuginea. On the inner surface of the testis the albuginea expands to form the mediastinum. The genital cords stop growing into the genital ridges, but in the interior of the ridges they continue growing, elongate and form the convoluted seminiferous tubules of the testis, 70–80 cm long. They are separated with the septa, which depart from the mediastinum and divide the testis into 100–250 testicular lobules. Each lobule consists of 1–4 convoluted seminiferous tubules. Near the mediastinum the tubules become straight, then they enter the mediastinum and pass into the tubules of the rete of testicle (rete testis). In the seminiferous tubules the epithelial cells differentiate into the supporting cells (sustentocytes), and the gonoblasts differentiate into gonocytes, and then into spermatogonia. Between the tubules the mesenchyme develops into a loose collagen tissue, forming the interstitium of testis. The interstitial Leydig's cells appear there by 2 months of development. These cells are large, oval or polygonal, with an oxyphilic cytoplasm containing glycogen, glycoproteins and large lipid secretion granules. They are arranged in groups and secrete male sex hormone (testosterone) into the blood which is activated in the prostate gland, causes hypothalamus masculinization

(reconstruction by the male pattern) and affects the development of the secondary sexual characteristics and reproductive cells. From Wolff's duct the epididymal duct (ductus epididimidis) differentiates at the end of the 2nd month. This duct forms the body and the tail of the epididymis; the vas deferens (ductus deferens) with vial and seminal vesicles extends from it. With the time the mesonephros tubules connect with the rete testis, turn into the efferent tubules of the testis (ductuli efferentes testis) and form the head of the epididymis. The vas deferens becomes ductus ejaculatorius in the prostate, which opens into the ductus urethra. On the front edge of the urogenital sinus the penis is laid from the mesenchyme of the genital tubercle. Up to 5 months of development the gonocytes actively multiply and close the lumen of the seminiferous tubules. Then the epithelium of the rete testis begins to produce the hormone Inhibin-2, which suppresses the production of FSH by the pituitary gland and the reproduction of gonocytes. By birth Inhibin-3 begins to be produced. It inhibits only the production of FSH and has no influence upon the gonocytes. In newborns the seminiferous convoluted tubules have no lumen. Its epithelium has only two kinds of cells – sustentocytes and spermatogonia. Spermatic excretory ducts are represented by the system of ducts, though which spermogenic cells move up into the uterine. The epithelium of the mucous tunic of the spermatic excretory ducts produces fluid that dilutes sperm and promotes saving and motulating spermatozoa. The epididymis is a reservoir that accumulates sperm. The prostate gland produces ekzo- and endocrine secrets that stimulate the motion of spermatozoa, give alkalin reaction to sperm.

Questions for self-control:

1.What are the stages of development of the reproductive system?
2. Name the tubules of the testes.
3. What functions do the sustentocytes perform?
4. Name the spermatogenesis periods.
5. What cells produce testosterone?
6. Name the endocrine and exocrine functions of the prostate.

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Lecture 20 (H7)
Histology of FEMALE REPRODUCTIVE SYSTEM.

LECTURE OUTLINE

- Development and general structure of the ovary.
- Structure of the cortex of the ovary.
- Structure of the primordial, primary, secondary and mature folliculi.
- Ovulation, its biological essence and hormonal regulation of this process.
- Stages of the formation of the Corpus luteum, its endocrine function.
- Artesia of the folliculi. Atretic body, its main differences from Corpus albicans and Corpus luteum.
- General structure of the wall of the uterus.
- Description of the stratum basalis and stratum functionalis of the endometrium and their vessels.
- Histophysiology of the myometrium and perimetrium. Structure of the wall of the uterine tube, the relief of the mucous tunic, the peculiarities of the epithelial cellular composition.
- General description of some cyclic changes in the uterus and ovary. Periods of the menstrual cycle.
- Hormonal adjusting of the cyclic changes in the uterus.
- Development and a general structure of the mammary gland.
- Structure features of the parenchyma of the mammary gland in the period of lactation and in the nonlactational state.

LEARNING OUTCOMES

1. Interpret the development and general structure of the ovary. The role of the interstitium.
2. Explain the incretory function of the ovary and correlation with the other endocrine glands.
3. Recognise the cortex of the ovary.
4. Explain the mechanisms of ovulation, its biological essence and hormonal regulation of this process.
5. Identify the stages of the formation of the Corpus luteum, its endocrine function.
6. Recognise the general structure of the wall of the uterus.
7. Describe of the stratum basalis and stratum functionalis of the endometrium and their vessels.
8. Explain the histophysiology of the myometrium.
9. Identify the morphological and functional changes of the endometrium in the menstrual phase.
10. Recognise the fine structure of the secretory portion of the mammary gland before lactation.
11. Identify the structure features of the parenchyma of the mammary gland in the period of lactation and in the nonlactational state.

In addition to the reproduction function of the ovaries, the production of oocytes capable of fertilization, the ovaries play a great part in the endocrine system. The sexual hormones are produced in the ovaries, growth and differentiation of the sexual system depending from it, and normal birth of children becoming possible. However, many experimental and clinical investigations proved, that the ovaries can not be studied separately, taking only their

importance in the sexual system into consideration. Their normal anatomic and morphologic development and physiology state have influence on the development of the somatic sexual signs. It promotes the transformation of the organism into specific woman organism with its peculiar morphological signs and features as for the substance exchange the tissue tonus. The OVARIES are oval in shape, weighing 5–7 g, 3–5 cm long, 1,5–3 cm wide, 0,7–1,5 cm thick. They are covered with tunica albuginea, thinner than in the testis, in order not to impede ovulation. Albuginea is covered with the serous membrane, and the outer surface of the ovary – with 1 layer of cubic fetal genital epithelium rings. Under the tunica lies the cortical substance of the follicles and the medulla of the loose connective tissue is in the ovary center. The uterus is a hollow muscular organ in which a fetus develops. It has a wall of 3 tunics: mucous – endometrium, muscular – myometrium, and the outer –serous (perimetrium). In the uterus body and fundus adventitia (the parametrium) is the dense connective tissue wich forms ligaments in the cervix (neck) of the uterus. The endometrium consists of simple prismatic epithelium and lamina propria. The epithelium forms crypts, simple straight tubular glands which appear by 4 years. At the premenstrual period cilia appear in the epithelium, and in the lamina propria – decidual cells producing sex hormones and prolactin. There are two layers in the endometrium distinguished by functions: functional and basal. The functional layer is thick. It changes during the menstrual cycle, pregnancy, and later is rejected. The basal layer is thin and fused with the myometrium. It contains the bottoms of the uterine glands. It remains almost unchanged after menstruation or childbirth. Due to it regeneration of the entire endometrium is performed. The myometrium is made up of 3 layers of smooth muscle. The inner submucosal layer is oblique longitudinal. The middle vascular layer is oblique circular and contains a lot of large vessels with a spiral course. The external supervascular layer is oblique longitudinal. Smooth muscle cells of the myometrium have organic specificity – they can form processes and increase in length up to 500 microns. Due to hypertrophy of the myometrium the uterus increases the weight from 50 g to 1 kg during pregnancy. After childbirth, the uterus involution develops and the uterus mass restores.

Questions for self-control:

1. What features of oogenesis do you know?
2. What is the follicle atresia?
3. What are the tunics of the oocyte?
4. What is ovulation?
5. What structures does the genital tract consist of?
6. What tunics of the uterine wall do you know?

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Lecture 21 (H8)

HUMAN EMBRYOLOGY

LECTURE OUTLINE

- Sex cells. Structure of a spermatozoon. Structure of the ovum. Classification of the oocytes
- Fertilization. three phases of fertilisation. Acrosomal reaction. Cortical reaction.
- Cleavage. Morula blastula Type of cleavage

LEARNING OUTCOMES

1. Describe how the spermatozoon penetrates into the oocyte
2. Know the process whereby a zygote is formed
3. Describe the development of the embryo from the first cells to the blastocyst
4. Know the important stages of the preimplantation phase
5. Describe the importance of these stages
6. Know the duration of the preimplantation phase

In humans, after ovulation in the upper third of the oviduct one ovum (sometimes two) matures. It is oligolecithal, secondarily izolecithal, d=120–130 m, surrounded with zona pellucida and corona radiata, and lives for 24 hours. Spermatozoa live for 5 days in the acidic environment, one day in the alkaline one. FERTILIZATION takes place in the upper third of the oviduct; it needs 60–100 million spermatozoa. There are 3 phases in fertilization.
First phase – convergence of gametes. It is provided with the properties of gametes and the reproductive tract. Spermatozoa are capable of rheotaxis (movement against the flow of liquid), have positive chemotaxis to the ovum (which produces gamons attracting them) and negative chemotaxis to the acidic environment of the vagina, which drives them into a neutral environment of the cervix. With a lack of progesterone the cervix environment may become alkaline and immobilize sperm. In the female genital tract the capacitation (activation) of sperm finishes by the action of their secretion. The uterus contracts and sucks the sperm. Then, due to the uterus peristalsis, for the next two hours spermatozoa move to the upper third of the oviduct, surround the ovum and begin to rotate it. Second phase – penetration of sperm into the ovum. This process lasts for 10–12 hours and begins with the acrosomal reaction. Enzymes that dissolve the corona radiata and zona pellucida are released from the acrosome. Cytolemmae of gametes merge, and the nucleus and centrioles of sperm enter the ovum cytoplasm, the tail is lost. Monospermy is characteristic of humans, so only one spermatozoon penetrates. Once the cortical reaction occurs in the ovum, the cortical granules release glycoproteins and form fertilization membrane that prevents polyspermy. Third phase – gamete fusion. It consists of 4 stages. 1st stage – two pronuclei, 2nd stage – synkaryon (dual nucleus), 3rd stage – nuclear fusion into a single diploid nucleus. A single-celled embryo called a zygote is formed. 4th stage – ooplasmatic segregation, implying movement of the zygote cytoplasm content and formation of presumptive germs. Different portions of the zygote cytoplasm will be parts of different blastomeres. CLEAVAGE of the human zygote is complete, uneven, and asynchronous. It starts at the end of the 1st day and takes place under the fertilization tunic. In 30 hours after fertilization two blastomeres (dark and light) are formed. Dark blastomeres are large; they are cleaved slowly and form the embryoblast, the material of the embryo and extraembryonic organs. Light blastomeres are finer, and are cleaved quickly. They grow around dark blastomeres and form the trophoblast. Up to the 4th day fragmentation is slow, and 2, 3, 5, 7 blastomeres are formed, by the 4th day the embryo

contains 7–12 blastomeres. The first 8 blastomeres are pluripotent, and each of them can give rise to the whole organism. Till the 5th day the cleavage goes fast, and the embryo consists of 100–107 blastomeres that form a dense cell globule – morula. Dark embryoblast blastomeres lie in the center of the morula (inside), and light trophoblast blastomeres lie in one layer around embryoblasts (outside). The trophoblast sucks fluid from the oviduct secretions and releases it inside the morula, so the embryo becomes a vesicle called a blastocyst. Its wall is formed by the trophoblast. The embryoblast forms the embryonic cell mass which lies in the blastocyst cavity on the inner surface of the trophoblast. During cleavage the embryo moves through the oviduct to the uterus. At the 5–6th day the embryo enters the uterus. Until the 7th day the embryo floats in the secretions of the uterine glands, it is the free blastocyst stage when the trophoblast prepares for implantation.
Capacitation: The process by which the sperm becomes capable of fertilizing an egg. Acrosome Reaction: A regulated exocytotic event in which an apical vesicle in the sperm head fuses with the sperm plasma membrane. The acrosome reaction is triggered in response to egg factors. Acrosin: A serine protease released during the acrosome reaction.
Cortical Reaction: A regulated exocytosis in which apically localized vesicles (cortical granules) in the egg fuse with plasma membrane after fertilization. Zona Pellucida: A coat surrounding the egg that contains three glycoproteins. Galactosyl transferase: An oligosaccaride modifying enzyme that is usually found in the Golgi but in sperm is on the cell surface. Thought to be important as the sperm receptor for the egg. Fertilin: An ADAM family protein on the sperm implicated in sperm-egg membrane fusion. Contains a fusion peptide resembling viral fusion peptides and a disintegrin domain involed in recognition. Pronuclei: The transitional male and female nuclei formed in the egg after fertilization. They fuse to form the diploid zygote nucleus. Polyspermy: The condition in which more than one sperm fertilizes an egg. Polyspermy leads to defective development.

Questions for self-control:

1. What are the 4 stages of embryonic development?
2. Name the stages of embryogenesis.
3. What is fertilization and when does it occur?
4. What is acrosomal reaction and when does it occur?
5. What is cortical reaction and when does it occur?
6. What is cleavage and when does it occur?
7. What is blastocyst?

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Lecture 24 (H9)

HUMAN EMBRYOLOGY

LECTURE OUTLINE

- Implantation
- Stages of implantation
- adhesion
- invasion (penetration).
- The various possibilities for hindering an implantation and thus a pregnancy

LEARNING OUTCOMES

1. Distinguish the stages of embryonic development that occur before implantation
2. Describe the histological structures of the endometrium
3. Explain the phases of endometrial changes during the menstruation cycle
4. Know the effects of the hypophysial hormones in the regulation of the menstruation cycle
5. Describe the process of implantation
6. Explain the various stages of implantation
7. Know the fundamental mechanisms of the implantation
8. List the normal types of implantation and the anomalies of the extra-uterine pregnancies
9. List the various possibilities for hindering an implantation and thus a pregnancy
10. List the normal types of implantation and the anomalies of the extra-uterine pregnancies

Implantation is the introduction of the embryo into the uterine wall. It begins on the 7–8th day and continues for about 40 hours. By this time, the uterine glands stop secreting, the uterus cavity becomes dry, the uterus contracts. The trophoblast develops fast and includes 2 layers. The inner layer called cytotrophoblast consists of dividing cells that replenish the outer layer called syncytiotrophoblast (simplastotrofoblast). It is a supercellular multinucleous structure which forms strong branching and anastomosing villi secreting enzymes. They dissolve the fertilization tunic; the embryo is actively hatched out from under this tunic and penetrates into 1or 2 adjacent uterine glands destroying the epithelium, connective tissue and blood vessels of the endometrium by enzymes. Due to the vascular hemorrhage a blood clot is formed over the embryo; later it is replaced with the connective tissue and the epithelium is restored over it. Trophoblast villi float in the maternal blood, break down nutrients, absorb cleavage products and O2. Furthermore, the syncytiotrophoblast secretes hormones that support the corpus luteum of the mother`s ovary to complete the formation of placenta.

Questions for self-control:

1. What are the stages of implantation?
2. What is the normal types of implantation and when does it occur?
3. What functions does syncytiotrophoblast perform?
4. How is a coordinated maturation of the gamete and of the endometrium guaranteed so that optimal conditions for the development and implantation of the embryo are assured?
5. How, during the implantation period, are the nutritional requirements of the blastocyst assured before the utero-placental circulation begins?
6. Which mechanisms play a role in controlling the reactions of the endometrium to the presence of a blastocyst?
7. Based on your knowledge of the implantation mechanisms of blastocysts, which measures could be employed to interrupt the further development of an embryo after an oocyte has been fertilized?

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Lecture 25 (H10)

HUMAN EMBRYOLOGY

LECTURE OUTLINE

- The differentiation of the embryonic germ layers, emanating from the trilaminar embryo
- The mechanism of gastrulation and especially the morphogenetic role of the primitive streak
- The arrangement of the intraembryonic mesoblast, its segmentation and the formation of the intraembryonic coelomic cavity
- The formation of the notochord and its role in the differentiations of nerve tissue
- The stages of neurulation and the first steps in the genesis of the central and peripheral nervous system

LEARNING OUTCOMES

1. Explain the bilaminar germ disc formation
2. Describe formation of embryonic mesoderm
3. Describe formation of embryonic endoderm
4. Describe formation of the notochord

Gastrulation is performed in 2 stages: the first stage occurs before the implantation, at the 6–7th day of the embryonic development, the second stage – at the 15–17th day. During the first stage of gastrulation the embryoblast splits up into two layers: epiblast and hypoblast. The epiblast is adjacent to the trophoblast and contains the material of ectoderm, a neural tube, mesoderm and a notochord. The hypoblast faces the blastocyst cavity and contains the material of endoderm. From the 7th to 15th days extraembryonic organs are laid. Embryoblast cells migrate into the blastocyst cavity forming the trabecles of extraembryonic mesoderm. They grow to the trophoblast, and by the 11th day they form a chorion. This chorion has villi on the entire surface. Villi initially consist only of the trophoblast and are called primary villi. Later they get extraembryonic mesoderm and are called secondary villi. By the 17th day vessels grow into villi mesoderm and they become tertiary villi. In the blastocyst cavity, between the mesoderm trabecles, cavities (lacunae) with serous fluid are formed. They separate the embryoblast from the trophoblast. The two cavities near the embryonic disc form the mesodermal germs of the amnion (on the side of the epiblast) and the yolk sac (on the side of the hypoblast). By the 13–14th day they accumulate the epiblast and hypoblast forming the amniotic bubble and the yolk sac. Ectoderm of the amniotic bubble fundus and endoderm of the yolk sac roof compose the embryonic shield, the material of the embryo body. By the 14th day the extraembryonic mesoderm chord grows from the embryonic shield towards the trophoblast, forming the amniotic stem, which is the mesoderm germ of allantois. By the 15th day the embryo has an embryonic shield and 4 extraembryonic organs. The second stage of gastrulation starts. In the embryonic shield the epiblast cells move like in the bird`s embryo and form the primary streak with Hensen's node (primary bundle), and they produce the chord and the embryonic mesoderm. The endoderm of the back part of the future primary intestine forms fingerlike protrusions transformed into the epithelium of allantois. It grows into the amniotic stem which will guide the ingrowth of vessels from the yolk sac to the chorionic villi. At the 17th day the embryo`s nutrition and breathing are carried out through these vessels. By the 20th day the chord is formed, the neural plate is laid and the segmentation of embryonic mesoderm and differentiation of somites in germs begin. From the 21st to 25th days the neural tube closes, the ganglion plate is segmented into the germs of the spinal ganglia. From the 20th–21st day the separation of the embryo from the yolk sac begins by means of trunk folds. They are formed on the edges of the embryonic shield from the parietal layer of ectoderm and mesoderm that bend toward endoderm, converge on the ventral side and merge, separating the embryo from the yolk sac. The body of the embryo invaginates into the amniotic cavity. Endoderm merges with the visceral layer of the mesoderm and forms the primary intestine

connected to the yolk sac with the yolk stalk, which is converted into the umbilical cord. At the 4th week the ends of the intestine form mouth and anus; gill arches, jaws and limbs are laid. By the 35th day the embryo has 43–44 somites. At the end of the second month histogenesis and laying of almost all organs is completed. At 2,5 months of development the embryo is 25 mm long, looks like a human being and from 3 months is called a fetus.

Questions for self-control:

1. What are second week of development occur?
2. What are third week of development occur?
3. What is embryonic mesoderm formation?
4. What is embryonic endoderm formation?
5. What is differentiation of a neural tube and neural crests?

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Langman. Textbook of Medical Embryology. – 9 th ed., 2012,

Lecture 26 (H11)

HUMAN EMBRYOLOGY

LECTURE OUTLINE

- The differentiations of the germinal layers during the fourth week of development that lead to an individualization of the embryo.
- The key concepts of the embryonic period that describe the first stages of organogenesis. Fetal phase. The intrauterine development of the child.

LEARNING OUTCOMES

1. Describe the process of neurulation and include definitions for the terms neural folds, neural tube, and neural tube closure.
2. Describe the first stages of organogenesis.
3. Summarize the process of organogenesis
4. Sensitivity of the embryo or fetus to teratogenic substances.

By the 20th day the chord is formed, the neural plate is laid and the segmentation of embryonic mesoderm and differentiation of somites in germs begin. From the 21st to 25th days the neural tube closes, the ganglion plate is segmented into the germs of the spinal ganglia. From the 20th–21st day the separation of the embryo from the yolk sac begins by means of trunk folds. They are formed on the edges of the embryonic shield from the parietal layer of ectoderm and mesoderm that bend toward endoderm, converge on the ventral side and merge, separating the embryo from the yolk sac. The body of the embryo invaginates into the amniotic cavity. Endoderm merges with the visceral layer of the mesoderm and forms the primary intestine connected to the yolk sac with the yolk stalk, which is converted into the umbilical cord. At the 4th week the ends of the intestine form mouth and anus; gill arches, jaws and limbs are laid. By the 35th day the embryo has 43–44 somites. At the end of the second month histogenesis and laying of almost all organs is completed. At 2,5 months of development the embryo is 25 mm long, looks like a human being and from 3 months is called a fetus. Malformations can lead to miscarriage, stillbirth, and various diseases. This problem was given a start in the work by Norman Gregg. He studied the mass malformations in Australia in 1941 and found out that all the mothers of children with deformities suffered rubella during pregnancy. Another wave of malformations in Western Europe in the 1960-s was associated with using a hypnotic drug tolidamid by pregnants. It has been found out that during the formation of an organ its tissue cells actively divide and differentiate, therefore they are especially sensitive to the harmful factors and can be damaged by them. The cells of other organs, which are less active in this period, may stay insensitive to the same factors. The periods of active differentiation of cells, tissues, organs and systems are called critical periods**.** The highest points of various organs differentiation occur in certain periods of embryogenesis, so there is an exact schedule of critical periods. For example, the rubella virus causes, according to the time of organ formations, diseases of eyes, brain, heart, organs of hearing. Rubella reveales in the newborn if the mother was ill before birth. Malformations of the embryo up to 2,5 months (two months and a half) are called embryopathy and those of the fetus from 2,5 months till birth – fetopathy. There are 9 critical periods in the human development:
1. Progenesis. Harmful factors cause genetic and chromosomal genomic mutations in the sperm and ovum.
2. Fertilization. Harmful factors cause acrosome defects, oligospermia (ejaculate < 1 ml), azoospermia (no spermatozoa in ejaculate), abnormal fertilization envelope, polyspermy (there may be even a teratoma). The risk of such mutations is especially high at 40-50 year-old women.
3. Implantation period (the 7th–8th day of the development). Harmful factors cause a delayed

implantation, abnormal breathing and malnutrition, embryopathy or death of the embryo.
4. Axial organs development and placenta formation period (the 3rd–8th week of the development). Harmful factors cause detachment of the placenta and a threat of miscarriage, the lack of the fetal limbs (the 5th–7th week) or heart (up to the 3rd week), severe heart defects (up to the 8th week), the double eye, double nose, double face, cleft lip and palate, lack of testis, uterus, kidneys, polycystosis and hydronephros.
5. Enhanced brain growth period (the 15th–20th week). Harmful factors may cause development of oligophrenia, sensorineural deafness, encephalocele, hydrocephalus, retinal cysts, violation of myelination, tumors from neuroblasts (clinical manifestation at 6–8 years of age).
6. Main functional and genital systems formation period (the 20th–24th week). Harmful factors may cause persistent functional disorders, heart defects, skeletal deformities, hypothyroidism, cretinism, convulsions and death during birth, the fusion of body parts in twins.
7. Birth period (normally 8 hours after birth). Harmful factors may cause fetal hypoxia or asphyxia, irreversible damages of the heart, lungs, kidneys, gastrointestinal tract, edema and hemorrhage in the brain, the child's cerebral palsy or death. Infections can cause a septic shock, meningitis, diseases of eye, skin, liver, etc.
8. Neonatal period (up to 1 year). In the early neonatal period adaptation of the child may be accompanied by physiological jaundice, uric acid infarction, sexual crises, and septic diseases. In the late neonatal period, hazards can cause disorders of development, allergodermatoses, and rachitis.
9. Puberty period (11–16 years), or Neuroendocrine restructuring period. Hazards (including infections, traumas, obesity) may cause puberty diseases (dyspituitarism, cardiomyopathy, vascular dystonia, glaucoma, coronary cataracts, and violation of hematopoiesis). In girls it may be expressed with anovulatory cycle, premenstrual syndrome, adreno-genital syndrome.

Questions for self-control:

1. Where is neural tube closure initiated and how does it proceed?
2. What is the embryological origin of neural crest cells?
3. Are they ectodermal, mesodermal, or endodermal in origin?
4. From what germ layer are somites formed? How are they organized, and what tissues do they form?
5. What are the major subdivisions of the gut tube, and what germ layer gives rise to these parts?
6. Why are the third to eighth weeks of embryogenesis so important for normal development and the most sensitive for induction of structural defects?

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Lecture 27 (H12)

HUMAN EMBRYOLOGY

LECTURE OUTLINE

- Extraembryonic organs.
- Chorion, Amnion, Yolk sac, Allantois, Umbilical cord, Placenta
- Placenta, Maternal Component, Fetal Component, Blood-Placental Barrier

LEARNING OUTCOMES

1. describe the process of Chorion development
2. distinguish between the maternal and fetal parts of the placenta
3. describe the morphology of the placenta
4. explain the development of the placental structures during pregnancy and their influence on the physiologic functions of the placenta
5. name the structural and functional characteristics of the fetal blood circulation and the properties of the hemato-placental barrier
6. list the endocrine functions of the placenta
7. explain the development of the amnion structures
8. explain the development of the yolk sac structures
9. explain the development of the chorion structures
10. describe the umbilical cord structures

By the 13–14th day they accumulate the epiblast and hypoblast forming the amniotic bubble and the yolk sac. Ectoderm of the amniotic bubble fundus and endoderm of the yolk sac roof compose the embryonic shield, the material of the embryo body. By the 14th day the extraembryonic mesoderm chord grows from the embryonic shield towards the trophoblast, forming the amniotic stem, which is the mesoderm germ of allantois. By the 15th day the embryo has an embryonic shield and 4 extraembryonic organs. From the 17th day placenta develops in parallel to the embryo. From the 3rd to 6th week placentation occurs (parts of the placenta formation). By the end of the third month it is completely formed. The functional layer of endometrium is transformed into decidua. It consists of 3 parts: 1) decidua basalis – a basic part which will constitute the maternal part of the placenta; 2) decidua parietalis is a parietal part lining the uterine wall free of the embryo; 3) decidua capsularis separates the fetus from the uterus cavity. The decidua basalis and decidua capsularis surround the chorion. The villi of the decidua capsularis are reduced (bald chorion) and in the decidua basalis the villi grow strongly, forming a branched chorion. The villi of the branched chorion are immersed into lacunae with the maternal blood; some of them become an anchor, merging with the decidua basalis of the endometrium. The placenta is disc-shaped, 15–18 cm in diameter, 2–3 cm thick, weighs 600 g. It consists of 2 parts: fetal (part fetalis) and maternal (part uterina). The fetus is connected to the placenta with the umbilical cord with the fetus vessels (2 arteries, 1 vein). The umbilical cord is formed by the mucous connective tissue with a high content of hyaluronic acid and water. It is covered with the doublelayered epithelium of the amnion.
The fetal part (part fetalis) of the placenta is a chorionic lamina with villi. They contain branches of the umbilical vessels with the fetal blood and are composed of the mucous connective tissue covered with the trophoblast. The external part of chorionic lamina (facing the fetus) merges with the wall of the amnion covered with the bilayer cubic epithelium. From inside the chorionic lamina is covered with the trophoblast. Thousands of highly branched stem villi extend away from the chorionic

lamina. A one-stem villus forms the basis of one placental lobule. Till 2,5 months of pregnancy the trophoblast (TPB) covering the villi is bilayer: the basal layer is cytoTPB (Langhans' cell layer), and the second layer is syncytioTPB. The cytoTFB is composed of undifferentiated cells; due to their division the syncytioTPB is replenished. In the second half of pregnancy the cytoTPB disappears because it is used for the renewal of the syncytioTPB. The syncytioTPB performs 5 functions: trophic, barrier, excretory, respiratory and endocrine. It produces 4 hormones: 1 – chorionic gonadotropin, like LH, stimulates the development of gonads and adrenal glands of the fetus (Pregnancy Test is introduction of pregnant women's urine to female mice which stimulates ovulation in mice); 2 – progesterone maintains pregnancy and suppresses contraction of the myometrium. It is produced from the 7th day of pregnancy, the maximum – by the 70th day, when the maternal corpus luteum stops working; the second maximum – at the 230th–240th day (at the 7th month); 3 – placental lactogen, which is similar to prolactin. It prepares the maternal mammary glands for lactation and stimulates the development of lungs and surfactant in the fetus (at the lack of this hormone the fetal lungs are underdeveloped), the maximum is secreted until childbirth; 4 – placental corticotropin, which determines the beginning of childbirth. At the end of pregnancy the trophoblast of chorionic villi is gradually replaced by oxyphilic homogeneous Langhans' fibrinoid – the decay products of the trophoblast and plasma proteins. The fibrinoid hinders the absorption of nutrients from the maternal blood. If pregnancy is pathologically prolonged, the fibrinoid accumulates Ca that creates a risk of fetal death. The maternal part (part uterina) of placenta is composed of the basal lamina, the connective tissue septa and lacunae with maternal blood. The basal lamina is a basal endometrial decidua; there are many decidual cells, which are the main source of prolactin during pregnancy. The basal lamina is covered with Rohr's fibrinoid – the decay products of immune complexes. At the places of attachment of anchor chorionic villi to the basal lamina part of the trophoblast is shifted from the villi and penetrates into the basal lamina, forming the peripheral trophoblast. It performs the endocrine function only. From the basal lamina the septa extend, which separate lacunae of maternal blood from each other and divide the placenta into lobules – cotyledons. A cotyledon is a functional unit of the placenta. It consists of a lacuna with blood and chorionic villi immersed into blood. At the edge of the placenta the basal lamina fuses with the chorion and forms closing plates preventing the bleeding of the lacunae. The blood of the fetus and the mother is separated from each other by the blood-placental barrier, which consists of the fibrinoid or TPB with the basement membrane, connective tissue of villi and fetal capillary endothelium with basement membrane.

Questions for self-control:

1. When does the placentation start?
2. What parts does the placenta consist of?
3. What parts does the tunica decidua consist of?
4. What functions does syncytiotrophoblast perform?
5. What placental functions do you know?

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Lecture 30 (H13)

Histology of the Nervous system

LECTURE OUTLINE

- nerve system general morphofunctional characteristic
- sources of origin
- structural and functional classification
- neuroglia – micro - and macroglia. gliocytes.
- peripheral nerve system. nerve truncs structure.
- dorsal root ganglion
- spinal cord

LEARNING OUTCOMES

1. Investigate the organs of nervous system in the specimens according to key features of structure.
2. Identify and classify the peripheral and central organs of nervous system.
3. Recognize the spinal ganglion in the specimens on the basis of key morphological features.
4. Determine the general structure of the peripheral nerve.
5. Identify the spinal cord and its horns in the specimen
6. know the functional significance of different nuclei.

The neuroglia consists of micro- and macroglia. The microgliais small macrophages with multibranch short processes. When the tissue is damaged they are involved, and the cells become ordinary macrophages (called granular spheres). The macroglia includes 3 kinds of cells:
1) ependymocytes cover the central canal of the spinal cord and brain ventricles. The cells have cilia in the apical part for the brain liquor circulation and long processes in the basal part to support the brain cells; 2) astrocytes are small cells with processes and a light nucleus, whose functions are supporting, trophic and protective. Plasmatic astrocytes are placed in the grey matter of the brain and have short branchy processes. Fibrous astrocytes are placed in the white matter and have long smooth processes. The astrocytes contact with the capillaries by processes and form thehemato-encephalon barrier possessing selective permeability; 3) oligodendrocytes form sheaths of neurons on the periphery. Satellite gliocytes form capsules around the neuron bodies in the ganglions.
Lemmocytesform Schwann sheaths around the neuron processes in the nerves. These cells carry out 5 functions: trophic, protective, phagocytosis of disintegration products, participation in the transfer of the nerve impulse and in nerve regeneration. The nerve fiber is a neuron process (the axialone), surrounded withlemmocytes which form the Schwann sheath around the process. It acts as an electrical isolator and protects the process from damages. The Schwann sheath can be myelinated and non-myelinated. Non-myelinated fibers are thin, 1–2 microns, the impulse passes slowly, 1–2 m/s. Lemmocytes cover the axial cylinder by means of their processes which close and form mesaxon (the dual membrane). Lemmocytes often form arope likethe fibers covering some axial cylinders which are separated only by a thin layer of the lemmocyte cytoplasm. So, the non-myelinated Schwann sheath does not create electrical isolation. Therefore, distribution of the nerve impulse on the neighboring fibers and its generalization are possible. The myelinated fiber is thick, up to 20 microns;there is only one axial cylinder. The lemmocyte processes grow, extend, and the mesaxon is wound spirally on the axial cylinder, forming the myelinated layer. The lemmocyte cytoplasm and thenucleus are pushed aside to the periphery forming the neurilemma. The axial

cylinder and lemmocytes grow with different rates, and slanting fissures are visible in the myelinated layer. These are the sites of myelin stratification; they are called myelin clefts (Schmidt – Lantermann'sincisures). On impregnating with osmium myelin is black. The myelin layer has small parts lacking myelin where the lemmocytes connect witheach other; these parts are called Ranvier`s nodes (or nodal gaps). The myelin consists of fat (phospholipids) and creates good electrical isolation; the impulse is transferred precisely to destination. Under the myelin the acting potential cannot arise. The impulse arises only in Ranvier`s nodes jumping through the myelin. Therefore, the rate of its movement is high – 100 km/s. The structure of the nerve. The nerve consists of bundles of myelinated and non-myelinated nerve fibers. Large nerves unite many bundles of fibers and are covered with the epineurium made of the connective tissue with vessels. Each bundle of fibers is covered with dense perineurium. Inside the bundle thin fibers of theloose connective tissue with capillaries form the endoneurium. Under the perineurium there is a fissure with liquid called the perineural space. It communicates with the brain liquor and can be «the infectiongate» which can invade the brain. The spinal cord. It is developed from the body part of the neural tube and lies in the vertebral canal, connected with the periphery by 31 pairs of mixed spinal nerves. The spinal cord is a long white cord divided into two halves by the ventral median fissure and the dorsal white commissure (from pia mater and gliocytes). The ventral and dorsal roots go out from the surface of the spinal cord. The spinal cord is segmented. The segment is a part of the spinal cord with two pairs of roots. There is dark grey matter in the center (on the slice it is shaped like a butterfly). The grey matter consists of the neuron bodies forming the functional centers of the spinal cord called neural nuclei. The neuron processes form a light white matter around the grey matter. The grey matter forms short and massive anterior horns, thin and long posterior horns and an intermediate zone between them which has lateral horns in the interval between the 8th cervical and 2nd lumbar segments. The right and left halves of the grey matter are connected with the central canal lined with the ependima and containing the liquor by the grey commissure. The grey matter horns divide the white matter into 3 pairs of funiculi: ventral, lateral and dorsal.

Questions for self-control:

1. What are the nervous tissue components?
2. Describe the classification of the neuroglia.
3. What are the functions of the neuroglia?
4. What neuron types do you know?
5. What kinds of nerve fibers do you know?
6. What synapses kinds do you know?

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Lecture 31 (H14)

Histology of the Nervous system

LECTURE OUTLINE

- Embrionic origin, structural and functional characteristics of the central nerve system.
- Cytoarchitecture and myeloarchitecture of cerebral cortex.
- Morphofunctional characteristic of cerebral cortex neurons.
- The agranular and granular types of cerebral cortex.
- The blood – brain barrier in terms of its structural correlates and its function.

LEARNING OUTCOMES

1. Identify the layers of the cerebellar cortex.
2. Recognise the cerebellum in the specimens and slides.
3. Explain the functional peculiarities of cerebellar cortex on the basis of cellular content and relationship with other organs of the nervous system.
4. Recognise the cerebral cortex.
5. Identify the layers of the cerebral cortex.
6. Interpret the cytoarchitecture of the cerebral cortex.
7. Explain the differences between sensory and motor cortex.
8. Describe the agranular and granular types of cerebral cortex.
9. Describe the blood – brain barrier in terms of its structural correlates and its function.

The brain consists of the trunk and the pallium (both the trunk and the pallium develop from 3 brain bubbles). The trunk consists of the medulla oblongata, the pons, the mesencephalon, the thalamus and the basal ganglia of the end brain. The grey matter is placed in the center as nuclei. The pallium is composed of the cerebral and cerebellar cortex. The cerebellum. It is the main center of balance and movement coordination. It has the form of two hemispheres. On their surface the most part of the grey matter forms the cerebellar cortex with sulci and gyri, the smaller part forms nuclei in the white matter in the middle of the cerebellum. The dentate nucleus transfers the information to the cerebral cortex and to the spinal cord; other nuclei transfer the impulse to the spinal cord. The cerebellar cortex has 3 layers. The external molecular layer is light, has inhibitory neurons and neuron processes of all layers. The middle ganglionic layer consists of one layer of large efferent neurons – piriform Purkinje neurons (the size is 35–60 microns). The internal granular layer is dark; it contains synaptic complexes «Cerebellum glomeruli» and 10 billion fine neurons. There are 3 groups of them: 1 – exciting cells-grains with a large dense nucleus and little cytoplasm, 2 – inhibitory Golgi cells of the second type with a short axon, 3) associative neurons – horizontal and Golgi cells of the first type with a long axon, connect the cortex sites. 2 kinds of afferent tracts come to the cerebellum: the moss fibers from the cerebral cortex and the climbing fibers from the spinal cord and the organ of balance. The climbing fibers pass into the molecular layer, climb along the dendrites of the Purkinje cells and excite them. The moss fibers come into the granular layer and branchlike moss. They form exciting synapses with the dendrites of the cells-grains which branch like a bird's foot. These synapse complexes form «the cerebellum glomeruli». The axons of the cells-grains go from them into the molecular layer, divide like T and excite all cortex neurons. The excited inhibitory neurons take part in processing the information and inhibit the piriform Purkinje neurons. The Purkinje cells collect the information and transfer it to the cerebellum nuclei. The inhibitory

neurons are of 4 kinds. 3 kinds of them lie in the molecular layer: 1 – basket neurons which form baskets around the bodies of the Purkinje cells; 2, 3 – fine and large stellate neurons which form inhibitory synapses with their dendrites. In the granular layer the 4th kind of the inhibitory neurons lies. It is Golgi cells of the 2nd type, their short axons enter the cerebellum glomeruli and inhibit the transfer of impulses from the moss fibers onto the cells-grains. Thus, they can inhibit the excitation of the Purkinje cells. Each Purkinje`s cell forms up to 60 thousand synapses. The inhibitory neurons can strengthen or block the exciting impulses, that leads to the inhibition or counter inhibition of the Purkinje cells. An intense impulse inhibits the Purkinje cells, blocks their inhibiting influence on the dentate nucleus. The nucleus neurons become excited and inhibit the pyramids of the cerebral cortex that leads to the counter inhibition of the motor neurons of the spinal cord, and a movement is made. And on the contrary, a weak impulse disinhibits the Purkinje cells, and a movement is not made. By the same principle the majority of reflexes work including the higher nervous activity. The cerebral cortex. The thickness of the cerebral cortex is 3 to 5 mm, it contains 14 to 17 billion neurons, all of them are multipolar, have different forms, pyramids prevail. They have the top and lateral dendrites, the axon passes from the basis of the cell. The pyramids can be small – 10 to 12 microns, middlesized – 20 to 30 microns, greater – 40 to 80 microns, and huge – 120 microns. New synapses are formed on the process terminals in the form of thorns and swellings, in nutritional disorder they die, but they remain near the perikaryon, that is why old men have long-term memory but no short-term memory. THE STRUCTURE. The cerebral cortex has cell- and myeloarchitectonics, or the certain arrangement of fibers and cells forming the cortical areas – the centers of the higher nervous activity. The cortical neurons lie in 6 layers: 1 – the molecular layer, external, contains fine neurons and many processes of neurons from all layers forming the tangential plexus; 2 – the external granular layer composed of fine inhibitory neurons; 3 – the pyramidal layer, the widest, pyramids are of different size. The top dendrite goes into the molecular layer, the lateral dendrites branch in their own layer and form a plexus – external Bajarge's strip, the axons form radial rays and make up the cortico-cortical and pyramidal tracts; 4 – the internal granular layer contains echinate stellate neurons, accepting excitation from the thalamo-cortical tracts; 5 – the ganglionar layer composed of huge pyramids – Besth's cells (120 microns). Their axons form the pyramidal tracts, and the lateral dendrites form the internal Bajarge's strip in the same layer; 6 – the layer of polymorphic cells, their axons compose the pyramidal ways. There are 2 types of cortex zones: 1 – granular type with well developed granular layers – the sensory zones where the higher analysis of information is performed; 2 – agranular type where pyramidal layers are well developed – these are motor zones.

Questions for self-control:

1. What functional parts does the nervous system have?
2. What organs does the central nervous system include?
3. What organs does the peripheral nervous system include?
4. What is the grey and white matter of the spinal cord?
5. What components make up the spinal ganglion?
6. Name the layers of the cerebellar cortex.
7. Name the layers of the cerebral cortex.
8. What is a structural and functional unit of the cortex?

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Lecture 34 (H15)

HISTOLOGY OF THE SENSE ORGANS. SPECIAL SENSES.

DEVELOPMENT, STRUCTURE AND HISTOPHYSIOLOGY OF THE THE EYE. OLFACTORY REGION OF THE NASAL CAVITY, TASTE BUDS AND SPECIALIZED PERIPHERAL RECEPTORS.

LECTURE OUTLINE

- Classifications of sensory receptors. List the receptors that fit into each class.
- The term analisator and their principle portions.
- Sense organs classification due to the origin and structure of the receptor cells.
- Visual organ. Eyeballgeneral structure, tunices, their portions and derivatives.
- Fibrous and vascular tunices of eyeball, their portions thin structure and functions.Cornea microscopic and histochemical charcteristic.
- Inner eye tunic. Retina nerve cells compounds. Ultrastructural and cytochemical characteristic of the photoceptor cells.
- Eye dioptric and accomodative apparatus.
- Olfactory region
- Taste buds

LEARNING OUTCOMES

1. Explain the organisation of the analysator.
2. Interpret the general features of the receptor zones.
3. Tractate the general structure of the eye globe.
4. Identify the parts of tunica fibrosa (sclera and cornea) in the specimen.
5. Interpret the functional properties of the choroid derivates.
6. Recognise the retina and its layers.
7. Differentiate the rods and cones in the electron micrographs.
8. Identify the olfactory epithelium.
9. Recognize the different types of cells in olfactory epithelium.
10. Identifu the taste buds.
11. Interpret the cellular content taste bud.

The organ of vision (eye) consists of the eyeball and the auxiliary organs including eye-moving muscles, eyelids and lacrimal apparatus. The muscles direct the eye at an object and provide fine oscillatory movements of the eyes for the volumetric image. From within the eyelids are lined with the mucous membrane –conjunctiva, – which fuses with the eyeball forming an arch. The tear is produced by the lacrimal glands lying in the conjunctive arch. The glands are alveolar and tubular with myoepithelial cells. Tears humidify the cornea and are discharged through the channels into the nasal cavity. The eye has 4 types of functional apparatuses. 1. Dioptrical apparatus is a system of lenses consisting of the cornea, the eye chambers, the crystalline lens and the vitreous body.
2. Accommodative apparatus is a system of the crystalline lens and ciliary bodies with the suspensory ligament. It changes the crystalline lens curvature for focusing the nearby and distant objects.
3. Adaptative apparatus is a system of the iris and pigmentary epithelium of the retina which adapts the eye to the light brightness.
4. Photosensory apparatus is the optical retina which is irritated by the light. The eye is filled with the

vitreous body which contains much hyaluronic acid, water and transparent protein vitrein. It does not regenerate and flows out in case of trauma, and the eye dies. In front of the vitreous body the crystalline lens lies. The suspensory ligament connects the lens with the eye wall. The crystalline lens is an elastic biconvex lens composed of stratified epithelium; the basal membrane forms a transparent capsule. The basal cell layer has a nucleus and is able to divide at the equator. The other layers of lens epithelium have no nucleus. These cells are filled with transparent protein crystalline and turn to lens prisms or fibers. With age elasticity of the crystalline lens decreases, crystalline denaturation begins, and cataract can develop. The eye wall has 3 sheaths: 1 – external fibrous, 2 – middle vascular, 3 – internal retina. In the anterior and posterior eye hemisphere they are different. The fibrous layer contains the posterior sclera and the anterior cornea joining at the limbus. The sclera consists of dense connective tissue with vessels, cells and thick wavy collagenous bundles. That is why it is white and opaque. The cornea is transparent since it has 2 features: 1 – it is made up of smooth collagenous plates in which fibers lie in parallel, but at the right angle to each other, 2 – it has no vessels and few cells, only fibrocytes. In the cornea there are 5 layers:
1) the external epithelium, which is stratified non-squamous (moist) epithelium rich in nerve endings (the corneal reflex), and regenerates well;
2) the anterior limiting Bowman's membrane, which is 6–9 mcm thick, supports the form and nutrition of the cornea, has many GAG and no cells;
3) proper substance (stroma), which is composed of collagenous plates;
4) the posterior limiting Descemet's membrane, which is 5–10 microns thick; it is the basal membrane of posterior epithelium of the cornea;
5) the inner epithelium, which is simple squamous epithelium.

Questions for self-control:

1. What are the functional apparatuses of the eye?
2. What are the tunics of the eye wall?
3. Name the layers of the cornea.
4. Name the layers of the optic part of the retina.

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Lecture 37 (H16)

HISTOLOGY OF THE SENSE ORGANS. SPECIAL SENSES.

THE ORGAN OF HEARING AND BALANCE

LECTURE OUTLINE

- General characteristic features of the audiovestibular organ: the external, middle and internal ear.
- Ultrastructure and functions of the tympanic membrane.
- Bone and membranous labyrinthes of the internal ear.
- Vestibular portion of the membranouth labyrinth - vestibular organ.
- Ampullary crests, spots of the utricle and saccule: disposition, ultrastructure and functions.
- The hearing organ. Membranous labyrinth of the cochlea.
- Spiral Corti's organ: disposition and functions.
- Cells components of the Corti's organ. Supporting cells: types,structure and disposition.
- Receptory cells of the Corti's organ: types and ultrastructure.
- Audiovestibular organ histophysiology.

LEARNING OUTCOMES

1. Identify the parts of the inner ear.
2. Recognize the receptor zone of the auditory system.
3. Interpret the cellular content and functions of the Corti organ.
4. Recognize the macula and cristae of the vestibular appratus.
5. Identify the different sensoepithelial cells of the vestibular apparatus.

The central nervous system receives some information as for the outside world and the inner state of the organism with the aid of senses. The sensations resulted from this information reflect something existing regardless of our consciousness - the objective reality of everything around us. Needless to say, without our sense ograns we would be completely helpless and unable ti survive for any appreciable length in time. Doctors of many specialities such as oculists, otorhinolaryngologists, neurologists, phychiatrists need deep knowledge of the structure and functions of the sense organs. The knowledge of morphofunctional pecularities of the recepient's organs are also necessary for pediatrists and therapeutists for preventing unfavourable influence of the environment on the histophysiology of the sense organs.

The organ of hearing and balance consists of the external, middle and internal ears. As the organ of hearing it perceives sounds, and as the organ of balance – awareness of the body position.
The external ear receives sound waves and consists of the ear concha (auricle, pinna), external auditory (acoustic) meatus, tympanic membrane (eardrum).The middle and internal ears are located in the temporal bone pyramid. The middle ear transmits sound waves from the air to fluids; it is filled with air and consists of the auditory (acoustic) tube, tympanic cavity and auditory ossicles (three small bones). The auditory tube (also called the Eustachian or pharyngotympanic tube) connects the tympanic cavity with the nasopharynx in order to equalize the air pressure in it with the atmospheric one. In the medial wall the tympanic cavity has two apertures – the oval and round windows, closed with membranes. The auditory ossicles (malleus or hammer, incus or anvil, stapes or stirrup) are connected with joints and form the system of levers which connects the eardrum with the oval window and strengthens the sound wave (in children the acoustic tube is short and wide,

infection can easily get into the middle ear, and otitis develops). The internal ear consists of the bony labyrinth with the built-in membranous labyrinth. The bony labyrinth consists of 3 parts: the vestibule, the cochlea and semicircular canals (ducts). It is filled with perilymph, similar to liquor, and is connected with the subarachnoid space. Infection can get through it into the skull cavity and cause otitic meningitis. The membranous labyrinth is filled with endolymph containing much K (150 mM) and little Na (16 mM). In the vestibule it forms 2 membranous sacs: round (or saccule) and oval (or utricle).Three semicircular canals with ampoules in their basis are placed perpendicularly to each other and connect with the utricle. The organ of balance (vestibular organ) is presented by the receptors called maculae and ampullar crests (cristae ampullares) which are placed in the membranous wall of the utricle and ampoules of the semicircular canals. These receptors have sensory epithelium made up of the basic and hair cells. The hair cells are of 2 types: piriform and columnar. They contact with the dendrites of the sensory neurons of the vestibular ganglia and have 60–80 motionless stereocilia and 1 mobile kinetociliumat – the cellapex. Ampullar crests (cristae ampullares) are located across the ampoules of the semicircular canals. They are the receptors of angular accelerations. The sensory epithelium lies on the periosteum outgrowth and is covered with a high gelatinous cupula (dome) composed of glycoproteins and GAG. The hairs of the sensory cells penetrate into the dome. When the head or body rotates, endolymph is displaced, the dome deviates, the hairs are bent, and the action potential appears. The maculae lie on the membranous wall of the utricle; they are the receptors of gravitation, linear accelerations and vibration. The hairs penetrate into the otolithic membrane with the crystals of Ca carbonate – they are called otoliths (otoconia).When the body changes its position in relation to gravitation otoliths are displaced and irritate the hairs.

Questions for self-control:

1. Which components make up the analyzers?
2. What are the parts of the hearing organ?
3. What is the structure of the balance organ?
4. What are the main cells of the Corti organ.

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EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body
Course – 2 Semester – 3
Number of credits – 11
Almaty 2021
Lecture №10
Overview of the Endocrine system.
The Hypothalamus and Pituitary Gland. Other Endocrine glands.

Outcomes:

1. define hormone and endocrine system;
2. name several organs of the endocrine system;
3. contrast endocrine with exocrine glands;
4. recognize the standard abbreviations for many hormones;
5. describe similarities and differences between the nervous and endocrine systems.

- The glands, tissues, and cells that secrete hormones constitute the ***endocrine system*;**
- The study of this system and the diagnosis and treatment of its disorders is called ***endocrinology*.**
- The most familiar hormone sources are the ***endocrine glands,*** such as the pituitary, thyroid, and adrenal glands, among others.
- The hormones are also secreted by numerous organs and tissues, such as the brain, heart, small intestine,bones, and adipose tissue.

Principal avenues of communication from cell to cell

1. **Gap junctions** join single-unit smooth muscle, cardiac muscle, epithelial, and other cells to each other. They enable cells to pass nutrients, electrolytes, and signaling molecules directly from the cytoplasm of one cell to the cytoplasm of the next through pores in their plasma membranes.
2. **Neurotransmitters** are released by neurons, diffuse across a narrow synaptic cleft, and bind to receptors on the surface of the next cell.
3. **Paracrines** are secreted by one cell, diffuse to nearby cells in the same tissue, and stimulate their physiology. Some call them *local hormones*.
4. **Hormones** in the strict sense, are chemical messengers that are transported by the bloodstream and stimulate physiological responses in cells of another tissue or organ, often a considerable distance away. Certain hormones produced by the pituitary gland in the head, for example, act on organs as far away as the pelvic cavity

Comparison of Endocrine and Exocrine Glands

- Exocrine glands secrete their products by way of a duct onto an epithelial surface such as the skin or the mucosa of the digestive tract.
- Endocrine glands, are ductless and release their secretions into the bloodstream.
- Exocrine secretions have extracellular effects such as the digestion of food, whereas endocrine secretions have intracellular effects—they alter cell metabolism.
- Endocrine glands have an unusually high density of blood capillaries; (*fenestrated capillaries)*

Comparison of the Nervous and Endocrine Systems

Nervous System	Endocrine System
Communicates by means of electrical impulses and neurotransmitters	Communicates by means of hormones
Releases neurotransmitters at synapses at specific target cells	Releases hormones into blood-stream for general distribution throughout body
Usually has relatively local, specific effects	Sometimes has very general, widespread effects
Reacts quickly to stimuli, usually within 1–10 ms	Reacts more slowly to stimuli, often taking seconds to days
Stops quickly when stimulus stops	May continue responding long after stimulus stops
Adapts relatively quickly to continual stimulation	Adapts relatively slowly; may respond for days to weeks

Abbreviation	Name	Source
ACTH	Adrenocorticotropic hormone (corticotropin)	Anterior pituitary
ADH	Antidiuretic hormone (arginine vasopressin)	Posterior pituitary
CRH	Corticotropin-releasing hormone	Hypothalamus
DHEA	Dehydroepiandrosterone	Adrenal cortex
EPO	Erythropoietin	Kidneys, liver
FSH	Follicle-stimulating hormone	Anterior pituitary
GH	Growth hormone (somatotropin)	Anterior pituitary
GHRH	Growth hormone–releasing hormone	Hypothalamus
GnRH	Gonadotropin-releasing hormone	Hypothalamus
IGFs	Insulin-like growth factors (somatomedins)	Liver, other tissues
LH	Luteinizing hormone	Anterior pituitary
NE	Norepinephrine	Adrenal medulla
OT	Oxytocin	Posterior pituitary
PIH	Prolactin-inhibiting hormone (dopamine)	Hypothalamus
PRL	Prolactin	Anterior pituitary
PTH	Parathyroid hormone (parathormone)	Parathyroids
T_3	Triiodothyronine	Thyroid
T_4	Thyroxine (tetraiodothyronine)	Thyroid
TH	Thyroid hormone (T_3 and T_4 collectively)	Thyroid
TRH	Thyrotropin-releasing hormone	Hypothalamus
TSH	Thyroid-stimulating hormone (thyrotropin)	Anterior pituitary

Questions for control

1. Identify three endocrine glands that are larger or more functional in infants or children than in adults. What is the term for the shrinkage of a gland with age?
2. Why does thyroid hormone have a calorigenic effect?
3. Name a glucocorticoid, a mineralocorticoid, and a catecholamine secreted by the adrenal gland.
4. Does the action of glucocorticoids more closely resemble that of glucagon or insulin? Explain.
5. Define hypoglycemic hormone and hyperglycemic hormone and give an example of each.
6. What is the difference between a gonadal hormone and a gonadotropin?

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OMiF1214 Morphology and physiology of human body
Course – 2 Semester – 3
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Lecture №11
Hormones and Their Actions.

Outcomes:

1. a. identify the chemical classes to which various hormones belong;
2. describe how hormones are synthesized and transported to their target organs;
3. describe how hormones stimulate their target cells;
4. explain how target cells regulate their sensitivity to circulating hormones;
5. describe how hormones affect each other when two or more of them stimulate the same target cells; and
6. discuss how hormones are removed from circulation after they have performed their roles.

Hormone Chemistry

Most hormones fall into three chemical classes: steroids, monoamines,
and peptides.

1. Steroid hormones are derived from cholesterol. They include sex steroids produced by the testes and ovaries (such as estrogens, progesterone, and testosterone) and corticosteroids produced by the adrenal gland (such as cortisol, aldosterone, and DHEA). The gonads and adrenal cortex are the only sites of steroid hormone synthesis. Calcitriol, the calcium-regulating hormone, is not a steroid but is derivedfrom one and has the same hydrophobic character and mode of action as the steroids, so it is commonly grouped with them.

2. Monoamines since this class also includes several neurotransmitters. The monoamine hormones include dopamine, epinephrine, norepinephrine, melatonin, and thyroid hormone. The first three of these are also called catecholamines. Monoamines are made from amino acids.

Hormone Secretion

Hormones are not secreted at steady rates, nor do they have constant levels in the bloodstream throughout the day. Rather, they are secreted in some cases on a daily (circadian) rhythm, in other cases on a monthly rhythm (in a woman's ovarian cycle), or under the influence of stimuli that signify a need for them. These stimuli are of three kinds.

1. Neural stimuli. Nerve fibers supply some endocrine glands and elicit the release of their hormones. For example, the sympathetic nervous system stimulates the adrenal medulla to secrete epinephrine and norepinephrine in situations of stress. In childbirth, nerve signals originate from stretch receptors in the uterus, travel up the spinal cord and brainstem to the hypothalamus, and stimulate the release of oxytocin.

2. Hormonal stimuli. Hormones from the hypothalamus regulate secretion by the anterior pituitary gland, and pituitary hormones stimulate other endocrine glands to release thyroid hormone, sex hormones, and cortisol.

3. Humoral stimuli. This refers to blood-borne stimuli. For example, rising blood glucose concentration stimulates the release of insulin, low blood osmolarity stimulates the secretion of aldosterone, and a low blood calcium level stimulates the secretion of parathyroid hormone

Hormone Clearance

Hormonal signals, like nervous signals, must be turned off when they have served their purpose. Most hormones are taken up and degraded by the liver and kidneys and then excreted in the bile or urine. Some are degraded by their target cells. As noted earlier, hormones that bind to transport proteins are removed from the blood much more slowly than hormones that do not employ transport proteins.

The rate of hormone removal is called the *metabolic clearance rate (MCR),* and the length of time required to clear 50% of the hormone from the blood is the *half-life.* The faster the MCR,
the shorter is the half-life. Growth hormone, for example, uses no transport protein and has a half-life of only 6 to 20 minutes. Thyroxine, by contrast, is protected by transport proteins and maintains a physiologically effective level in the blood for up to 2 weeks after its secretion ceases.

Questions for control

1. What are the three chemical classes of hormones? Name at least one hormone in each class.
2. Why do corticosteroids and thyroid hormones require transport proteins to travel in the bloodstream?
3. Explain how MIT, DIT, T3, and T4 relate to each other structurally.
4. Where are hormone receptors located in target cells?
5. Name one hormone that employs each receptor location.
6. Explain how one hormone molecule can activate millionsof enzyme molecules

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Course – 2 Semester – 3
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Lecture №13
Endocrine Disorders

Outcomes:

1. explain some general causes and examples of hormone hyposecretion and hypersecretion;
2. briefly describe some common disorders of pituitary, thyroid, parathyroid, and adrenal function;
3. in more detail, describe the causes and pathology of diabetes mellitus.

Hyposecretion and Hypersecretion

Inadequate hormone release is called hyposecretion. It can result from tumors or lesions that destroy an endocrine gland or interfere with its ability to receive signals from another cell. For example, a fractured sphenoid bone can sever the hypothalamo‑hypophyseal tract and prevent the transport of oxytocin and antidiuretic hormone (ADH) to the posterior pituitary. The resulting ADH hyposecretion disables the water-conserving capability of the kidneys and leads to diabetes insipidus, an output of abundant but glucose-free urine. (*Insipidus* means "without taste" and refers to the lack of sweetness of the urine, in contrast to the sugary urine of diabetes mellitus.) Autoimmune diseases can also lead to hormone hyposecretion when endocrine cells are attacked by *autoantibodies*– antibodies that fail to distinguish foreign matter from one's own tissues. This is one of the causes of diabetes mellitus. A congenital absence or underdevelopment of the pituitary gland causes *panhypopituitarism*, wide-spectrum hyposecretion of multiple hormones affected by the pituitary, requiring lifelong multihormone replacement therapy.

Excessive hormone release, called **hypersecretion,** has multiple causes. Some tumors result in the overgrowth of functional endocrine tissue. A **pheochromocytoma,** for example, is a tumor of the adrenal medulla that secretes excessive amounts of epinephrine and norepinephrine. Some tumors in nonendocrine organs produce hormones. For example, some lung tumors secrete ACTH and overstimulate cortisol secretion by the adrenal gland. Whereas certain autoimmune disorders can cause endocrine hyposecretion, others cause hypersecretion.

An example of this is **toxic goiter** (Graves disease), in which autoantibodies mimic the effect of TSH on the thyroid, activating the TSH receptor and causing thyroid hypersecretion. Endocrine hypersecretion disorders can also be mimicked by excess or long-term clinical administration of hormones such as cortisol.

Pituitary Disorders

The hypersecretion of growth hormone (GH) in childhood or adolescence, before the epiphyseal plates (growth zones) of the long bones are depleted, causes **gigantism,** whereas childhood hyposecretion causes **pituitary dwarfism.** Now that growth hormone is plentiful, made by genetically engineered bacteriacontaining the human GH gene, pituitary dwarfism has become rare. In adulthood, after the epiphyseal plates have closed, GH hyposecretion causes little if any problem, but hypersecretion causes **acromegaly**—thickening of the bones and soft tissues, with especially noticeable effects on the hands, feet, and face

Thyroid and Parathyroid Disorders

Congenital hypothyroidism is thyroid hyposecretion present from birth. Severe or prolonged adult hypothyroidism can cause **myxedema.** Both syndromes can be treated with oral thyroid hormone. A more conspicuous, often striking abnormality of the thyroid is **endemic goiter.** It results from a deficiency of dietary iodine.

The parathyroids, because of their location and small size, are sometimes accidentally removed in thyroid surgery or degenerate when neck surgeries cut off their blood supply. Without hormone replacement therapy, the resulting **hypoparathyroidism** causes a rapid decline in blood calcium level; in as little as 2 or 3 days, this can lead to a fatal, suffocating spasm of the muscles of the larynx *(hypocalcemic tetany)*. **Hyperparathyroidism,** excess PTH secretion, is usually caused by a parathyroid tumor. It causes the bones to become soft, deformed, and fragile; it raises the blood levels of calcium and phosphate ions; and it promotes the formation of *renal calculi* (kidney stones) composed of calcium phosphate.

Adrenal Disorders

Cushing syndrome is excess cortisol secretion owing to any of several causes: ACTH hypersecretion by the pituitary, ACTH secreting tumors, or hyperactivity of the adrenal cortex independently of ACTH. **Adrenogenital syndrome (AGS),** the hypersecretion of adrenal androgens, commonly accompanies Cushing syndrome.

Diabetes Mellitus

Diabetes mellitus31 **(DM)** can be defined as a disruption of carbohydrate, fat, and protein metabolism resulting from the hyposecretion or inaction of insulin. The classic signs and symptoms with which patients often first present to a physician are “the three polys”: **polyuria** (excessive urine output), **polydipsia**(intense thirst), and **polyphagia** (ravenous hunger). Blood and urine tests can confirm a diagnosis of DM by revealing three further signs: **hyperglycemia** (elevated blood glucose), **glycosuria** (glucose in the urine), and **ketonuria** (ketones in the urine). DM was originally named for the sweetness of the urine stemming from glycosuria. Before the advent of chemical tests for glucose, physicians tasted their patients’ urine as part of their diagnostic process.

Questions for control

1. Explain some causes of hormone hyposecretion, and give examples. Do the same for hypersecretion.
2. Why does a lack of dietary iodine lead to TSH hypersecretion?
3. Why does the thyroid gland enlarge in endemic goiter?
4. In diabetes mellitus, explain the chain of events that lead to (a) osmotic diuresis, (b) ketoacidosis and coma, and (c) gangrene of the lower limbs.

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EDUCATIONAL AND METHODICAL COMPLEX OF DISCIPLINE
OMiF1214 Morphology and physiology of human body
Course – 2 Semester – 3
Number of credits – 11
Almaty 2021
Lecture №14
Stress and Adaptation Eicosanoids and Other Signaling Molecules

Outcomes:

1. give a physiological definition of stress;
2. discuss how the body adapts to stress through its endocrine and sympathetic nervous systems.
3. explain what eicosanoids are and how they are produced;
4. identify some classes and functions of eicosanoids; and
5. describe several physiological roles of prostaglandins.

Stress is defined as any situation that upsets homeostasis and threatens one's physical or emotional well-being. It affects us all from time to time, and we react to it in ways that are mediated mainly by the endocrine and sympathetic nervous systems. Physical causes of stress *(stressors)* include injury, surgery, hemorrhage, infection, intense exercise, temperature extremes, pain, and malnutrition. Emotional causes include anger, grief, depression, anxiety, and guilt. Whatever the cause, the body reacts to stress in a fairly consistent way called the **stress response** or **general adaptation syndrome (GAS).**

The response typically involves elevated levels of epinephrine and cortisol; some physiologists now define *stress* as any situation that raises the cortisol level. The GAS typically occurs in three stages, which are called the *alarm reaction,* the *stage of resistance,* and the *stage of exhaustion*.

The **eicosanoids**28 (eye-CO-sah-noyds) are an important family of paracrine secretions. They have 20-carbon backbones derived from a polyunsaturated fatty acid called **arachidonic acid** (ah-RACK-ih-DON-ic). Some peptide hormones and other stimuli liberate arachidonic acid from one of the phospholipids of the plasma membrane, and the following two enzymes then convert it to various eicosanoids.

Lipoxygenase helps to convert arachidonic acid to **leukotrienes,** eicosanoids that mediate allergic and inflammatory reactions. **Cyclooxygenase** converts arachidonic acid to three other eicosanoids:

1. **Prostacyclin** is produced by the walls of the blood vessels, where it inhibits blood clotting and vasoconstriction.
2. **Thromboxanes** are produced by blood platelets. In the event of injury, they override prostacyclin and stimulate vasoconstriction and clotting.
3. **Prostaglandins (PGs)** are the most diverse eicosanoids. They have a five-sided carbon ring in their backbone. They are named PG for *prostaglandin*, plus a third letter that indicates the type of ring structure (PGE, PGF, etc.) and a subscript that indicates the number of C−C double bonds in the side chain—such as the $PGF_{2\alpha}$.

Questions for control

1. Define stress from the standpoint of endocrinology.
2. Describe the stages of the general adaptation syndrome.

3. List six hormones that show increased secretion in the stress response. Describe how each one contributes to recovery from stress.
4. What are eicosanoids and how do they differ from neurotransmitters and hormones?
5. Distinguish between paracrine and endocrine effects.
6. State four functions of prostaglandins.

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Course – 1 Semester – 2
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Almaty 2021

Lecture 22

The Respiratory System 1-2
Anatomy of the Respiratory System. Pulmonary Ventilation

Outcomes:

1. state the functions of the respiratory system;
2. name and describe the organs of this system;
3. trace the flow of air from the nose to the pulmonary alveoli; and
4. relate the function of any portion of the respiratory tract to its gross and microscopic anatomy.
5. name the muscles of respiration and describe their roles in breathing;
6. describe the brainstem centers that control breathing and the inputs they receive from other levels of the nervous system;
7. explain how pressure gradients account for the flow of air into and out of the lungs, and how those gradients are produced;
8. identify the sources of resistance to airflow and discuss their relevance to respiration;
9. explain the significance of anatomical dead space to alveolar ventilation;
10. define the clinical measurements of pulmonary volume and capacity; and
11. define terms for various deviations from the normal pattern of breathing.

The term respiration can mean ventilation of the lungs (breathing) or the use of oxygen in cellular metabolism. In this chapter, we are concerned with the first process. The respiratory system is an organ system that rhythmically takes in air and expels it from the body, thereby supplying the body with oxygen and expelling the carbon dioxide that it generates. However, it has a broader range of functions than is commonly supposed:

1. Gas exchange. It provides for oxygen and carbon dioxide exchange between the blood and air.
2. Communication. It serves for speech and other vocalization (laughing, crying).
3. Olfaction. It provides the sense of smell, which is important in social interactions, food selection, and avoiding danger (such as a gas leak or spoiled food).
4. Acid–base balance. By eliminating CO_2, it helps to control the pH of the body fluids. Excess CO_2 reacts with water and generates acid; therefore, if respiration doesn't keep pace with CO_2 production, acid accumulates and the body fluids have an abnormally low pH (acidosis).
5. Blood pressure regulation. The lungs carry out a step in synthesizing angiotensin II, which helps to regulate blood pressure.
6. Blood and lymph flow. Breathing creates pressure gradients between the thorax and abdomen that promote the flow of lymph and venous blood.
7. Blood filtration. The lungs filter small blood clots from the bloodstream and dissolve them, preventing clots from obstructing more vital pathways such as the coronary, cerebral, and renal circulation.

8. Expulsion of abdominal contents. Breath-holding and abdominal contraction help to expel abdominal contents during urination, defecation, and childbirth.

The principal organs of the respiratory system are the nose, pharynx, larynx, trachea, bronchi, and lungs. Within the lungs, air flows along a dead-end pathway consisting essentially of bronchi → bronchioles → alveoli (with some refinements to be introduced later). Incoming air stops in the *alveoli* (millions of tiny, thin-walled air sacs), exchanges gases with the bloodstream through the alveolar wall, and then flows back out.

The **conducting zone** of the respiratory system consists of those passages that serve only for airflow, essentially from the nostrils through the major bronchioles. The walls of these passages are too thick for adequate diffusion of oxygen from the air into the blood. The **respiratory zone** consists of the alveoli and other gas-exchange regions of the distal airway. The airway from the nose through the larynx is often called the **upper respiratory tract** (that is, the respiratory organs in the head and neck), and the regions from the trachea through the lungs compose the **lower respiratory tract** (the respiratory organs of the thorax). However, these are inexact terms and various authorities place the dividing line between the upper and lower tracts at different points.

With the foregoing anatomical background, our next objective is to understand how the lungs are ventilated. Breathing, or pulmonary ventilation, consists of a repetitive cycle of **inspiration** (inhaling) and **expiration** (exhaling). One complete breath, in and out, is called a **respiratory cycle.** We must distinguish at times between quiet and forced respiration. **Quiet respiration** refers to relaxed, unconscious, automatic breathing, the way one would breathe when reading a book or listening to a class lecture and not thinking about breathing. **Forced respiration** means unusually deep or rapid breathing, as in a state of exercise or when singing, playing a wind instrument, blowing up a balloon, coughing, or sneezing.

Questions for control

1. A dust particle is inhaled and gets into an alveolus without being trapped along the way. Describe the path it takes, naming all air passages from external naris to alveolus. What would happen to it after arrival in the alveolus?
2. Describe the histology of the epithelium and lamina propria of the nasal cavity and the functions of the cell types present.
3. Palpate two of your laryngeal cartilages and name them. Name the ones that cannot be palpated on a living person.
4. Explain why contraction of the diaphragm causes inspiration but contraction of the transverse abdominal muscle causes expiration.
5. Which brainstem respiratory nucleus is indispensable to respiration? What do the other nuclei do?
6. Explain why Boyle’s law is relevant to the action of the respiratory
7. muscles.
8. Explain why eupnea requires little or no action by the muscles of expiration.
9. Identify a benefit and a disadvantage of normal (nonpathological) bronchoconstriction.

10. Suppose a healthy person has a tidal volume of 650 mL, an anatomical dead space of 160 mL, and a respiratory rate of 14 breaths per minute. Calculate her alveolar ventilation rate.
1. Suppose a person has a total lung capacity of 5,800 mL, a residual volume of 1,200 mL, an inspiratory reserve volume of 2,400 mL, and an expiratory reserve volume of 1,400 mL. Calculate his tidal volume.

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Lecture 23 Human tissue 7-8
Respiratory system: nasal cavity, trachea, bronchi,bronchioles, alveolar ducts.
Histology of urinary system

LECTURE OUTLINE

- general features of the Respiratory system.
- components and basic functions of the Respiratory system.
- nasal cavity
- bronchial tree
- alveoli. Alveolar cell types
- general features of the Urinary system.
- components of the Urinary system
- kidneys. nephrons.
- ureters. urinary bladder. urethra.

LEARNING OUTCOMES

1. name the 3 divisions of the Respiratory system.
2. describe the respiratory tract walls in terms of the arrangements, composition, function of their layers and cells.
3. describe the blood-air barrier's structure and function.
4. recognize the bronchi in a micrograph and identify their structural components.
5. name the organs of the urinary system.
6. identify and describe the structure, function, location of each component of a nephron in micrograph.

The respiratory system performs the respiratory function and a number of functions not related to breathing. The respiratory function is gas exchange between the organism and the environment: O2 is absorbed and CO2 is eliminated. The respiratory system consists of 2 parts: the conducting part, or airways, and the respiratory one. In the airways the air is dried or humidified, purified from particulate matter, the inhaled air is warmed or cooled. The conducting part consists of nasal cavities, nasopharynx, larynx, trachea and bronchi. The respiratory part consists of pulmonary acini where the gas exchange of the blood and the air is performed. The airways have a wall composed of 4 tunics: mucous (mucosa), submucous (submucosa), fibro-cartilaginous and adventitia. *The mucosa* is composed of epithelium, lamina propria and muscular mucosa. *Pseudostratified ciliated epithelium* contains ciliary, goblet and endocrine cells. *Lamina propria* consists of a loose collagen tissue rich in elastic fibers and vessels; there are lymphoid follicles there. *Muscular mucosa* is formed of circular smooth muscle bundles. *Submucosa* contains a loose collagen tissue with serous-mucous glands. *Fibro-cartilaginous tunic* consists of a dense connective tissue and the hyaline cartilage; the elastic

cartilage occurs as well. The dense connective tissue merges with the perichondrium. *Adventitia* consists of a loose collagen tissue with blood vessels and nerves.
The urinary system performs 5 functions: 1 – urinary excretion of useless body substances, 2 – participation in water-salt metabolism, 3 – maintaining acid-base homeostasis, 4 – endocrine function, 5 – hematopoietic function (it produces erythropoietin; in the fetus and in newborns kidneys have hematopoiesis foci). The urinary system includes the urine-producing organs: kidneys and the urine tract, which consists of collecting tubes, papillary tubules, cups, a pelvis, ureters, a bladder, a urethra. The structural and functional unit of the kidney is the NEPHRON. It is a complex epithelial tubule, which begins with a capsule surrounding the vascular glomerulus. Together they form a *renal corpuscle*. The nephron consists of 5 parts: 1– a capsule of renal corpuscles, 2 – a proximal tubule, 3 – a nephron loop (Henle's loop), 4 – a distal tubule, 5 – a short connecting tubule, linking the nephron and the collecting duct. Urine is produced in two stages: *filtration and reabsorption*. *The primary urine is filtered through the capillaries of the vascular glomerulus* into the cavity of the renal corpuscle capsule. From the capsule it passes to other parts of the nephron where reabsoption occurs. It is *absorption of useful substances from the primary urine into the blood*. The renal corpuscle has two poles: 1 – a *vascular pole*, where the afferent arteriole enters the renal corpuscle and the efferent arteriole exits from it, 2 – a *urinary pole*, where the nephron capsule passes to the proximal tubule. The proximal and distal tubules are presented with *convoluted tubules*, and the nephron loop with *straight tubules*. From the nephron the *secondary urine* is collected in the *collecting tubule* which begins the *urinary tract*. The urinary tract consists of ureters which take the urine from the renal pelvis, a urinary bladder and a urethra. They have somewhat similar histologic structure, with the walls containing three tunics: mucosa, submucosa, muscular and adventitia, except for the upper part of the bladder that is covered with serosa.

Questions for self-control:

1. Name the distinctive features of the organ structure of the respiratory tract.
2. Name the tunics of the respiratory tract wall.
3. What is the structural and functional unit of the respiratory part?
4. What is the surfactant?
5. What functions does the urinary system perform?
6. What is the structural and functional unit of the kidney?
7. Describe the blood circulation in the kidney.
8. Describe the microscopic structure of the nephrons.

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Lecture 24

The Respiratory System 3
Gas Exchange and Transport

Outcomes:

1. define partial pressure and discuss its relationship to a gas mixture such as air;
2. contrast the composition of inspired and alveolar air;
3. discuss how partial pressure affects gas transport by the blood;
4. describe the mechanisms of transporting O2 and CO2;
5. describe the factors that govern gas exchange in the lungs and systemic capillaries; explain how gas exchange is adjusted to the metabolic needs of different tissues; and discuss the effect of blood gases and pH on the respiratory rhythm.

Composition of Air

Air consists of about 78.6% nitrogen; 20.9% oxygen; 0.04% carbon dioxide; several quantitatively minor gases such as argon, neon, helium, methane, and ozone; and a variable amount of water vapor. Water vapor constitutes from 0% to 4%, depending on temperature and humidity; we will use a value of 0.5%, typical of a cool clear day.

- The **total atmospheric pressure** is a sum of the contributions of these individual gases—a principle known as **Dalton's law**.
- The separate contribution of each gas in a mixture is called its partial pressure and is symbolized with a **P** followed by the formula of the gas, such as **PN2**.
- Applying Dalton's law to the aforementioned mixture of gases in the air gives us the following:

PN2 + PO2 + PH2O + PCO2≈ 597 + 159 + 3.7 + 0.3= 760.0 mm Hg.

The Gas Laws of Respiratory Physiology

Boyle's law	The pressure of a given quantity of gas is inversely proportional to its volume (assuming a constant temperature).
Charles's law	The volume of a given quantity of gas is directly proportional to its absolute temperature (assuming a constant pressure).
Dalton's law	The total pressure of a gas mixture is equal to the sum of the partial pressures of its individual gases.
Henry's law	At the air–water interface, the amount of gas that dissolves in water is determined by its solubility in water and its partial pressure in the air (assuming a constant temperature).

This is the composition of the air we inhale, but it is not the composition of air in the alveoli. Alveolar air can be sampled with an apparatus that collects the last 10 mL of expired air. its composition differs from that of the atmosphere because of three influences:

(1) It is humidified by contact with the mucous membranes, so its PH2o is more than 10 times higher than that of the inhaled air.

(2) Freshly inspired air mixes with residual air left from the previous respiratory cycle, so its oxygen is diluted and it is enriched with CO2 from the residual air.

(3) Alveolar air exchanges O2 and CO2 with the blood. Thus, the PO2 of alveolar air is about 65% that of inhaled air, and its PCO2 is more than 130 times higher.

Alveolar Gas Exchange

- Air in the alveolus is in contact with the film of water covering the alveolar epithelium. For oxygen to get into the blood, it must dissolve in this water and pass through the respiratory membrane separating the air from the bloodstream.
- For carbon dioxide to leave the blood, it must pass the other way and diffuse out of the water film into the alveolar air.
- This back-and-forth traffic of O2 and CO2 across the respiratory membrane is called *alveolar gas exchange.*
- The reason that O2 can diffuse in one direction and CO2 in the other is that each gas diffuses down its own partial pressure gradient.
- Whenever air and water are in contact with each other, gases diffuse down their gradients until the partial pressure of each gas in the air is equal to its partial pressure in the water. If a gas has a greater partial pressure in the water than in the air, it diffuses into the air; the smell of chlorine near a swimming pool is evidence of this. If its partial pressure is greater in the air, it diffuses into the water.

Questions for control

1. Why is the composition of alveolar air different from that of the atmosphere?
2. What four factors affect the efficiency of alveolar gas exchange?
3. Explain how perfusion of a pulmonary lobule changes if it is poorly ventilated.
4. How is most oxygen transported in the blood, and why does carbon monoxide interfere with this?
5. What are the three ways in which blood transports CO2?
6. Give two reasons why highly active tissues can extract more oxygen from the blood than less active tissues do.
7. Define hypocapnia and hypercapnia. Name the pH imbalances that result from these conditions and explain the relationship between Pco2 and pH.
8. What is the most potent chemical stimulus to respiration, and where are the most effective chemoreceptors for it located?
9. Explain how changes in pulmonary ventilation can correct pH imbalances.

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Lecture 25

The Respiratory System 4
Respiratory Disorders Questions for control

Outcomes:

- explain the significance of anatomical dead space to alveolar ventilation;
- define the clinical measurements of pulmonary volume and capacity;
- define terms for various deviations from the normal pattern of breathing
- describe the forms and effects of oxygen deficiency and oxygen excess;
- describe the chronic obstructive pulmonary diseases and their consequences; explain how lung cancer begins, progresses, and exerts its lethal effects

Alveolar Ventilation

- Air that actually enters the alveoli becomes available for gas exchange, but not all inhaled air gets that far. About 150 mL of it fills the conducting zone of the airway. Since this air cannot exchange gases with the blood, the conducting zone is called the **anatomical dead space. The dead space is typically about 1 mL** per pound of body weight in a healthy person.
- **Physiological (total) dead space is the sum of anatomical** dead space and any pathological alveolar dead space that may exist.
- If a person inhales 500 mL of air and 150 mL of it stays in the dead space, then 350 mL ventilates the alveoli. Multiplying this by the respiratory rate gives the **alveolar ventilation rate (AVR)—**
- for example, 350 mL/breath × 12 breaths/min. = 4,200 mL/min.
- The lungs never completely empty during expiration. There is always some leftover air called the *residual volume, typically* about 1,300 mL that one cannot exhale even with maximum effort.

- Clinicians often measure a patient's pulmonary ventilation in order to assess the severity of a respiratory disease or monitor the patient's improvement or deterioration. The process of making such measurements is called **spirometry.**

Four values are called *respiratory volumes: tidal* volume, inspiratory reserve volume, expiratory reserve volume, and residual volume.

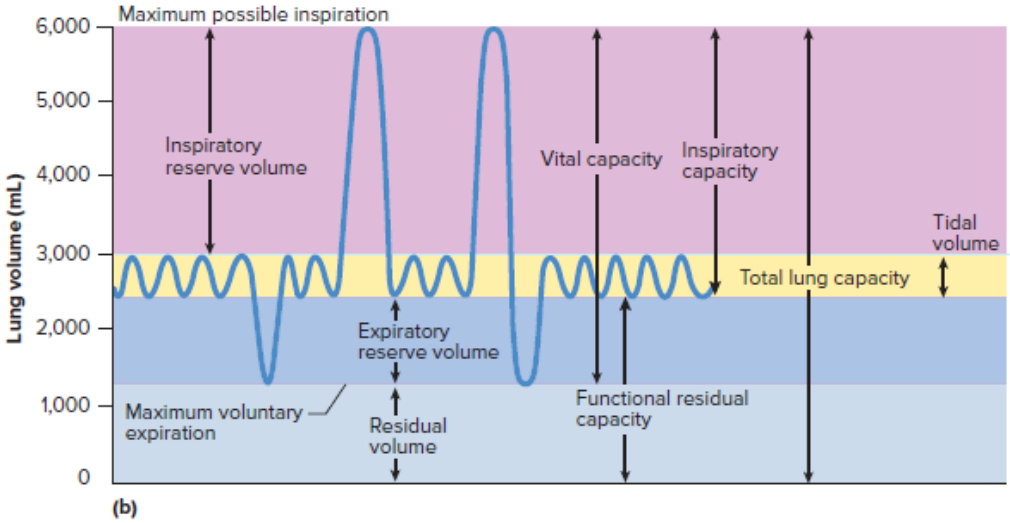

TABLE 22.2 Respiratory Volumes and Capacities for an Average Young Adult Male

Measurement	Typical Value	Definition
Respiratory Volumes		
Tidal volume (TV)	500 mL	Amount of air inhaled and exhaled in one cycle during quiet breathing
Inspiratory reserve volume (IRV)	3,000 mL	Amount of air in excess of tidal volume that can be inhaled with maximum effort
Expiratory reserve volume (ERV)	1,200 mL	Amount of air in excess of tidal volume that can be exhaled with maximum effort
Residual volume (RV)	1,300 mL	Amount of air remaining in the lungs after maximum expiration; the amount that can never be voluntarily exhaled
Respiratory Capacities		
Vital capacity (VC)	4,700 mL	The amount of air that can be inhaled and then exhaled with maximum effort; the deepest possible breath (VC = ERV + TV + IRV)
Inspiratory capacity (IC)	3,500 mL	Maximum amount of air that can be inhaled after a normal tidal expiration (IC = TV + IRV)
Functional residual capacity (FRC)	2,500 mL	Amount of air remaining in the lungs after a normal tidal expiration (FRC = RV + ERV)
Total lung capacity (TLC)	6,000 mL	Maximum amount of air the lungs can contain (TLC = RV + VC)

TABLE 22.5 Some Disorders of the Respiratory System

Acute rhinitis	The common cold. Caused by many types of viruses that infect the upper respiratory tract. Symptoms include congestion, increased nasal secretion, sneezing, and dry cough. Transmitted especially by contact of contaminated hands with mucous membranes; not transmitted orally.
Adult respiratory distress syndrome	Acute lung inflammation and alveolar injury stemming from trauma, infection, burns, aspiration of vomit, inhalation of noxious gases, drug overdoses, and other causes. Alveolar injury is accompanied by severe pulmonary edema and hemorrhaging, followed by fibrosis that progressively destroys lung tissue. Fatal in about 40% of cases under age 60 and in 60% of cases over age 65.
Pneumonia	A lower respiratory infection caused by any of several viruses, fungi, or protozoans, but most often the bacterium *Streptococcus pneumoniae*. Causes filling of alveoli with fluid and dead leukocytes and thickening of the respiratory membrane, which interferes with gas exchange and causes hypoxemia. Especially dangerous to infants, the elderly, and people with compromised immune systems, such as AIDS and leukemia patients.
Sleep apnea	Cessation of breathing for 10 seconds or longer during sleep; sometimes occurs hundreds of times per night, often accompanied by restlessness and alternating with snoring. Can result from altered function of CNS respiratory centers, airway obstruction, or both. Over time, may lead to daytime drowsiness, hypoxemia, polycythemia, pulmonary hypertension, congestive heart failure, and cardiac arrhythmia. Most common in obese people and men.
Tuberculosis (TB)	Pulmonary infection with the bacterium *Mycobacterium tuberculosis*, which invades the lungs by way of air, blood, or lymph. Stimulates the lung to form fibrous nodules called tubercles around the bacteria. Progressive fibrosis compromises the elastic recoil and ventilation of the lungs and causes pulmonary hemorrhaging as it invades blood vessels. Especially common among impoverished and homeless people and becoming increasingly common among people with AIDS.

You can find other respiratory system disorders described in the following places: *Cystic fibrosis* in Deeper Insight 3.2; *pulmonary hypertension* and *pulmonary edema* in section 19.5; *cor pulmonale* in sections 19.6 and 22.4; *asthma* in Deeper Insight 21.3; *Ondine's curse* in Deeper Insight 22.2; *pneumothorax* and *atelectasis* in section 22.2; *apnea, dyspnea, orthopnea, hyperpnea, tachypnea, hyper- and hypoventilation, Kussmaul respiration,* and *respiratory arrest* in table 22.3; *carbon monoxide poisoning* in Deeper Insight 22.4; *hypoxia, COPDs (emphysema* and *chronic bronchitis),* and *lung cancer* in section 22.4; *decompression sickness* in Deeper Insight 22.5; *respiratory acidosis* and *alkalosis* in section 24.3; and *infant respiratory distress syndrome* in section 29.3.

Questions for control

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Lecture 26

The urinary System 1
Functions of the Urinary System. Anatomy of the Kidney

Outcomes:
a. name and locate the organs of the urinary system;
b. list several functions of the kidneys in addition to urine formation;
c. name the major nitrogenous wastes and identify their sources;
d. define excretion and identify the systems that excrete wastes.
e. describe the location and general appearance of the kidneys;
f. identify the external and internal features of the kidney;
g. trace the flow of blood through the kidney;
h. trace the flow of fluid through the renal tubules;
i. describe the nerve supply to the kidney

Functions of the Kidneys

1. They filter the blood and excrete the toxic metabolic wastes.
2. They regulate blood volume, pressure, and osmolarity by regulating water output.
3. They regulate the electrolyte and acid–base balance of the body fluids.
4. They secrete the hormone erythropoietin, which stimulates the production of red blood cells and thus supports the oxygen-carrying capacity of the blood.
5. They help to regulate calcium homeostasis and bone metabolism by participating in the synthesis of calcitriol.
6. They clear hormones and drugs from the blood and thereby limit their action.
7. They detoxify free radicals.
8. In conditions of extreme starvation, they help to support the blood glucose level by synthesizing glucose from amino acids.

Nitrogenous Wastes

- A **waste** is any substance that is useless to the body or present in excess of the body's needs.
- A **metabolic waste** is a waste substance produced by the body. Among the most toxic of our metabolic wastes are small nitrogen-containing compounds called **nitrogenous wastes**.
- About 50% of the nitrogenous waste is **urea**, a byproduct of protein catabolism.
- Proteins are hydrolyzed to amino acids, and then the —NH2 group is removed from each amino acid.

- The —NH2 forms **ammonia**, which is exceedingly toxic but which the liver quickly converts to urea, CO(NH2)2, a somewhat less toxic waste.
- Other nitrogenous wastes in the urine include **uric acid** and **creatinine**, produced by the catabolism of **nucleic acids** and **creatine phosphate**.
- Although less toxic than ammonia and less abundant than urea, these too are potentially harmful. The level of nitrogenous waste in the blood is typically expressed as **blood urea nitrogen** (BUN), 10 to 20 mg/dL.
- An elevated BUN is called **azotemia** and may indicate renal insufficiency. It can progress to **uremia**, a syndrome of diarrhea, vomiting, dyspnea, and cardiac arrhythmia stemming from the toxicity of the nitrogenous wastes.

Excretion

Excretion is the process of separating wastes from the body fluids and eliminating them from the body. It is carried out by four organ systems:

1. The respiratory system excretes carbon dioxide, small amounts of other gases, and water.
2. The integumentary system excretes water, inorganic salts, lactate, and urea in the sweat.
3. The digestive system not only eliminates food residue (which is not a process of excretion) but also actively excretes water, salts, carbon dioxide, lipids, bile pigments, cholesterol, and other metabolic wastes.
4. The urinary system excretes a broad variety of metabolic wastes, toxins, drugs, hormones, salts, hydrogen ions, and water

Position and Associated Structures

The kidneys lie against the posterior abdominal wall at the level of vertebrae T12 to L3. The right kidney is slightly lower than the left because of the space occupied by the large right lobe of the liver above it. Rib 12 crosses the approximate middle of the left kidney. The kidneys are retroperitoneal, along with the *ureters, urinary bladder, renal artery and vein, and the adrenal glands*

Each kidney weighs about 150 g and measures about 11 cm long, 6 cm wide, and 3 cm thick. The lateral surface is convex, and the medial surface is concave and has a slit, **the hilum**, that admits the renal nerves, blood vessels, lymphatics, and ureter.

The kidney is protected by **three layers of connective tissue**:

(1) **A fibrous renal fascia**, immediately deep to the parietal peritoneum, binds the kidney and associated organs to the abdominal wall;

(2) **the perirenal fat capsule**, a layer of adipose tissue, cushions the kidney and holds it in place; and

(3) **the fibrous capsule** encloses the kidney like a cellophane wrapper anchored at the hilum, and protects it from trauma and infection.

Questions for control

1. State at least four functions of the kidneys other than forming urine.
2. List four nitrogenous wastes and their metabolic sources.
3. Name some wastes eliminated by three systems other than the urinary system.
4. Arrange the following in order from the most numerous to the least numerous structures in a kidney: glomeruli, major calyces, minor calyces, cortical radiate arteries, interlobar arteries.

5. Trace the path taken by one red blood cell from the renal artery to the renal vein.
6. Consider one molecule of urea in the urine. Trace the route that it took from the point where it left the bloodstream to the point where it left the body.

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Lecture 27

The urinary System 2
Urine Formation I: Glomerular Filtration

Outcomes:

1. describe the process by which the kidney filters the blood plasma, including the relevant cellular structure of the glomerulus
2. Explain the forces that promote and oppose filtration, and calculate the filtration pressure if given the magnitude of these forces
3. describe how the nervous system, hormones, and the nephron itself regulate filtration

- The kidney converts blood plasma to urine in four stages:

1. glomerular filtration,
2. tubular reabsorption,
3. tubular secretion,
4. water conservation

- The fluid in the capsular space, called ***glomerular filtrate***, is similar to blood plasma except that it **has almost no protein**.
- The fluid from the proximal convoluted tubule through the distal convoluted tubule is called ***tubular fluid***. It differs from the glomerular filtrate because of substances removed and added by the tubule cells.
- The fluid is called ***urine*** once it enters the collecting duct, since it undergoes little alteration beyond that point except for a change in water content.

The Filtration Membrane

Glomerular filtration, discussed in this section, is a process in which water and some solutes in the blood plasma pass from capillaries of the glomerulus into the capsular space of the nephron. To do so, fluid passes through three barriers that constitute a **filtration membrane:**

1. The **fenestrated endothelium** of the capillary. Endothelial cells of the glomerular capillaries are honeycombed with large filtration pores about 70 to 90 nm in diameter. Like fenestrated capillaries elsewhere, these are highly permeable, although their pores are small enough to exclude blood cells from the filtrate.

2. **The basement membrane.**

- This consists of a proteoglycan gel. A few particles may penetrate its small spaces, but most would be held back.
- On the basis of size alone, the basement membrane excludes molecules larger than 8 nm.

- Even some smaller molecules, however, are held back by a negative charge on the proteoglycans.
- Blood albumin is slightly smaller than 7 nm, but it is also negatively charged and thus repelled by the basement membrane.
- Although the blood plasma is 7% protein, the glomerular filtrate is only 0.03% protein. It has traces of albumin and smaller polypeptides, including some hormones.

3. **Filtration slits**.

- A podocyte of the glomerular capsule is shaped somewhat like an octopus, with a bulbous cell body and several thick arms.
- Each arm has numerous little extensions called **foot processes (pedicels)** that wrap around the capillaries and interdigitate with each other.
- The foot processes have negatively charged **filtration slits** about 30 nm wide between them, which are an additional obstacle to large anions.

Questions for control

1. Name the four major processes in urine production.
2. Trace the movement of a urea molecule from the blood to the capsular space, and name the barriers it passes through.
3. Calculate the net filtration pressure in a patient whose blood COP is only 10 mm Hg because of hypoproteinemia.
4. Assume other relevant variables to be normal.
5. Assume a person is moderately dehydrated and has low blood pressure. Describe the homeostatic mechanisms that would help the kidneys maintain a normal GFR.

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Lecture 28-29

The urinary System 4
Urine Formation III: Water Conservation Basic literature:

Outcomes:
a. describe how the renal tubules reabsorb useful solutes from the glomerular filtrate and return them to the blood;
b. describe how the tubules secrete solutes from the blood into the tubular fluid;
c. describe how the nephron regulates water excretion

The Proximal Convoluted Tubule

- reabsorbs about 65% of the glomerular filtrate
- The importance of the PCT is reflected in its relatively great length and prominent microvilli, which increase its absorptive surface area. Its cells also contain abundant large mitochondria that provide ATP for active transport.

Tubular Reabsorption
the process of reclaiming water and solutes from the tubular fluid and returning them to the blood.
two routes of reabsorption:
(1) t***he transcellular route***, in which substances pass through the cytoplasm and out the base of the epithelial cells;
(2) ***the paracellular route***, in which substances pass through gaps between the cells
solvent drag - The "tight" junctions between the epithelial cells are quite leaky and allow significant amounts of water to pass through. As it travels through the epithelium, water carries with it a variety of dissolved solutes. This process is solvent drag.
Sodium Chloride

- the most abundant cation in the glomerular filtrate, with a concentration of 140 mEq/L in the fluid entering the proximal convoluted tubule and only 12 mEq/L in the cytoplasm of the epithelial cells.

Two types of transport proteins in the apical cell surface are responsible for sodium uptake:
(1) **various symports** that simultaneously bind Na+ and another solute such as glucose, aminoacids, or lactate;
(2) **an Na+–H+ antiport** that pulls Na+ into the cell while pumping H+ out of the cell into the tubular fluid. This antiport is a means not only of reabsorbing sodium, but also of eliminating acid from the body fluids. Angiotensin II activates the Na+–H+ antiport and thereby exerts a strong influence on sodium reabsorption.
Sodium Chloride

- **Sodium** is prevented from accumulating in the epithelial cells by Na+–K+ pumps in the basal domain of the plasma membrane, which pump Na+ out into the extracellular fluid. From there, it is picked up by the peritubular capillaries and returned to the bloodstream.

- These Na+–K+ pumps, like those anywhere, are ATP-consuming active transport pumps. Although the sodium transporting symports in the apical membrane do not consume ATP, they are considered an example of **secondary active transport** because of their dependence on the Na+–K+ pumps at the base of the cell.
- **Chloride ions**, being negatively charged, follow Na+ because they are electrically attracted to it.

- antiports in the apical cell membrane that absorb Cl– in exchange for other anions that they eject into the tubular fluid.
- Chloride and potassium ions are driven out through the basal cell surface by a K+–Cl– symport. Both Na+ and Cl– also pass through the tubule epithelium by the paracellular route.

Other Electrolytes

- *Potassium*, *magnesium*, and *phosphate* ions pass through the paracellular route with water.
- Phosphate is also cotransported into the epithelial cells with Na+.
- Roughly 52% of the filtered calcium is reabsorbed by the paracellular route and 14% by the transcellular route in the PCT. *Calcium* absorption here is independent of hormonal influence, but another 33% of the calcium is reabsorbed later in the nephron under the influence of parathyroid hormone. The remaining 1%, normally, is excreted in the urine.

Questions for control

1. The reabsorption of water, Cl–, and glucose by the PCT is linked to the reabsorption of Na+, but in three very different ways. Contrast these three mechanisms.
2. Explain why a substance appears in the urine if its rate of glomerular filtration exceeds the Tm of the renal tubule.
3. Contrast the effects of aldosterone and natriuretic peptides on the renal tubule.

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Lecture 30

The urinary System 5
Urine and Renal Function Tests

Outcomes:

1. describe the functional anatomy of the ureters, urinary bladder, and male and female urethra;
2. explain how the nervous system and urethral sphincters control the voiding of urine;
3. and describe some physical and chemical properties of urine.

- Medical diagnosis often rests on determining the current and recent physiological state of the tissues. No two fluids are as valuable for this purpose as blood and urine.
- **Urinalysis,** the examination of the physical and chemical properties of urine, is therefore one of the most routine procedures in medical examinations.
- The principal characteristics of urine and certain tests used to evaluate renal function.

The basic composition and properties of urine are as follows:

- ❑ Appearance
- ❑ Odor
- ❑ Specific gravity
- ❑ Osmolarity
- ❑ pH

Chemical composition

Physical Properties		
Specific gravity	1.001–1.028	
Osmolarity	50–1,200 mOsm/L	
pH	6.0 (range 4.5–8.2)	
Solute	**Concentration***	**Output****
Inorganic Ions		
Chloride	533 mg/dL	6.4 g/day
Sodium	333 mg/dL	4.0 g/day
Potassium	166 mg/dL	2.0 g/day
Phosphate	83 mg/dL	1 g/day
Ammonia	60 mg/dL	0.68 g/day
Calcium	17 mg/dL	0.2 g/day
Magnesium	13 mg/dL	0.16 g/day
Nitrogenous Wastes		
Urea	1.8 g/dL	21 g/day
Creatinine	150 mg/dL	1.8 g/day
Uric acid	40 mg/dL	0.5 g/day
Urobilin	125 µg/dL	1.52 mg/day
Bilirubin	20 µg/dL	0.24 mg/day
Other Organics		
Amino acids	288 µg/dL	3.5 mg/day
Ketones	17 µg/dL	0.21 mg/day
Carbohydrates	9 µg/dL	0.11 mg/day
Lipids	1.6 µg/dL	0.02 mg/day

Questions for control

1. Define oliguria and polyuria. Which of these is characteristic of diabetes?
2. Identify a cause of glycosuria other than diabetes mellitus.
3. How is the diuresis produced by furosemide like the diuresis produced by diabetes mellitus? How are they different?
4. Explain why GFR cannot be determined by measuring the amount of NaCl in the urine.

Basic literature:

1. Saladin, Kenneth S: Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education) на англ. яз.
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5. Andersson D, Medical Terminology: The Best and Most Effective Way to Memorize, Pronounce and Understand Medical Terms: Second Edition, ISBN-13 : 978-1519066626, 2016

Lecture 7 Nutrition.

Lecture outlines

A. Body Weight and Energy Balance
B. Appetite
C. Calories
D. Nutrients
1.Carbohydrates
2.Fiber
3.Lipids
4.Proteins
5. Minerals and Vitamins

Learning Outcomes

1.Describe some factors that regulate hunger and satiety;
2.Define *nutrient* and list the six major categories of nutrients;
3.State the function of each class of macronutrients, the approximate amounts required in the diet, and some major dietary sources of each;
4.Name the blood lipoproteins, state their functions, and describe how they differ from each other; and
5.Name the major vitamins and minerals required by the body and the general functions they serve.

Nutrition and diet affect your metabolism. More energy is required to break down fats and proteins than carbohydrates; however, all excess calories that are ingested will be stored as fat in the body. On average, a person requires 1500 to 2000 calories for normal daily activity, although routine exercise will increase that amount. If you ingest more than that, the remainder is stored for later use. Conversely, if you ingest less than that, the energy stores in your body will be depleted. Both the quantity and quality of the food you eat affect your metabolism and can affect your overall health. Eating too much or too little can result in serious medical conditions, including cardiovascular disease, cancer, and diabetes.
Vitamins and minerals are essential parts of the diet. They are needed for the proper function of metabolic pathways in the body. Vitamins are not stored in the body, so they must be obtained from the diet or synthesized from precursors available in the diet. Minerals are also obtained from the diet, but they are also stored, primarily in skeletal tissues.

Control Questions

1.Name two hormones that regulate short-term hunger and satiety. How does leptin differ from these in its effects?
2.What class of nutrients provides most of the calories in the diet? What class of nutrients provides the body's major reserves of stored energy?
3.Contrast the functions of VLDLs, LDLs, and HDLs. Explain how this is related to the fact that a high blood HDL level is desirable, but a high VLDL–LDL level is undesirable.

Reference

1.Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2.Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company)

Lecture 8 Metabolic States and Metabolic Rate Body Heat and Thermoregulation

Lecture outlines

A. Body Weight and Energy Balance
B. Appetite
C. Calories
D. Nutrients
1.Carbohydrates
2.Fiber
3.Lipids
4.Proteins
5. Minerals and Vitamins

Learning Outcomes

1.Define the absorptive and postabsorptive states; Explain what happens to carbohydrates, fats, and proteins in each of these states;Describe the hormonal and nervous regulation of each state;
2.Define *metabolic rate* and *basal metabolic rate* and describe some factors that alter the metabolic rate.
3. Identify the principal sources of body heat; describe some factors that cause variations in body temperature; define and contrast the different forms of heat loss;
4.describe how the hypothalamus monitors and controls body temperature; describe conditions in which the body temperature is excessively high or low.

There are two main metabolic states of the body: absorptive (fed), postabsorptive (fasting). During any given day, your metabolism switches between absorptive and postabsorptive states. When the body is fed, glucose, fats, and proteins are absorbed across the intestinal membrane and enter the bloodstream and lymphatic system to be used immediately for fuel. Any excess is stored for later fasting stages. As blood glucose levels rise, the pancreas releases insulin to stimulate the uptake of glucose by hepatocytes in the liver, muscle cells/fibers, and adipocytes (fat cells), and to promote its conversion to glycogen. As the postabsorptive state begins, glucose levels drop, and there is a corresponding drop in insulin levels. Falling glucose levels trigger the pancreas to release glucagon to turn off glycogen synthesis in the liver and stimulate its breakdown into glucose. The glucose is released into the bloodstream to serve as a fuel source for cells throughout the body. If glycogen stores are depleted during fasting, alternative sources, including fatty acids and proteins, can be metabolized and used as fuel. When the body once again enters the absorptive

state after fasting, fats and proteins are digested and used to replenish fat and protein stores, whereas glucose is processed and used first to replenish the glycogen stores in the peripheral tissues, then in the liver. If the fast is not broken and starvation begins to set in, during the initial days, glucose produced from gluconeogenesis is still used by the brain and organs. After a few days, however, ketone bodies are created from fats and serve as the preferential fuel source for the heart and other organs, so that the brain can still use glucose. Once these stores are depleted, proteins will be catabolized first from the organs with fast turnover, such as the intestinal lining. Muscle will be spared to prevent the wasting of muscle tissue; however, these proteins will be used if alternative stores are not available.

Some of the energy from the food that is ingested is used to maintain the core temperature of the body. Most of the energy derived from the food is released as heat. The core temperature is kept around 36.5–37.5 °C (97.7–99.5 °F). This is tightly regulated by the hypothalamus in the brain, which senses changes in the core temperature and operates like a thermostat to increase sweating or shivering, or inducing other mechanisms to return the temperature to its normal range. The body can also gain or lose heat through mechanisms of heat exchange. Conduction transfers heat from one object to another through physical contact. Convection transfers heat to air or water. Radiation transfers heat via infrared radiation. Evaporation transfers heat as water changes state from a liquid to a gas.

Control Questions

1.Define *absorptive* and *post absorptive states*.In which state is the body storing excess fuel? In which state is it drawing from these stored fuel reserves? What hormone primarily regulates the absorptive state, and what are the major effects of this hormone?

2.What is the primary source of body heat? What mechanisms of heat loss are aided by convection?

4.Describe the positive feedback loops that can cause death from hyper- and hypothermia.

Reference

1.Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)

2.Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company)

Lecture 16 Male Reproductive Anatomy. Puberty, Hormonal Control and Climacteric.

Lecture outlines

A. Male Reproductive Anatomy
1.The Scrotum
2.The Testes
3. The Spermatic Ducts
4. The Accessory Glands
5. The Penis
B. Puberty, Hormonal Control, and Climacteric
1. Puberty and Adolescence
2. Hormonal Control of Male Reproductive Function
3. Aging and Sexual Function

Learning Outcomes

1.Describe the anatomy of the scrotum, testes, and penis;
2.Describe the pathway taken by a sperm cell from its formation to its ejaculation, naming all the passages it travels;
3.State the names, locations, and functions of the male accessory reproductive glands.
4.Describe the hormonal control of puberty and the resulting changes in the male body;
5.Describe *male climacteric* and the effect of aging on male reproductive function.

Key Terms

Androgens Generic term for hormones related to testosterone.
Estrogens The female sex hormones.
Gamete A sex cell, either a sperm or an ovum.
Gonads (gone = seed) The primary sex glands—the ovaries and testes.
Meiosis (mei = less) A form of cell division in which the daughter cells contain one-half the number of chromosomes as the parent cell.
Menopause (men = month; paus = stop) The cessation of monthly female reproductive cycles.
Menstrual cycle The repetitive monthly changes in the endometrium.
Oogenesis (oo = ovum, egg; genesis = origin) The process of ova formation.
Ovarian cycle The repetitive monthly changes in the ovary.
Ovulation The release of a secondary oocyte from an ovary.

Puberty (puber = grown up) The age at which reproductive organs mature.
Semen (semin = seed) Fluid composed of sperm and secretions of male accessory glands.
Spermatogenesis The process of sperm formation in the testes.

The common purpose of the male and female reproductive systems is to produce offspring.The functions of the male reproductive system are to produce spermatozoa, secrete androgens, and transfer spermatozoa to the reproductive system of the female. Features of the male reproductive system include the primary sex organs (the testes), secondary sex organs (those that are essential for reproduction), and secondary sex characteristics (sexual attractants, expressed after puberty).
The saclike scrotum, located in the urogenital portion of the perineum, supports and protects the testes and regulates their position relative to the pelvic region of the body.Each testis is contained within its own scrotal compartment and is separated from the other by the scrotal septum.
The testes are partitioned into wedge-shaped lobules; the lobules are composed of seminiferous tubules, which produce sperm cells, and of interstitial tissue, which produces androgens.
Spermatogenesis occurs by meiotic division of the cells that line the seminiferous tubules. At the end of the first meiotic division, two secondary spermatocytes have been produced. At the end of the second meiotic division, four haploid spermatids have been produced. The conversion of spermatids to spermatozoa is called spermiogenesis. A sperm consists of a head and a flagellum and matures in the epididymides prior to ejaculation.The acrosome of the head contains digestive enzymes for penetrating an ovum. The flagellum provides undulating movement of about 3 mm per hour.The epididymides and the ductus deferentia are the components of the spermatic ducts. The highly coiled epididymides are the tubular structures on the testes where spermatozoa mature and are stored. The ductus deferentia convey spermatozoa from the epididymides to the ejaculatory ducts during emission. Each ductus deferens forms a component of the spermatic cord. The seminal vesicles and prostate provide additives to the spermatozoa in the formation of semen. The seminal vesicles are located posterior to the base of the urinary bladder; they secrete about 60% of the additive fluid of semen. The prostate surrounds the urethra just below the urinary bladder; it secretes about 40% of the additive fluid of semen. Spermatozoa constitute less than 1% of the volume of an ejaculate. The small bulbourethral glands secrete fluid that serves as a lubricant for the erect penis in preparation for coitus. The male urethra, which serves both the urinary and reproductive systems, is divided into prostatic, membranous, and spongy portions. The penis is specialized to become erect for insertion into the vagina during coitus. The body of the penis consists of three columns of erectile tissue,

the spongy urethra, and associated vessels and nerves. The root of the penis is attached to the pubic arch and urogenital diaphragm. The glans penis is the terminal end, which is covered with the prepuce in an uncircumcised male.
At puberty, the hypothalamus secretes GnRH, which stimulates the anterior lobe of the pituitary to release FSH and LH. LH stimulates the production of testosterone. FSH and testosterone stimulate the production of sperm. Testosterone stimulates the maturation of the male reproductive organs, and the continuation of sperm production. It also develops and maintains the male secondary sex characteristics. Testosterone secretion is regulated by a negative-feedback mechanism. Sperm production is kept within normal limits by inhibin exerting a negative-feedback control on FSH secretion.

Control Questions

1.State the names and locations of two muscles that help regulate the temperature of the testes.
2.Name all the ducts that the sperm follow, in order, from the time they form in the testis to the time of ejaculation.
3.State the source, target organ, and effect of GnRH. Identify the target cells and effects of FSH and LH. Explain how testicular hormones affect the secretion of FSH and LH.
4.Describe the major effects of androgens on the body.

Reference

1.Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2.Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company)

Lecture 17 Sperm and Semen, Male Sexual Response

Lecture outlines

A.Sperm and Semen
1. Spermatogenesis
2. The Spermatozoon
3. Semen
B. Male Sexual Response
1.Anatomical Foundations
2. Excitement and Plateau
3. Orgasm and Ejaculation
4. Resolution

Learning Outcomes

1.Describe the sequence of cell types in spermatogenesis, and relate these to the stages of meiosis;
2.Describe the role of nurse cells in spermatogenesis; describe and label a sperm cell;
3.Describe the composition of semen and functions of its components.
4.Describe the blood and nerve supply to the penis and explain how these govern erection and ejaculation.

Spermatogenesis is the Process of Formation of Spermatocytes From Spermatogonia. Spermatogenesis is initiated at puberty, continues throughout the remainder of a man's life, and takes place in the walls of the *seminiferous tubules*.The initial step in the process is transformation of *type A spermatogonia,* which are epithelioid-like cells, to *type B spermatogonia,* a process involving four divisions. The type B cells embed in the Sertoli cells. In association with the Sertoli cells, the type B cells are transformed to *primary spermatocytes* and then, in a step involving the first meiotic division, to *secondary spermatocytes.* The secondary spermatocytes undergo a second meiotic division, yielding *spermatids,* each of which has 23 unpaired chromosomes. The steps described are stimulated by *testosterone* and *follicle-stimulating hormone (FSH).*
Spermiogenesis Is the Process of Transformation of the Spermatids, Which Are Still Epithelioid, to Sperm Cells. The process of spermiogenesis takes place with the cells embedded in the Sertoli cells; it requires *estrogen* and *FSH.*
Once the sperm cells are formed, they are extruded into the lumen of the tubule in a process stimulated by *luteinizing hormone (LH)*. The first division of the type A spermatogonia to extrusion of the sperm cells requires a period of

approximately 64 days. The newly formed sperm cells are not functional and require a *maturation process,* which takes place in the *epididymis* over a period of 12 days. Maturation requires both *testosterone* and *estrogen.* The mature sperm are stored in the *vas deferens.*

As is true for most cells in the body, the structure of sperm cells speaks to their function. Sperm have a distinctive head, mid-piece, and tail region. The head of the sperm contains the extremely compact haploid nucleus with very little cytoplasm. These qualities contribute to the overall small size of the sperm (the head is only 5 μm long). A structure called the acrosome covers most of the head of the sperm cell as a "cap" that is filled with lysosomal enzymes important for preparing sperm to participate in fertilization. Tightly packed mitochondria fill the mid-piece of the sperm. ATP produced by these mitochondria will power the flagellum, which extends from the neck and the mid-piece through the tail of the sperm, enabling it to move the entire sperm cell. The central strand of the flagellum, the axial filament, is formed from one centriole inside the maturing sperm cell during the final stages of spermatogenesis.

Semen (seminal fluid) – fluid expelled during orgasm,2-5 mL of fluid expelled during ejaculation,60% seminal vesicle fluid, 30% prostatic fluid, and 10% sperm and spermatic duct secretions, prostate produces a thin, milky white fluid, contains calcium, citrate, and phosphate ions,a clotting enzyme, protein-hydrolyzing enzyme called serine protease (prostate-specific antigen); seminal vesicles contribute viscous yellowish fluid, contains fructose and other carbohydrates, citrate, prostaglandins, and protein called proseminogelin.

Mechanisms of Erection, Emission, and Ejaculation

Erection of the penis occurs as the erectile tissue becomes engorged with blood. Emission is the movement of the spermatozoa from the epididymides to the ejaculatory ducts, and ejaculation is the forceful expulsion of semen from the ejaculatory ducts and urethra of the penis.

Parasympathetic stimuli to arteries in the penis cause the erectile tissue to engorge with blood as arteriole flow increases and venous drainage decreases.

Ejaculation is the result of sympathetic reflexes in the smooth muscles of the male reproductive organs

Control Questions

1.Name the stages of spermatogenesis from spermatogonium to spermatozoa. How do they differ in the number of chromosomes per cell and chromatids per chromosome?

2.Describe the two major parts of a spermatozoon and state what organelles or cytoskeletal components are contained in each.

3.List the major contributions of the seminal vesicles and prostate to the semen, and state the functions of these components.
4.Explain how penile blood circulation changes during sexual arousal and why the penis becomes enlarged and stiffened.

Reference

1.Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2.Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company)

Lecture 22 Oogenesis and the Sexual Cycle. Female Sexual Response

Lecture outlines

A.Oogenesis and the Sexual Cycle
1. Oogenesis
2. Folliculogenesis
3. The Sexual Cycle
B.Female Sexual Response
1. Excitement and Plateau
2.Orgasm
3. Resolution

Learning Outcomes

1.Describe the process of egg production (oogenesis);
2.Describe changes in the ovarian follicles in relation to oogenesis; describe the hormonal events that regulate the ovarian cycle;
3.Describe how the uterus changes during the menstrual cycle.

Oogenesis is the process of producing female sex cells from oogonia. Millions of oogonia are formed during fetal development, but most degenerate. Those that remain become primary oocytes containing 46 chromosomes and are enveloped by a single layer of squamous follicular epithelial cells, forming primordial ovarian follicles. The mature ovarian follicle grows until it ruptures, releasing the secondary oocyte in ovulation. The infundibulum of a uterine tube receives the secondary oocyte, and the uterine tube carries it toward the uterus. If the secondary oocyte is penetrated by a sperm, the second meiotic division occurs, forming the ovum and a second polar body. Then, the sperm nucleus and ovum nucleus unite at fertilization.
Ovulation and menstruation are reproductive cyclic events that are regulated by hormones secreted by the hypothalamus, the anterior pituitary, and the ovaries.
The menstrual cycle is divided into menstrual, proliferative, and secretory phases. The principal hormones that regulate ovulation and menstruation are estrogen, progesterone, follicle-stimulating hormone (FSH), and luteinizing hormone (LH).
Sexual stimulation causes erection of the clitoris, bulbs of the vestibule, and nipples and secretion by the vestibular glands. Sexual response culminates in orgasm, which produces rhythmic contractions of muscles in the walls of the uterus and uterine tubes and a feeling of intense pleasure.

Control Questions

1.What are the similarities and the differences between oogenesis and spermatogenesis?
2.If a woman has lower than normal blood levels of estrogens and LH, and higher than normal blood levels of GnRH, which organ(s) does (do) not function normally? Why?

Reference

1.Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2.Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company)

Lecture 23 Pregnancy and Childbirth. Lactation

Lecture outlines

A.Pregnancy and Childbirth
1.Prenatal Development
2. Hormones of Pregnancy
3 Adjustments to Pregnancy
4 Childbirth
5 The Puerperium
B Lactation
1.Development of the Mammary Glands
2.Colostrum and Milk Synthesis
3.Milk Ejection
4.Breast Milk

Learning Outcomes

1.List the major hormones that regulate pregnancy and explain their roles;
2.Describe a woman's bodily adaptations to pregnancy; describe the physiological changes that occur in a woman during the weeks following childbirth;
3.Identify the physical and chemical stimuli that increase uterine contractility in late pregnancy;
4.Describe the mechanism of labor contractions; name and describe the three stages of labor;
5.Describe development of the breasts in pregnancy; describe the shifting hormonal balance that regulates the onset and continuation of lactation;
6.Describe the mechanism of milk ejection;
7.Contrast colostrum with breast milk and discuss the benefits of breast-feeding.

Hormones (especially estrogens, progesterone, and hCG) secreted by the corpus luteum and later by the placenta are responsible for most of the changes experienced during pregnancy. Estrogen maintains the pregnancy, promotes fetal viability, and stimulates tissue growth in the mother and developing fetus. Progesterone prevents new ovarian follicles from developing and suppresses uterine contractility.Pregnancy weight gain primarily occurs in the breasts and abdominal region. Nausea, heartburn, and frequent urination are common during pregnancy. Maternal blood volume increases by 30 percent during pregnancy and respiratory minute volume increases by 50 percent. The skin may develop stretch marks and melanin production may increase.Toward the

late stages of pregnancy, a drop in progesterone and stretching forces from the fetus lead to increasing uterine irritability and prompt labor. Contractions serve to dilate the cervix and expel the newborn. Delivery of the placenta and associated fetal membranes follows.

The lactating mother supplies all the hydration and nutrients that a growing infant needs for the first 4–6 months of life. During pregnancy, the body prepares for lactation by stimulating the growth and development of branching lactiferous ducts and alveoli lined with milk-secreting lactocytes, and by creating colostrum. These functions are attributable to the actions of several hormones, including prolactin. Following childbirth, suckling triggers oxytocin release, which stimulates myoepithelial cells to squeeze milk from alveoli. Breast milk then drains toward the nipple pores to be consumed by the infant. Colostrum, the milk produced in the first postpartum days, provides immunoglobulins that increase the newborn's immune defenses. Colostrum, transitional milk, and mature breast milk are ideally suited to each stage of the newborn's development, and breastfeeding helps the newborn's digestive system expel meconium and clear bilirubin. Mature milk changes from the beginning to the end of a feeding. Foremilk quenches the infant's thirst, whereas hindmilk satisfies the infant's appetite.

Control Questions

1.List the roles of HCG, estrogen, progesterone, and HCS in pregnancy
2.Describe the positive feedback theory of labor.
2.Explain why a miscarriage is likely if the placenta is too slow to take over its hormone-producing role.
3.Why is little or no milk secreted while a woman is pregnant? How does a lactating breast differ from a nonlactating breast in structure? What stimulates these differences to develop during pregnancy? How does suckling stimulate milk ejection?

Reference

1.Kenneth S Saladin - Anatomy & Physiology. The Unity of Form and Function (2016, McGraw-Hill Education)
2.Barbara Gylys - Medical Terminology Systems (2012, F.A. Davis Company)