CURRICULUM OF PHYSIOLOGY

GENERAL MEDICINE

ACADEMIC YEAR 2023/2024

Textbooks:
Vanders´s Human Physiology (E. Widmaier, H. Raff, K.Strang)
MOODLE = http://lms.lfp.cuni.cz/course/view.php?id=117

GENERAL PHYSIOLOGY AND PHYSIOLOGY OF EXCITABLE TISSUES

Functional morphology of the cell. – Cell membrane; structure, principal functions. – Nucleus and nucleolus; structure, composition, function. – Ribosomes; function, relation to endoplasmic reticulum. – Endoplasmic reticulum; role in intermediary metabolism and storage of calcium ions. – Golgi apparatus. – Cytoskeleton; fibre types and functions. – Mitochondria; structure, roles in intermediary and energy metabolism. – Lysosomes and peroxisomes.

Biological membranes. – Cytoplasmic membrane; composition, functions. – Membrane phospholipids; structure, importance, role. Factors affecting membrane fluidity. – Membrane proteins. Integral and peripheral proteins. Functions of membrane proteins. Examples. – Glycocalyx.

Membrane channels. – Classification according selectivity, localisation, gating. Types of gated membrane channels. – Voltage-gated membrane channels; structure, types, principal roles, examples. – Ligand-gated membrane channels; structure, typical ligands, examples. – Mechanosensitive membrane channels; localisation, role, examples. – Aquaporins. – Intercellular channels.

Membrane transport. Composition of extracellular and intracellular fluid. – Active and passive transmembrane trafficking of substances. – Passive transport. Diffusion. Fick's first law of diffusion. Diffusion coefficient. Facilitated diffusion. Transport maximum. – Active transport. Primary active transport. Na-K-ATPase. Secondary active transport. Symport. Antiport. – Endocytosis and exocytosis.

Intercellular communication. – Types, typical features, major differences. – Gap junction; structure, function, regulation, examples. – Autocrine and paracrine signalling; significance, examples, characteristic. – Endocrine signalling; characteristic, hormone definition, responses of target tissues. – Nervous signalling; synapse, characteristic, types of synapses.

Synapse. – Definition. – Classification according to the mode of transmission, elements in contact, function. – Specialised synapses. – Structure of a synapse. – Electrical synapse; synaptic delay, direction and mode of information transmission. – Chemical synapse; presynaptic element, synaptic vesicles, synaptic cleft, postsynaptic and subsynaptic membrane, receptors. – Inhibitory and excitatory postsynaptic potential. – Principal morphological and functional differences between electrical and chemical synapse.

Neurotransmitters. – Definition of neurotransmitter, criteria. – Typical neurotransmitters in the human nervous system. – Catecholamines; compounds, sources, synthesis, receptors, degradation. – Acetylcholine; sources, synthesis, receptors, degradation. – Principal roles of dopamine, serotonin, glutamic acid, glycine and GABA.
Receptors. – Properties of receptors for chemical messengers. – Intracellular receptors; cytoplasmic and nuclear receptors. – Membrane receptors; major classification. – Second

messenger; explanation, examples. – Receptor channels. – G protein-coupled receptors; sequence of events from binding of a ligand to the receptor to degradation of second messenger. – G proteins acting via adenylyl cyclase. G proteins acting via phospholipase C. G proteins acting via phosphodiesterase. – Catalytic receptors; classification; typical responses to stimulation. Guanylyl cyclases. Tyrosine kinases.

Resting membrane potential. Electrochemical equilibrium potential. Nernst equation. The impact of intracellular and extracellular fluid composition on electrochemical equilibrium potential. – Resting membrane potential; typical values. Influence of potassium and sodium currents and Na-K-ATPase activity. – Driving potential. – Influence of hyperkalaemia and hypokalaemia on membrane potential.

Graded membrane response to stimulation and its propagation. – Excitable and non-excitable membrane. – Local (graded) response to stimulation; characteristic, amplitude, polarity, summation. – Propagation of graded potential; relation to intensity of stimulation and length constant. Characteristic of length constant. – Examples of graded potential. Sequence of events leading to generation of graded potential.

Action potential and its propagation. – Excitable and non-excitable membrane. – Conditions essential for action potential generation. – Sequence of events leading to generation of action potential. – Characteristic of action potential; threshold, phases, amplitude, polarity, summation, refractoriness, channels, duration. – Propagation of action potential on myelinated and unmyelinated membrane. – Types of nerve fibres; velocity of conduction of nerve impulses.

Physiology of skeletal muscle. – Structure of skeletal muscle. Sarcolemma and T-tubules. Sarcoplasmic reticulum. Myofibrils. Sarcomeres. Myofilaments. Contractile, regulatory and structural proteins. – Excitation-contraction coupling. – Molecular basis of contraction, formation of cross bridges. Role of ATP. – Mechanism of relaxation. – Summation phenomena. – Length-tension relation. – Types of muscle fibres. – Metabolism of skeletal muscle. Energy sources. Oxygen debt. Muscle fatigue.

Neuromuscular transmission. – Neuromuscular junction. Motor unit. – Structure of neuromuscular junction. – Acetylcholine; synthesis, release, receptors, degradation. – Sequence of events during neuromuscular transmission. – Effects of drugs on the neuromuscular junction; botulinum toxin, tubocurarine, neostigmine, suxamethonium.

Physiology of smooth muscle. – Structure and types of smooth muscle tissue. – Types of stimulation resulting in smooth muscle contraction. – Electrical activity. – Excitation-contraction coupling. – Molecular basis of contraction, formation of cross bridges. – Regulation of contraction – nervous and humoral. – Principal differences between smooth and skeletal muscle.

Body fluids. – Composition of human body. – Total body water. – Extracellular fluid. Plasma. Interstitial fluid. Transcellular fluids. – Intracellular fluid. – Composition of body fluids. – Determinants of total body water volume and composition. – Measurement of volumes of body fluid compartments. – Indicator-dilution method. Indicators. Calculated volumes.

Homeostasis. – Internal environment of the body; definition, causes of potential instability. – Homeostasis; definition, means, examples. – Complex regulation. – Regulated variables. – pH, acids and bases, acid-base balance, buffering systems of the blood and plasma. – Ionic composition, endocrine control. – Osmotic conditions in the body fluids; osmolality, molarity, osmotic pressure.

PHYSIOLOGY OF BLOOD AND THE IMMUNE SYSTEM

MOODLE

General characteristics and main functions of the blood. (MOODLE) Blood functions. Blood pH, blood buffers. – Blood volume. – Hematocrit. – Blood and plasma viscosities. – Erythrocytes sedimentation rate. Factors affecting erythrocytes sedimentation rate. Diagnostic significance of sedimentation rate.

Plasma. (MOODLE) Volume and composition of plasma, plasma osmolality. – Inorganic compounds of the plasma, their concentrations and functions. – Organic compounds of the plasma. Plasma proteins, their functions. Plasma lipids.

Erythrocytes. (MOODLE) Erythrocytes count and size. Price-Jones curve. – Erythrocyte's shape and its functions. – MCH, MCHC a MCV. – The RBC membrane and cytoskeleton. – Hemoglobin concentration, composition, types, functions, and forms. –The RBC energy metabolism.

Erythropoiesis. (MOODLE) Ontogenesis of erythropoiesis. Sites of RBCs production during prenatal and postnatal life. - Hematopoietic stem cells. - Reticulocytes and their diagnostic significance. - The factors necessary for normal erythropoiesis. – Iron metabolism. – Role of vitamin B_{12} and folic acid. – Hormonal regulation of erythropoiesis. - Sex differences in the number of red blood cells

Destruction of erythrocytes. (MOODLE) RBCs life span. – The site and mechanism of red blood cell destruction. - Hemoglobin destruction. – Bilirubin metabolism, concentration in plasma. Bile pigments. Entero–hepatic circulation. – Icterus. Physiological neonatal jaundice. – Hemolysis.

Blood groups. (MOODLE, seminar) Agglutinogens and agglutinins. – ABO system. – Rh system. – Other blood groups systems and their relevance. – Blood typing. – Cross–matching of the blood. – Process of immunization. Hemolytic disease of the newborn.

Thrombocytes. (MOODLE) Platelet's count, lifetime, production and structure. - Platelet's granules. Substances released by platelets. – Platelet's functions. - The role of platelets in the organization and regulation of physiological hemostasis. Formation of the platelet plugs.

Hemostasis. (MOODLE, lecture) Basic processes of hemostasis. - Vascular spasm. – Fate of blood clot. Fibrinolytic system. – Prevention of blood clotting in the vascular system. – Endothelial cells and their function in hemostasis. – Anticoagulants for clinical use. – Quick's test.

Hemocoagulation. (MOODLE, lecture) Clotting factors. Role of vitamin K. – Hemocoagulation cascade. – Cell based model of coagulation. – Clot retraction. – Blood serum and its composition.

White blood cells and endothelial cells. (MOODLE) Total white blood cell (WBC) count. – Differential WBC count. – Production of WBCs. – Individual types of leukocytes and their functions. - Mononuclear-phagocytic system. – Function of the endothelium.

Nonspecific immune defenses. (lecture) Definition. – First and second line of defense. - Protective proteins. – Cells involved in nonspecific immune processes. – Chemotaxis. Phagocytosis. Opsonization. Inflammation.

Specific immune defenses. Function of T-lymphocytes. (lecture) Cellular and humoral components of acquired immunity. - Overview of T-cells and their functions. – T-cell receptors. - Interaction of T-lymphocyte cells with antigen-presenting cells. - Cytokines. – Role of cytotoxic lymphocytes. - Immune tolerance against own tissues.

Specific immune defenses. Function of B-lymphocytes. (lecture) Cellular and humoral components of acquired immunity. – B-cells production. Plasma cells. Memory cells. – Functions of B-cells. – Immunoglobulins (Ig), their structure and functions. – Types of Ig. – Interaction of Ig with antigen. - Active and passive humoral immunity. – Primary and secondary immune response.

SPECIAL SENSES

Lectures, seminars.

General physiology of senses. Sensory receptors, their classification. – Receptor potential. - Primary sensory coding. - Sensory transduction. Sensation and perception. – Receptor adaptation. Lateral inhibition. – General characteristics of ascending neural pathways. Central control of afferent information. – Brain cortex and perceptual processing. - Factors affecting perception.

Somatosensory system. Types of somatosensory receptors. – Mechanoreceptors, their morphology, localization and function. – Threshold pressure. Punctate localization of skin sensation. Two-point discrimination. Receptive field. Sensory unit. –Thermoception. Thermoreceptors. - Somatic sensory afferent fibers and their characteristics. – Segmental innervation: dermatomal map. – Neural pathways involved in transmission of somatosensory information. - Primary somatosensory cortex. – Higher-order cortical representations. Damage to somatosensory cortices.

Nociception. Definition and function of pain. – Pain stimulus. – Nociceptors, their structure and classification. - Conduction of nociceptive signals. Fast and slow pain. – Hyperalgesia and sensitization. – Visceral pain. Referred pain, Head´s zones. - Central pathways for nociception. – Cortical representations. – Modulation of pain transmission. Stress-induced analgesia.

Taste. Taste buds. Their location, structure and innervations. – Basic taste modalities. – Receptor stimulation. Mechanisms of transduction. - Factors influencing taste sensation. - Taste pathways. Cortical projections. - Taste abnormalities.

Smell. Olfactory epithelium, location and morphology. – Odorant receptors, mechanism of their stimulation, adaptation. - Primary smell sensation. - Discrimination of different odors. – Olfactory neural pathways. Cortical projections. – Factors influencing olfactory discrimination. - Smell abnormalities.

Vision. Light. Visible spectrum. - The principal structures of the eye. – The optics of vision. – Lens. Accommodation of the lens. Near and fare point. – Pupillary functions. Pupillary reflexes. – Intraocular fluid. Production and function. – Defects in vision. Use of corrective lenses. – Visual acuity.

Retina and phototransduction. Visual pathway. Organization of the retina. Types of neurons. – Photoreceptors. – Types of photopigments. – Photochemistry of vision. Transformation of light signal to electrical. Light and dark adaptation. - Color vision. The

sensitivities of the photopigments. - Color blindness. – Visual field. Visual pathways. – Eye movements. Optokinetic nystagmus.

Hearing. Sound. Sound waves. Sound frequency. – The sound transmission in the ear. - External and middle ear. - Function of the tympanic membrane and ossicles. – Inner ear. – Organ of Corti. Hair cells. Auditory encoding. – Electrical responses of hair cells. – Neural pathway in hearing. – Sound localization. - Bone versus air conduction. Defects of hearing.

Vestibular function. Semicircular canals. Organization and function of an ampulla. Receptors. – Mechanisms of transduction. – Structure and function of utricle and saccule. Otholitic organ. Mechanism of its stimulation. – Neural pathways of vestibular apparatus. – Nystagmus. Physiological nystagmus. Types and characteristics. – Motion sickness.

NERVOUS SYSTEM

Lectures, teaching materials on MOODLE.

Main features of structure and function of the nervous system. Cellular components of the nervous system and their functions. – Relations between neurons. Regulation of impulse transmission. – Types and functions of supporting cells. Potassium spatial buffering. - Organization of the human nervous system. – Components of the peripheral nervous system and their main functions. - Components of the central nervous system and their main functions. The thalamus, division and functions. – Basic functional unit of the nervous system.

The cerebrospinal fluid system. Composition, production and functions. – Circulation and absorption of the cerebrospinal fluid. - Blood–cerebrospinal fluid barrier, its morphology and functions. - Blood-brain barrier, its morphology and functions. – Circumventricular organs. - Metabolism of the central nervous system.

Electrical activity of the brain. Neocortical organization. - The electroencephalogram (EEG), source, recording, assessment. - EEG rhythms. – Mechanisms producing EEG arousal. – Evoked cortical potentials. – Clinical uses of the EEG.

Alert behavior and sleep. Consciousness. - Consciousness system and its localization. - The reticular formation and the reticular activating system. - Levels of consciousness. – Sleep patterns. Non-REM sleep. REM sleep and its function. – Genesis of sleep. – Distribution of sleep stages in a typical night. – Normal sleep cycles at various ages. – Sleep disorders.

Biological rhythms. Biological rhythms and their types. – Exogenous and endogenous rhythms. – Circadian rhythm. Melatonin. – Circadian rhythm disorder.

Higher cognitive functions. Cognition. Cognitive processes. - Higher order integrative cortices. Localization and functional role. – Symbolic cortical functions. - Damage to the association cortices. Agnosias. Apraxia. Delayed spatial response.

Functional asymmetry of the hemispheres and language. Morphological and functional asymmetry of the hemispheres, hemisphere dominancy. - Primary language areas of the brain. Model for language. - Wernicke´s aphasia. - Broca´s aphasia. - Conduction aphasia. – Aprosodia. – Disorders in reading and writing.

Emotions, motivation and affective behavior. Definition of emotions. – Basic emotions. – Components of emotions. - Physiological changes associated with emotions. – The limbic system. Papez circuit. – Functional importance of the amygdala. The relationship between the

amygdala and neocortex. – Cortical lateralization of emotional functions. – Motivation. - Instincts. - Drives. - Anatomic substrate of the reward and punishment. – Addiction.

Learning. Two major classes of learning. - Habituation. - Sensitization. - Classical conditioning. - Conditioned and unconditioned stimulus and response. - Appetitive and defensive conditioning. - Extinction. - Reinforcement. - Operant conditioning in comparison with classical conditioning. - Food aversion conditioning. - Conditioning as a therapeutic technique.

Memory. Definition of memory. – Stages of memory. – Main categories of memory. – Process of memory encoding. – The neural basis of memory. – Synaptic neuronal plasticity. – Important brain areas involved in memory. – Forgetting curve. Learning pyramid. - Amnesia.

Hypothalamus. The structure and functions of the hypothalamus. Hypothalamic connections. – Role of the hypothalamus in homeostasis and thermoregulation. – Relation to autonomic function. - Relation to endocrine system. - Relation to food intake regulation.

Autonomic nervous system – sympathetic division. Structure and localization. – Classical mediators of sympathetic systems. Production, release and destruction. - Receptors of sympathetic system. Localization, function. – Function and effects of the sympathetic system.

Autonomic nervous system – parasympathetic division. Structure and localization. – Classical mediator of parasympathetic systems. Production, release and destruction. - Receptors of parasympathetic systems. Localization, function. – Function and effects of the parasympathetic system.

Somatic nervous system. Motor neurons. Classes of movement. - Motor neurons of the spinal cord. Types, organization and functions. Motor neuron pools. – Motor neuron's arrangements in the spinal cord. – Types and function of interneurons and propriospinal neurons. - Motor neurons of the brainstem. - The ventromedial system pathways, the origin, course, terminations, and function. - The dorsolateral system pathways, the origin, course, terminations, and function. - The final common pathway.

Motor functions of the spinal cord – proprioceptive reflexes. Basic reflex circuitry. – The myotatic (stretch) reflex. - Muscle spindle, morphology and innervation. - Functional role of alpha-gamma coactivation. – Reciprocal innervation. – Functions of stretch reflex. - The inverse myotatic reflex. – Golgi tendon organ, morphology, innervation and mechanisms of its activation. - Spinal connections, reflex response. – Functional importance of Ib afferents signaling.

Motor functions of the spinal cord – exteroceptive reflexes. Exteroceptive (flexor) reflex. Receptors, afferents, spinal connections, reflex response. - Crossed extensor reflex. – Scratch reflex. - Spinal cord reflexes that cause muscle spasm. – Mass reflex. - Spinal cord transection and spinal shock. - Spinal animal.

Motor functions of the brain stem and locomotion. Involvement of the brain stem in motor activity. - Muscle tone. Definition, causes and regulation. – Decerebrate and decorticate rigidity. - Posture. Functions, mechanisms of adjustments. – Posture-regulating system of the central nervous system. - Postural reflexes. - Balance. Static and dynamic equilibrium. – Pathways involved in balance. Cerebellar influence to balance. - Locomotion. – Neural mechanisms controlling walking. – Location and function of the central pattern generator. - Sensory inputs regulating stepping. – Supraspinal regulation of stepping.

Cerebellum. Structure of the cerebellum. – Neurons and circuits within the cerebellum.

Functional unit of the cerebellum. - Projections to the cerebellum. - Projections from the cerebellum. - Functional organization of the cerebellum. – Vestibulocerebellum, input, output, and functions. – Spinocerebellum, input, output, and functions. Topographic organization. – Cerebrocerebellum, input, output, and functions. – Nonmotor functions of the cerebellum. - Consequences of cerebellar lesions.

Functions of the basal ganglia. The principal nuclei of the basal ganglia. - Projections to the basal ganglia. – Projections from the basal ganglia. – Circuits within the basal ganglia system. Neurotransmitters in different parts of the basal ganglia. – Mechanism of the basal ganglia function. – Manifestations of the basal ganglia disorders.

Voluntary movement. Processes leading to purposeful movements. - Regions of neocortex involved in performance of voluntary movements, their organization, roles, functional connections and consequences of their damage. – Subcortical projections to the motor cortices. – Role of central motor neurons in the muscle control. - Symptoms caused by interruption of central motor pathways.

ENDOCRINOLOGY

General Endocrinology. – Definition of hormones. – Endocrine glands and endocrine tissues. – Chemical classification of hormones and their synthesis. – Mechanism of hormone secretion. - Control of hormone secretion. Negative and positive feedback loops. – Transport of hormones in the circulation and their half-lives. – Elimination of hormones from blood. – Hormone receptors, their location and regulation. – Signal transduction of peptide and catecholamines. – Signal transduction of steroids. – Signal transduction of thyroid hormones.

Hypothalamus and Posterior Pituitary. – Morphology. – System hypothalamus-pituitary gland. System hypothalamus-posterior pituitary gland. – Hormones of the posterior pituitary. – Chemistry, synthesis, transport, storage and secretion of antidiuretic hormone (ADH) and oxytocin. – ADH, receptors and effects. – Regulation of ADH secretion. – Disorders of ADH secretion. – Oxytocin. Effect in the pregnant uterus. Milk ejection. Suckling reflex.

Hypothalamus and Anterior Pituitary. – Morphology. Endocrine cells of the anterior pituitary. - Anterior pituitary hormones – System hypothalamus-anterior pituitary gland. Releasing and inhibitory hormones of the hypothalamus. – Growth hormone (GH). Metabolic effects. Growth effects. Somatomedins. – Growth, hormonal regulation. – Regulation of GH secretion. Pituitary insufficiency. Pituitary hyperfunction.

Thyroid Gland. - Functional anatomy. Thyroid hormones (TH). – Synthesis, storage and secretion of TH. Thyroglobulin. – Transport of TH by the blood. – TH receptors and action of TH on target cells. – Effects of TH. Metabolism. Growth. Specific effects of TH. – Regulation of TH secretion and synthesis. The hypothalamopituitary-thyroid axis. – Hypothyroidism. Hyperthyroidism.

Hormonal Control of Calcium and Phosphate Metabolism, Physiology of Bone. Role of calcium and phosphate in the body. Calcium and phosphate metabolism. – Bone physiology. Bone growth. Osteoblasts and osteoclasts. Bone remodeling. Bone diseases. – Hormonal control of calcium and phosphate metabolism. – Vitamin D. Synthesis and its regulation. Effects. Vitamin D deficiency. – Parathyroid gland. Morphology. Parathyroid hormone (PTH). Effects. Regulation of secretion. Abnormalities of PTH secretion. – Calcitonin. Effects. Regulation of secretion.

Adrenal Medulla. – Morphology of adrenal gland. – Hormones of adrenal medulla. Synthesis

and metabolism. Effects of catecholamines. Receptors. Metabolic effects. Effects in cardiovascular system. Other effects. – Fight and flight response. –Pheochromocytoma.

Adrenal Cortex – Glucocorticoids. – Functional anatomy of the adrenal gland. - Hormones of the adrenal cortex. – Synthesis of hormones in zona fasciculata and reticularis. Regulation of synthesis. – Cortisol. Transport and metabolism. – Effects of glucocorticoids. Metabolic effects. Resistance to stress. – Adrenal androgens. –Abnormalities of adrenocortical secretion. Addison disease. Cushing syndrome. Adrenogenital syndrome.

Adrenal Cortex – Mineralocorticoids. – Adrenal steroids with mineralocorticoid activity. – Synthesis of aldosterone and its regulation. Transport and metabolism. of aldosterone in the blood. – Target cells and cellular mechanism of aldosterone action. - Effects of aldosterone. – Regulation of aldosterone secretion. Renin-angiotensin system, plasma potassium and sodium levels, ACTH. – Abnormalities of mineralocorticoid secretion. Addison disease and Conn syndrome.

Endocrine Pancreas. – Islets of Langerhans. Morphology, hormones. – Insulin chemistry and synthesis. – Insulin receptor and mechanism of cellular action. – Effects of insulin on carbohydrate, lipid, and protein metabolism in the liver, muscle, and adipose tissue. Effect on growth. – Control of insulin secretion. – Diabetes mellitus. Complications. Diabetic coma. – Glucagon, synthesis, signal transduction. – Effects of glucagon. – Control of glucagon secretion. – Effects of somatostatin, and pancreatic polypeptide.

Male Reproduction. – Male reproductive system. – Spermatogenesis. Sertoli cells. Spermatozoon. – Erection. Reflex arch. – Ejaculation. Reflex arch of emission and ejaculation. – Semen. – Endocrine function of testes. Testosterone. Synthesis and its regulation. Transport and metabolism. – Testosterone functions. – Regulation of testicular functions. – Abnormalities of testicular functions.

Female Reproduction. – Female reproductive system. – Menstrual cycle. Folliculogenesis. Oogenesis. – Ovarian cycle. – Endometrial cycle. – Other cyclic changes. – Menstruation. Menstrual blood. – Menstrual abnormalities.

Endocrine functions of ovaries. – Ovarian hormones. Synthesis. Secretion. Transport and metabolism. – Estrogens and its effects. – Progesterone and its effects. – Hormonal control of ovarian function. Hypothalamus. Anterior pituitary. The plasma levels of FSH, LH, estrogen, and progesterone during a typical ovarian cycle. Feedback effects. – Puberty. Menopause.

Pregnancy and Lactation. – Fertilization. Acrosomal reaction. – Transport in tube. Blastocysts. Implantation. – Hormonal regulation of pregnancy. Human chorionic gonadotropin. Human chorionic somatomammotropin. – Placenta. Changes in pregnancy. – Parturition. Initiation of parturition. Oxytocin effects. – Lactation. Breast development. Role of prolactin. Initiation of lactation. Milk secretion and ejection. Milk ejection reflex. Mother´s milk.

CARDIOVASCULAR PHYSIOLOGY

General Properties of the Cardiovascular System. – Systemic and pulmonary circulations. Differences in the resistance, pressure gradients and blood flow. – The heart – anatomy, electrical pacemaker and conducting system, cardiac muscle, valves of the heart, coronary circulation, autonomic innervation of the heart.

Electrophysiology of Working Ventricular Cardiomyocytes. – Resting membrane potential and its determinants. Background currents. – Action potential – phases, duration, ionic channels, refractory period, relation to contraction. Plateau phase and its importance.

Conduction System of the Heart. – Anatomy, hierarchy, conduction velocities. – Electrophysiology of the pacemaker sinoatrial cells. Slow diastolic depolarization. Action potential – characteristic, ionic currents. – Characteristic of atrioventricular node. – Properties of Purkinje fibres.

Cardiac Muscle. – Structure of the cardiac muscle. – Structure of the cardiac sarcomere. Contractile proteins. Actin, myosin. Regulatory proteins. Troponin, tropomyosin. – Sarcolemma. T-tubules. Dihydropyridine receptors. Sodium-calcium exchanger. – Sarcoplasmic reticulum. Structure. Function. Ryanodine receptors. Calcium pump of sarcoplasmic reticulum. Phospholamban. – Excitation-contraction coupling. – Molecular mechanism of contraction. – Major differences between the cardiac and skeletal muscles.

Cardiac Contractility and its Regulation. – Contractile apparatus. – Excitation-contraction coupling. – Calcium cycling in cardiac myocytes. Calcium-induced calcium release. Calcium homeostasis during diastole. – Regulation of inotropism. – Autoregulation. Frank-Starling mechanism. – Catecholamines, sympathetic stimulation. Receptors. Second messenger. Target proteins in the cardiac myocyte. – Effect of the increased heart rate on the cardiac contractility. – Contractile effect of inhibition of Na-K-ATPase. – Acetylcholine. Receptors. Target proteins.

Cardiac Cycle. – Events during the cardiac cycle. Systole and diastole. – Individual subphases of the cardiac systole and diastole: timing, duration, pressure and volume changes in the heart compartments, role of the valves, importance of atrial contraction. – Relationship between electrical and mechanical events in the cardiac cycle. – Systemic and pulmonary circulation pressures during the cardiac cycle. – Heart sounds.

Electrocardiogram. – Origin of ECG. Intracellular and extracellular recording of the electrical activity of working ventricular cardiomyocyte. – ECG waves, intervals and segments. – Relationship of ECG curve to the sequence of electrical excitation of the heart. – Relationship between ECG curve and cardiac cycle. – Overview of ECG registration techniques – standard limb leads, augmented leads, chest leads. – Basic interpretation of the electrocardiogram: action, heart rate, rhythm, electrical axis, description of individual waves and intervals. – Construction of the electrical axis from the ECG by means of Einthoven's triangle.

Recording of the Cardiac Activity from the Body Surface. – Heart sounds. Phonocardiography. – Arterial pulse wave, registration. Arterial sphygmography. – Pressure-volume changes in veins near the heart. Phlebography. – Relationship between pressure, volume, acoustic and electrical events in the cardiac cycle.

Cardiac Output. – Definition. – Cardiac volumes. End-systolic volume. Stroke volume. End-diastolic volume. – Ejection fraction. – Resting and maximal cardiac output. – Determination of cardiac output. Fick principle. – Determinants of the stroke volume. Preload. Afterload. Contractility. Duration of contraction. – Determinants of the heart rate. Positive and negative chronotropic effects. Heart rate as a function of duration of systole and diastole. Maximum heart rate. – Cardiac index. – Pressure-volume loops. Effects of preload, afterload and contractility.

The Vascular System: General Features. – General terms and definitions. Flow. Pressure. Resistance. Compliance. Velocity. – Relationship between flow, resistance and pressure gradient. – Relationship between blood flow velocity and total cross- sectional area. – Viscosity and its determinants. – Laminar and turbulent flow. Reynolds number. – Determinants of the systemic vascular resistance. Resistances in parallel and in series. – Vascular compliance. – Laplace law. Vascular wall tension. – Hagen-Poiseuille equation. – Bernoulli's principle. Effect on blood pressure in narrowed vessels. – Types of blood vessels. – Structure of vascular walls.

– Function of the individual types of vessels. – Distribution of the blood volume in the cardiovascular system.

The Vascular System: Arteries. – Types and functions of arteries. – Structure of arterial wall. – Blood flow velocity in arteries. – Resistance and compliance of arteries. – Arterial pressure. Systolic pressure. Diastolic pressure. Pulse pressure. Mean arterial pressure. Changes with age. – Measurement of arterial pressure. Korotkoff sounds. – Pressures in the right and left circulations. – Pressure gradients in arteries. – Arterioles. Structure. Function.

The Vascular System: Microcirculation. – Design of microcirculation. – Three major types of capillaries. Structure of the capillary wall. Permeability. – Mechanisms of capillary exchange. – Diffusion. Fick's law of diffusion. – Bulk flow. Filtration and reabsorption. – Vesicular transport. – Hydrostatic and oncotic pressures in capillaries. Tissue (interstitial) hydrostatic and oncotic pressures. Net driving force. – The role of lymphatics. – Vesicular transport.

The Vascular System: Veins. – Major functions of veins. – Structure of veins. – Blood flow in veins. Mechanisms facilitating venous return. – Resistance and compliance of veins. – Effect of gravitational pressure on venous pressure. – Central venous pressure. Factors influencing central venous pressure.

The Lymphatic System. – Anatomy of the lymphatic system. Lymphatic capillaries. Lymphatic vessels and valves. Lymph nodes. – Formation of the lymph. – The lymph flow and functions. Factors facilitating the lymph flow. – Composition of the lymph.

Regulation of the Heart. – Chronotropy, inotropy, dromotropy, bathmotropy. – Intrinsic control. – Extrinsic control by the autonomic nervous system. – Cardiovascular centers. – Innervation of the heart. Parasympathetic pre- and postganglionic neurons, neurotransmitters, receptors, agonists and antagonists. – Sympathetic pre- and postganglionic neurons, neurotransmitters, receptors, agonists and antagonists. – The effects of autonomic neurotransmitters on heart rate, contractility, conduction and excitability. – Signal transduction. G proteins and cyclic AMP as a second messenger. – Peripheral cardiac neuronal interactions. Pre- and postsynaptic receptors.

Local Control of the Tissue Blood Flow. – Role of arterioles in regulation of tissue blood flow. – Myogenic autoregulation. – Metabolic autoregulation. Active hyperemia. Flow autoregulation. Reactive hyperemia. Response to injury. – Local humoral factors. Role of endothelial cells. Serotonin. Bradykinin. Nitric oxide. Histamine.

Extrinsic Control of the Tissue Blood Flow. – Innervation of vessels. Neurotransmitters. Receptors. – Hormones. Epinephrine. Vasopressin. Angiotensin II. Atrial natriuretic peptide. – Differences in norepinephrine and epinephrine effects on tissue blood flow.

Short-Term Regulation of Mean Arterial Pressure. – Neural control. – Arterial baroreceptors. Location and innervation of baroreceptors. Pressure range for baroreceptors firing. Reflex arc. Functional responses to stimulation of baroreceptors. Adaptation of baroreceptors. – Peripheral chemoreceptors, location, innervation, stimuli, and role in regulation of arterial pressure. Respiratory and cardiovascular response to stimulation. – The CNS ischemic response. – Atrial pressure/volume reflex, receptors, stimuli, and reflex responses. – Venoconstriction.

Humoral and Long-Term Regulation of Mean Arterial Pressure. – Catecholamines. Origin, synthesis, degradation, cardiovascular effects. Comparison of the effects of intravenous infusion of epinephrine and norepinephrine on arterial blood pressure, peripheral resistance and cardiac output. – The renin-angiotensin-aldosterone system. Origin, function, converting enzyme. The principal effects of angiotensin II, mechanisms of water and salt retention. –

Antidiuretic hormone. Origin, site of secretion, renal and cardiovascular effects. – Atrial natriuretic peptide. Origin, vascular and renal effects. – The renal-body fluid feedback system. – Relationship between water and salt intake and output and mean arterial pressure. Pressure diuresis and natriuresis, mechanism.

Coronary Circulation and Cardiac Metabolism. – Functional anatomy of the coronary vessels. – Coronary blood flow at rest and during exercise. Pressure gradients in coronary circulation. – Relationship between oxygen consumption and coronary blood flow. Extraction of oxygen. – Regulation of coronary blood flow. Metabolic autoregulation. Effects of autonomic neural activity on coronary blood flow. – Energy sources for the heart contraction and their relative contribution to total uptake of oxygen. – The major metabolic processes of cardiac muscle to produce energy. – ATP as a fuel for the contraction process.

RESPIRATION

Lectures, seminars

Organization and Functions of the Respiratory System. – Respiratory functions. Non-respiratory functions. – Anatomy of respiratory system. Conducting and respiratory zones. – Alveolar cells. – Control of bronchial musculature. – Pleura. Pleural fluid

Mechanics of Pulmonary Ventilation. – Pulmonary pressures. – Forces affecting alveolar wall. Pneumothorax. – Pulmonary ventilation. Boyle's law – Respiratory muscles and their function. – Mechanism of inspiration. – Mechanism of expiration. – Compliance. Determinants of lung compliance, surface tension, surfactant. – Resistances of respiratory system. – Work of breathing.

Spirometry (seminars). – Static parameters. Volumes and capacities. – Dynamic parameters. Forced expiration of vital capacity, performing the maneuver, forced vital capacity, forced expiratory volume in one second (FEV1), forced expiratory flow between 25% and 75% FVC ($FEF_{25-75\%}$). – Minute ventilation, maximal voluntary ventilation. – Factors affecting spirometric parameters. BTPS correction.

Pulmonary Circulation. – Bronchial vessel. – Pulmonary circulation. Morphology and parameters of pulmonary circulations. – Pulmonary capillaries. – Local differences in blood flow. – Differences between systemic and pulmonary circulations.

Exchange of Gases in Alveoli and Tissues. – Alveolar ventilation, the anatomic, alveolar and physiological dead space. Local differences in pulmonary ventilation. – Respiratory membrane. – Partial pressure. Partial pressures of O_2 and CO_2 in atmospheric and alveolar air, arterial and venous bloods. – Diffusing capacity. Factors affecting rate of diffusion. Diffusion coefficient. Pressure gradient. Surface area. Ventilation-perfusion quotient. Diffusion length.

Transport of Oxygen in Blood. – Oxygen content in arterial and venous bloods. Arteriovenous difference. – Forms of oxygen transport in the blood. – Hemoglobin, its structure, site of oxygen binding. – Effect of pO_2 on hemoglobin saturation, the oxygen-hemoglobin dissociation curve, cooperativity of hemoglobin subunits. – Effects of blood pCO_2, pH, temperature, and 2,3-disphosphoglycerate on hemoglobin saturation. Bohr´s effect. – Oxygen exchange in the tissue. – Fetal hemoglobin. – CO poisoning.

Transport of Carbon Dioxide. – Carbon dioxide content in arterial and venous bloods. Arteriovenous difference. – Transport forms of CO_2 in the blood. Dissolved carbon dioxide in the blood. Carbaminohemoglobin. Conversion of carbon dioxide to bicarbonate, carbonic anhydrase, transport of bicarbonate across the erythrocyte membrane. – Carbone dioxide

binding curve. – Haldane effect. – Respiratory quotient. Carbone dioxide exchange in the tissue.

Neural Control of Respiration. – Respiratory centers in brainstem. Respiratory neurons. Dorsal and ventral respiratory groups. Pneumotaxic center. – Receptors in airways and lungs. Hering - Breuer reflex. – Afferentation from proprioceptors and baroreceptors. – The effect of limbic system, motor cortex and temperature on respiration. – Voluntary control of respiration.

Chemical Control of Respiration. – The central chemoreceptors. The effect of CO_2 and H^+ on alveolar ventilation. Adaptation of central chemoreceptors. – The peripheral chemoreceptors. The effect of O_2 on alveolar ventilation. – Hypercapnia and hypocapnia. – Hypoxia, its types and effects. – Hyperoxia. Oxygen therapy.

Adaptation of Respiration under Physiological Conditions. – Respiration during exercise. Nervous and chemical control. – Hyperbaric conditions. Diving and its dangers. Decompression sickness. – Respiration at high altitude. Acclimatization to high altitude. Acute and chronic mountain sickness.

PHYSIOLOGY OF THE KIDNEY

Physiological Anatomy of the Kidney. Overview of renal functions. - Structure of the kidney. Cortex. Medulla. – Nephron-functional unit of the kidney. Cortical and juxtamedullary nephrons. – Anatomy of the nephron. Glomerulus.Tubule. – Bowman‘s capsule. Proximal tubule. Loop of Henle. Distal tubule. Collecting duct. – Kidney blood vessels. Afferent and efferent arterioles. Peritubullar capillary network. Vasa recta. Juxtaglomerular apparatus. - Principles of urine formation.

Glomerular Filtration. Glomerular filtration membrane. - Net filtration pressure. – Glomerular filtrate. Composition. Glomerular filtration rate. – Renal plasma flow. Filtration fraction. – Physiological control of glomerular filtration and renal blood flow. Nervous regulation. Humoral regulation. Autoregulation. Tubuloglomerular feedback. Myogenic autoregulation.

Clearance. Definition. Calculation. Minimal and maximal values of clearance. - Inulin clearance. Endogenous creatinine clearance. Comparison, advantages, disadvantages, clinical use. - Paraaminohippuric acid (PAH) clearance. – Free water clearance. Clearance and fractional excretion of sodium, potassium and calcium. Clinical use.

Tubular Functions. Mechanisms of transport. – Transport maximum, threshold substances. Reabsorption of glucose. Renal threshold. – Active transport. Primary active transport. Transport of sodium. Secondary active transport. Pinocytosis. - Passive transport. Osmosis. Transport of chloride, urea and creatinine. – Transport in proximal tubule. Transport in loop of Henle. Transport in distal tubule and collecting duct. - Tubular secretion. – Regulation of tubular reabsorption. Glomerulotubular balance. Peritubular capillary and renal interstitial fluid physical forces. Pressure natriuresis and pressure diuresis. Hormonal control of reabsorption. Sympathetic nervous system activation.

Excretion of Water. Reabsorption of water in tubular segments. – Excreting excess water by forming a dilute urine. – Conserving water by excreting a concentrated urine. Obligatory urine volume. Osmotic stratification of renal medulla. Countercurrent multiplier system (loop of Henle). Role of distal tubule and collecting duct. Contribution of urea. Recirculation of urea. Countercurrent exchange system (vasa recta). - Mechanism of water reabsorption. Role of antidiuretic hormone (ADH). Diabetes insipidus. – Water diuresis. Osmotic diuresis.

Excretion of Sodium, Chloride, Potassium and Other Ions. Reabsorption of sodium in tubular segments. Mechanisms of sodium reabsorption. Reabsorption of sodium in late distal tubule and in collecting duct. Role of aldosterone. – Excretion of potassium. Reabsorption of potassium. Secretion of potassium. Principal cells. Intercalated cells. Regulation of potassium secretion.– Excretion of chloride. – Excretion of calcium. Regulation of calcium reabsorption. – Excretion of phosphate. - Excretion of magnesium.

Regulation of Renal Functions. Autoregulation mechanisms. Tubuloglomerular feedback. Glomerulotubular balance. – Regulation of sodium excretion. Sodium balance. Regulation of glomerular filtration. Role of baroreceptors. Regulation of tubular reabsorption. Aldosterone. Renin. Angiotensin II. Atrial natriuretic factor. – Regulation of potassium excretion. Aldosterone. – Regulation of water excretion. ADH. Regulation of ADH secretion. Osmoreceptors. - Thirst. Stimuli for thirst. Thirst center.

Acid-Base Balance and Kidney. Plasmatic pH. Acidosis, alkalosis. Sources of hydrogen ions. - Acid-base buffer systems. Bicarbonate buffer system. – The role of kidney in the acid-base regulation. Secretion of hydrogen ions. Filtration and reabsorption of bicarbonate ions. Generation of new bicarbonate ions. – Renal response to acidosis. Tubular buffers. The role of ammonium ion and ammonia. Renal response to alkalosis. – Respiratory acidosis and alkalosis. Metabolic acidosis and alkalosis.

Micturition. Ureter Ureterorenal reflex. – Bladder. Detrusor muscle. Innervation of the bladder. Internal sphincter. External sphincter. – Micturition reflex. - Supraspinal control of micturition.

ALIMENTARY TRACT

Vander´s Human Physiology and seminars

Gastrointestinal Motility – Gastrointestinal smooth muscle, structure, basis of contraction. Differences between skeletal, smooth and cardiac muscle. – Enteric nervous system. Extrinsic innervation of the gut. – Peristalsis. Myenteric reflex. – General patterns of movement of the gut-mixing and propulsive movements. – Nervous and hormonal control of gastrointestinal motility.

Regulation of Gastrointestinal Processes – Neural regulation. Enteric nervous system, extrinsic innervation. Long and short reflexes and their role in the regulation of gastrointestinal processes. – Hormonal regulation. Secretin, cholecystokinin, gastrin, somatostatin, GIP. – Phases of gastrointestinal control.

Mouth, Pharynx, and Oesophagus – Chewing. Swallowing – voluntary and involuntary phases. Swallowing centre. The role of myenteric nerve plexus in deglutition. – The saliva-pH, organic constituents, inorganic constituents, regulation of secretion. Secretory mechanisms - electrolyte secretion, protein secretion. – Oesophagus – function and innervation of lower oesophageal sphincter.

The Stomach - Function. - Anatomy. Gastric glands. - Hydrochloric acid secretion. Functions of HCl. The role of carbonic anhydrase. - Enzyme secretion, pH optima of secreted enzymes. - Intrinsic factor. - Control of gastric secretion - role of reflexes and gastrin. - Gastric motility. Role of pyloric sphincter in gastric emptying. Receptive relaxation. - Nervous and humoral control of gastric motility.

The Pancreas (exocrine) - Function and structure. - Composition of pancreatic juice - electrolytes, enzymes. Bicarbonate secretion in duct epithelial cells. - Nervous and hormonal

control of pancreatic secretion. Role of cholecystokinin and secretin. - Mechanisms to prevent enzyme activation inside the gland.

The Small Intestine - Intestinal wall structure. Intestinal glands. - Intestinal juice - constituents, daily amount. - Absorptive capacity, enterocytes. - Electrical basis of small bowel contraction, patterns of movement. Migrating motor complex. - Regulation of intestinal motility.

Digestion and Absorption - Digestion and absorption in the mouth, the stomach, small and large intestines. - Mechanisms of absorption. - Digestion and absorption of carbohydrates. - Digestion and absorption of protein. - Digestion and absorption of fat. - Absorption of vitamins, ions, and water.

The Large Intestine - Function, anatomy, innervation. - Colonic movements, haustrations, mass movements. - Defecation - anal sphincters, innervation. Defecation reflex. - Absorption in the colon. - Faeces - daily amount, composition.

The Liver and Bile - Liver lobule. Perivenous and periportal zones. - Liver blood supply, blood flow. - Kupffer cells. - Metabolic functions of the liver. Carbohydrate metabolism. Fat metabolism. Protein metabolism. Detoxification. Storage. - Endocrine functions. - Bile. Composition. Bile acids. Bile pigments. - Control of bile secretion. - Control of gallbladder contraction.

METABOLISM AND TEMPERATURE REGULATION

Metabolism (Seminar) – Metabolism. Anabolic reactions. Catabolic reactions. – Chemical energy consumption. – Principle of calorimetry. Direct calorimetry. Indirect calorimetry. – Metabolic rate. Basal metabolic rate (BMR). Basal conditions. Average values of BMR. – Factors affecting the metabolic rate.

Regulation of Body Temperature (Seminar) – Poikilotherms and homeotherms. – Body temperature – core temperature, shell temperature. – Heat transport. – Heat loss - radiation, conduction, convection, evaporation – perspiration, sweating and its regulation. – Central and peripheral thermoreceptors. – Thermoregulation centre. – Temperature decreasing mechanisms. – Temperature increasing mechanisms. – Thermoregulation during physical exercise. – Temperature regulation in new-borns. – Temperature adaptation. – Fever. Hyperthermia. Hypothermia.

PRACTICAL EXERCISE

Hematology

1. Hematocrit determination
2. Determination of MCH, MCHC and MCV
3. Fragility of red blood cells in hypotonic saline
4. Blood typing – AB0 and Rh systems
5. Bed-side test
6. Sedimentation rate
7. Quick´s prothrombin time

General physiology, central and peripheral nervous systems

8. Determination of plasma volume
9. Somatic reflexes
10. Cerebellar functions
11. Visceral reflexes

Sense organs
12. Visual acuity
13. Astigmatism
14. Optokinetic nystagmus
15. Blind spot experiment (Mariott)
16. Color Vision
17. Hearing tests

Circulation and respiration
18. Blood pressure
19. Heart sounds
20. ECG
21. Demonstration of negative intrapleural pressure in rat
22. CO_2 content in expired air after voluntary hyperventilation and after apnea
23. Spirometry - static values
24. Spirometry - dynamic values

Metabolism, endocrinology, kidney and GIT
25. Basal metabolic rate
26. Creatinine clearance. Glomerular filtration. Tubular reabsorption