Dear Students,

These **learning objectives** summarize the most important concepts required on the exams (written and oral). They consist of 3 parts: 1. title 2. learning objectives 3. normal values. The **title is the same as the respective topic of the semifinal exam**. The learning objectives **consist of tasks and questions**, and in some cases they also contain useful hints for the answers. 3. The **normal values** usually appear where they are first encountered, but they might important for any later topic as well. For those normal values, where value ranges are given, the student is expected to be able to give at least a value that is WITHIN the normal range along with the CORRECT unit. **Important: on the oral exams the picked topic will contain ONLY the title**, not the detailed objectives. The students are required to know by then what belongs to the topic! ***The questions of the entry exam are selected from the terms/definitions/principles marked in red and the standard values.***
We hope these objectives will assist you in preparing for a successful exam.

Learning Objectives (LO)
1st semester Academic year 2023/24

1. Principles of control theory

Define the term of internal environment (milieu intérieur) and explain the importance of its control?
Define the terms homeostasis and homeostatic parameters. List at least 5 controlled functions and/or parameters in human.
Describe the major forms of physiological controlling circuits (humoral, neuronal).
Describe the parts of the neuronal reflex arch and explain their respective functions in control (receptor, afferent branch/pathway, center, set point, efferent branch/pathway and effector).
Define negative and positive feedback control. Give examples for processes controlled by negative feedback, positive feedback. Give examples of guidance!
Characterize endocrine, paracrine and autocrine humoral control based on the release site of the mediators and their path to the target cells.
Define ,,behavioral control" and explain its importance/necessity. Give examples!

2. Passive transport mechanisms of the cell membrane

Describe and make a schematic drawing of the molecular structure of the plasma membrane (fluid mosaic model).
Explain how the distribution of phospholipids and proteins influences the membrane permeability of ions, hydrophylic and hydrophobic compounds.
Define simple diffusion and explain how changes in the driving forces (chemical and electrical gradient, in steady state situation) and membrane properties will influence the transport rate. State Fick's law of diffusion.
Define the following terms regarding ion channels: selectivity, gating, activation and inactivation.
Compare the gating mechanisms of intra- and extracellular ligand-gated, voltage-gated, heat sensitive and mechanical-gated ion channels.
Describe the role of water channels (aquaporins) in the water permeabiliy of the cell membrane. Define osmosis.
Explain how the different permeability of the cell membrane to water and solutes will generate an osmotic pressure.
Define filtration and give examples for this kind of transports.
Characterize facilitated diffusion. Define the types of the carriers: (uniporter, symporter, antiporter). Define the terms: transport maximum, saturation, competitive and non-competitive inhibition.

Normal values: plasma osmolality: 290 mosm/kg H_2O, osmolality induced by plasma proteins: 1.6 mosm/kg H_2O, osmotic pressure: 28 mmHg

3. Active transport mechanisms of the cell membrane.

Define the terms primary and secondary active transport. Define the terms: transport maximum, saturation, competitive and non-competitive inhibition.
Describe how energy from ATP hydrolysis is used to transport ions such as Na^+, K^+, Ca^{2+} and H^+ against their electrochemical differences via examples.
Explain how energy from the $Na^+$and K^+ electrochemical gradients across the plasma membrane can be used to drive the

net ,,uphill" (against gradient) movement of other solutes (e.g., Na^+/glucose co- transport; Na^+/Ca^{2+}-exchange) - secondary active transports.
Explain the role and significance of ATP-binding cassette (ABC) transporters via examples.
Define the term vesicular transport: endocytosis, exocytosis and transcytosis. Give examles for specific and aspecific vesicular transport processes.

4. The resting membrane potential
Explain the origin of the resting membrane potential, the electric and chemical forces that determine the diffusion of ions.
State the Nernst equation used to determine the equilibrium potential of ions. What is the meaning of the equilibrium potential?
State Goldman-Hodgkin-Katz-equation. Resting membrane potential values in different cell types (smooth muscle, skeletal muscle, cardiac muscle, neuron).
Explain the importance of the simultaneous passive ion currents (eg. Na^+, K^+) and active ion pumping (Na^+-K^+-ATPase) in determining the membrane potential and cellular volume. Explain the possible mechanism and consequence of the inhibition of the Na^+-K^+-ATPase.

Normal values: extracellular ion concentrations: Na^+: 138-151 (145) mM, K^+: 3.4-5.2 (4) mM, HCO_3^- 21- 28.5 (24) mM, Cl^-: 101-111 (110) mM, Ca^{2+}: ionized 1.25 mM; typical intracellular (cytoplasmic) ion concentrations: Na^+: 15 mM; K^+: 150 mM; HCO_3^-: 8 mM; Cl^-: 4mM; Ca^{2+}: 10^{-4} mM ; EK+: -97 mV; ENa+:+61 mV; ECl-: -88 mV; ECa++: 126 mV

5. The electric properties of neuronal membranes. The axonal propagation of the action potential. Axon classification.
Define and compare the electrotonic (local, graded) potentials with the action potential (activation threshold; direction and amplitude of potential change; propagation velocity; refractericity; summation; mechanism; biological function).
Describe the ionic background of local electrotonic potentials: excitatory postsynaptic potential (EPSP), inhibitory postsynaptic potential (IPSP), end plate potential (EPP) and receptor potential. Describe the temporal and spatial summation of postsynaptic potentials (EPSPs and IPSPs), and their role to trigger an action potential.
Make a schematic drawing of the membrane potential changes during an action potential recorded in the giant squid axon. Using the drawing, identify the phases of the action potential. Explain the terms threshold and the "all or none" principle.
Characterize the voltage-gated Na^+-, K^+- and Ca^{2+}-channels functionally (gating, activation and inactivation). Describe the role of voltage-gated Na^+- and K^+-channels in the phases of the neuronal action potential (depolarisation, ,,overshoot", repolarisation, after-hyperpolarization). Define and explain the terms absolute and relative refractory periods.
Describe the propagation of the action potential in myelinated and unmyelinated axons. Explain saltatory conduction.
Describe the various axon classes based on the Erlanger-Gasser-classification. Describe the action mechanism of local anesthetic drugs. Determine the sensitivity of axon classes to local anesthetics – order of blocking of sensory functions.

Normal values: action potential duration in nerves: 1 ms, typical action potential propagation velocities in the axon classes of peripheral nerves (Erlanger-Gasser classification): Aα: 100 m/s, Aβ: 50 m/s, Aγ: 20 m/s, Aδ: 15 m/s, B: 7 m/s, C: 1 m/s

6. Neurotransmission.
Characterize electric synapses including the description of the molecular structure of gap junction operating in these synapses. Compare transmission between electric and chemical synapses (direction of information, speed and way of transmission). Describe the main types of signaling molecules (mediators): autocrine and paracrine signaling molecules, hormones, neurotransmitters, neurohormones and cytokines.
Describe the consecutive events of chemical neurotransmission (starting with the depolarization of presynaptic membrane ending with the development of the graded electric response of the postsynaptic membrane (postsynaptic potential, PSP).
Describe the common features of classical neurotransmitters.

Group the mediators based on their chemical structure: 1. acetyl- choline, 2. amino acids (glutamate, glycine, GABA), 3. biogenic amines (dopamine, noradrenaline, adrenaline, histamine, serotonin), 4. gases (NO, CO), 5. lipids (endocannabinoids, 6. peptides (endophins, encephalins, dynorphins, substance P, CGRP, VIP), 7. purines. Describe the synthesis, mechanism of action and significance of NO.
Describe the fate of released neurotransmitters: receptor binding, enzymatic degradation, diffusion, reuptake.

Normal values: synaptic delay: 1-1.5 ms

7. Receptors, signal transduction mechanisms.
Define the terms: receptor, ligand, agonist, antagonist (competitive, non-competitive).
Classification of receptors: 1. based on localization (cell membrane receptors, cytosolic receptors, nuclear receptors, intracellular membrane receptors (IP_3, ryanodin), 2. based on function (ionotropic receptors, metabotropic receptors, receptor enzymes, and enzyme-linked receptors).
Ionotropic receptors: selective and non-selective receptors, cation and anion channels. Give 1-1 examples.
G-protein coupled metabotropic receptors. Heterotrimer G-proteins: types ($G_s/G_i/G_q$) and functions.
Define the term second messengers, describe the most important members (cAMP, cGMP, calcium, IP_3/DAG).
Explain the function of receptor enzymes and enzyme-linked receptors through 1-1 example (tyrosine kinase receptors).
Describe the following terms related to membrane receptors: activation, inactivation, internalization, up-regulation, down-regulation, sensitization, desensitization.
Signal transduction via intracellular receptors: the function of cytosolic and nuclear receptors explained through 1-1 example (steroid and thyroid hormone receptors).

8. The parasympathetic division of the autonomic nervous system.
Characterize the structural organization of the parasympathethic nervous system: give the location of the cell bodies and axons of pre- and postganglionic neurons.
Classify the prae- and postganglionic axons of the autonomic nervous system found in peripheral nerves according to the Erlanger-Gasser classification (B and C fibers).
Characterize the synaptic connection between the preganglionic axon and the ganglion cell (acetylcholine and neuronal type nicotinic Ach receptor). Describe the biosynthesis, synaptic release, and elimination of acetyl-choline. Describe the effects of acetyl-choline of the receptors of target cells (muscarinic Ach receptor). Give examples of parasympathethic effects mediated by cholinergic receptors.
Give further neurotransmitters released by parasympathetic nerves, and give examples of parasympathetic effects mediated by such neurotransmitters (co-transmitters: VIP). Define the term autonomic tone.

9. The sympathetic division of the autonomic nervous system. The adrenal medulla.
Characterize the structural organization of the sympathethic nervous system: give the location of the cell bodies and axons of pre- and postganglionic neurons.
The sympathetic adrenergic system: describe the biosynthesis of noradrenaline and adrenaline, the synaptic release and elimination of noradrenaline.
List the adrenergic receptor types (α and β) found on target cells along with the respective signal transduction pathways (type of G-protein, second messenger…).
Give examples of adrenergic effects mediated by each receptor type.
Describe the anatomical structure of the adrenal medulla and the regulation of hormone release. Give examples of sympathetic cholinergic effects (blood vessels in striated muscle, sweat gland).

10. Fluid compartments of the body. The blood plasma.
Define the terms extracellular (intra- and extravascular) and intracellular fluid, determine their volume. Define the transcellular compartment.
Describe the fractions obtained by centrifugation (cells, plasma). Define the term hematocrit and give the normal value in healthy adult person.
List the anorganic and organic constituents of the blood plasma with respect to their functions. Give the normal values.
Identify and characterize the lipoproteins found in the blood plasma (VLDL, LDL, HDL).

Normal values: total body water: ~60% of body weight, (intracellular 40%, extracellular 20%), interstitial fluid volume: 11 L, blood volume: 5-6 L (80 ml/kg body weight), plasma volume: 3 L, hematocrit: 0,44-0,46, plasma osmolality: 290

mOsm/kgH_2O, plasma Na^+: 138-151 mM, plasma K^+: 3.4-5.2 mM, plasma HCO_3- 21-28.5mM, plasma Cl^-: 101-111 mM, plasma Ca^{2+}: 2,4-2,8 mM (total), 1.25 mM (free, ionized), plasma glucose: 4,2-5,9 mM, plasma bilirubin: 5,0-17,0 µmol/L, plasma proteins: 60-80 g/L, plasma albumine: 34-45 g/L, plasma total cholesterol: <5,17 mM, plasma total lipids: 4,5- 10 g/L

11. The general features of red blood cells. Erythropoesis. Hemoglobin degradation, bilirubin metabolism.
Describe the following parameters of the red blood cells: count, size, shape, life span, structure. Describe the red bone marrow and enlist the main progenitors of red blood cells. Provide the definition of reticulocyte.
Describe the main stages and mechanisms of iron turnover: absorption (ferroportin), transport (transferrin), storage (ferritin, hemosiderin). Explain the role of vitamin B_{12} and folic acid in the formation of red blood cells.
Erythropoietin: production (kidney), trigger, function. Enlist some important hormonal influences on erythropoiesis (e.g., growth hormone, testosterone). Enlist and describe the types of anemias.
Characterize the osmotic resistance of the red blood cells. Describe the mechanism of blood sedimentation, the method of its measurement, significance and normal value.
Describe the chemical structure of the hemoglobin molecule. Enlist and define special/pathological hemoglobin forms (HbF, methemoglobin, carboxy-hemoglobin) and give their functional characteristics.
Describe the fate of old erythrocytes and the role of macrophages in the process.
Describe the steps of the degradation of hemoglobin, the fate of iron, globin chains, and the porphyrin ring.
The release of bilirubin from macrophages, transport in blood, uptake in liver, conjugation and secretion into the bile.
Provide the definition of direct and indirect bilirubin.
The fate of bilirubin in the intestines, the enterohepatic circulation and secretion.

Normal values: count: 4.3-5.2 million/µL, diameter: 7-8 µm, height: 1-2 µm , life span: 120 days, sedimentation rate: 3-10 mm/hour, blood hemoglobin concentration: 135-160 g/L, osmotic resistance: 0.45-0.50% NaCl solution, iron RDA (recommended dietary allowance): 10-20 mg, daily iron loss: 1-3 mg, relative reticulocyte count: 0.4-1.5%, plasma bilirubin: <17.0 µM.

12. White blood cell types. The differential leucocyte count. Cellular and humoral elements of the innate immunity.
What is the normal value of leukocyte count?
Enlist the types of white blood cells and characterize their structure and function. Describe the qualitative blood smear, enlist the normal values of the differential white blood cell count (%). Describe the significance of phagocytosis and the basic mechanism of inflammatory reaction.
Describe the elements and role of the monocyte/macrophage system (transvascular migration). Expound the main elements and functions of the complement system.
What are the functions of the natural killer (NK) cells, granulocytes and mast cells.
Protection of "surface barriers" (mechanical, chemical and biological barriers: skin, saliva, tears, gastric juice with acids and proteases, natural flora…). Protective reflexes: coughing, sneeze.

Normal values: white blood cell count: 4000-10000 cell/µL, neutrophils: 60-80%, lymphocytes: 20- 30%, monocytes: 2-6%, eosinophils: 1-5%, basophils: 0-1%.

13. The humoral and cellular elements of the specific (adaptive) immunity.
Define the antigen in general and delineate the process of antigen presentation. What are the roles of MHC (type I. and II) and CD (type 4 and 8) proteins? Compare the role of helper and cytotoxic T-cells.
What is the role of the B-cells? Explain the cooperation of antigen presenting cells, T-cells, and B-cells (connection between the humoral and cellular immune responses).
Describe the role and structure of immunoglobulins and their subtypes and functions. Enlist the main groups of cytokines, and provide some examples for their functions. Differentiate active and passive immunization (naturally and artificially acquired).

14. The AB0 and Rh blood groups.
Describe the antigens and the circulating antibodies (Landsteiner-rules, the presence and types of immunoglobulines).
Describe the process of the blood group determinations (Serafol card – bedside method). Compatibility tests before

blood transfusion (major and minor test, biological test).
Expound the process of Rh-sensitization (anti-D prophylaxis, erythroblastosis foetalis).
What is the definition of agglutination and hemolysis, what are their consequences?

15. The characterization and functions of thrombocytes. Primary hemostasis.
What is the normal value of thrombocyte count?
Describe the most important morphological features of the thrombocytes, size and types of granules. Explain the adhesion, aggregation and activation of thrombocytes.
Elaborate the role of primary hemostasis, enlist and characterize the significance of its major processes (vasoconstriction, activation and aggregation of platelets). Enlist the factors that activate thrombocytes and their origin (site of production). Describe the role of endothelial cells in hemostasis. How the impairment of thrombocyte function can be measured (bleeding time)?

Normal values: thrombocyte count: 150000-300000 /μL, bleeding time (Ivy's method): 3-5 min

16. Secondary hemostasis: blood clotting (coagulation). Inhibition of clotting. Fibrinolysis.
Compare the white and red thrombus.
Define the coagulation factors, their nomenclature, site of synthesis, and the mechanism of their action.
Describe the extrinsic and intrinsic pathways of coagulation. Expound the common phase of blood coagulation and the formation of the stable fibrin mesh.
Explain the role of vitamin K in the synthesis of the so-called vitamin K-dependent coagulation factors.
Define the term serum and compare its composition with the blood plasma.
Compare prothrombin time and coagulation time. Define INR, its calculation and significance.
Expound the activation and regulation of the plasmin system.
Describe the following systems and their regulation: thrombomodulin/protein C; heparin/antithrombin.
Enlist substances that can be used to inhibit blood coagulation in vitro (EDTA, oxalate) and define their mechanism of action.
Enlist substances and drugs that can be used in vivo to inhibit thrombocyte activation and blood coagulation or to facilitate fibrinolysis (inhibitors of cyclooxygenase, heparin, vitamin K antagonists and plasminogen activators) and define their mechanism of action.

Normal values: prothrombin time: 18-20 s, INR: 0.8-1.2, coagulation time (Lee-White method): 5-8 min, fibrinogen: 3 g/L

17. The peripheral nervous system: motor neurons, neuromuscular junction.
Give the anatomical locations of the cell bodies of motor neurons (ventral horn of the spinal cord gray matter, motor nuclei of cranial nerves), and classify the motor axons found in peripheral nerves according to the Erlanger-Gasser classification (Aα and Aγ fibers).
Make a schematic figure of the neuromuscular junction found in striated muscles, and indicate the consecutive steps of neuromuscular transmission.
Compare the differences between the end plate potential (EPP) and the muscle fiber's action potential.
Define the targets of muscle relaxants in the neuromuscular junction. List the inhibitors of the neuromuscular junction (curare, succinylcholine, botulinum toxin), give their targets and mechanisms of actions.
Define the term motor unit. Describe motor recruitment during various levels of muscle activity.

18. Structural comparison of the skeletal and smooth muscle. Muscle subtypes, contraction types
Compare the two muscle tissues based on the following aspects: occurrence in the body, structural elements, regulatory proteins, light microscopic appearance.
Describe the structure of the functional unit (sarcomere) of the skeletal muscle.
Compare the red and white types of skeletal muscle with a special reference to their structure, energy sources, and function. Define and compare the isometric, isotonic, and auxotonic contractions. Energy sources of the working muscles.
Define the terms and compare single-unit and multi-unit smooth muscles in the aspects of intercellular connections, control and occurence. Differentiate the phasic and tonic contraction of smooth muscle with their occurence in body.

19. Comparison of the skeletal and smooth muscle based on their function.
Compare the muscle tissues based on the aspects: the development of calcium sign, source and role of calcium, the differences in acto-myosin regulation, chemical and mechanical steps of actin-myosin cross bridges (sliding-filament process). Summarize the intracellular pathways that control contraction and relaxation.
Distinguish between electromechanical coupling and pharmacomechanical coupling. Give specific examples of which transmitter can cause smooth muscle contraction and relaxation via which receptor.
Summarize the role of ATP in muscle contraction and relaxation. What is the mechanism of rigor mortis („stiffness of death")?
Characterize the difference between muscle twitch and tetanus (complete and incomplete), and explain the contraction summation.
Characterize the factors that increase the muscle power (increasing the number of actomyosine complexes): 1. increasing the number of activated motor units, 2. increasing the frequency of action potential (increased calcium) - tetanic contraction, 3. resting length of sarcomere, 4. exercise.

20. Cardiac muscle: structural and functional characterization, the excitation-contraction coupling. The metabolic properties of the cardiac muscle.
Compare the cardiac and the skeletal muscle with respect to the arrangement of myofilaments.
Describe the role of gap junctions in creating a functional syncytium.
Provide specific details about the source of intracellular Ca^{2+} increase. Outline the sequence of events that occurs between the initiation of an action potential in a cardiac muscle cell, the resulting contraction and then relaxation of that cell.
Contrast the duration of the action potential and the refractory period in a cardiac muscle and skeletal muscle. Sketch the temporal relationship between an action potential and the resulting contraction (twitch) in a cardiac muscle cell and in a skeletal muscle fiber. Based on this graph, explain why cardiac muscle cannot remain in a state of sustained (tetanic) contraction.
Characterize the substrates supplying the energy metabolism of cardiac muscle fibers, and describe quantitatively the contribution of the cardiac muscle to resting oxygen consumption. Give the normal values of oxygen extraction and arteriovenous oxygen difference in the coronary circulation, and explain how these values are unique when compared with other body organs.

Normal values: heart $AVDO_2$: more than double of the body average (114 mL/L).

21. Cardiac muscle: cellular electrophysiology. Electrocardiography (ECG)
Sketch a typical action potential in a ventricular muscle and a pacemaker cell. Describe how ionic currents and ion channels contribute to the four phases of the cardiac action potential.
How does the long plateau of the cardiac action potential develop and what is its functional role?
Beginning in the SA node, diagram the normal sequence of cardiac activation (depolarization) and the role played by the specialized conducting system.
Explain the functional significance of the slow conduction through the AV node.
Contrast the sympathetic and parasympathetic nervous system influence on heart rate and cardiac excitation in general.
Define the terms: positive and negative chronotropic and dromotropic effects (bradycardia, tachycardia). How does hyperkalaemia affect the excitability of the cardiac muscle?
Explain how ECG is generated. Describe the electrode conventions used by clinicians to standardize ECG recordings (unipolar and bipolar leads). Name the parts of a typical bipolar (Lead II) ECG tracing, explain the relationship between each of the waves, intervals, and segments in relation to the electrical state of the heart and give their normal value.

Normal values: duration of the myocardial action potential: 200-300 ms. Frequency of the intrinsic pacemaker, the SA node: 100/min, conduction speed in the AV node: 0.02-0.05 m/s, in the Purkinje fibers: 2-4 m/s, standard paper speed for ECG recording: 25mm/s (1mm=40ms); standard amplitude 1cm=1mV; P wave: <100 ms; PQ interval: 120-200 ms; QRS complex: 80 ms (<100 ms); QT interval: 320-390 ms.

22. Cardiac cycle.
Draw, in temporal relationship, the pressure changes in the left atrium, ventricle and in the aorta, the volume changes of the left ventricle, and the valve positions during the mechanical cardiac cycle. Identify the phases of the cardiac cycle on the graph. Explain the pressure changes in the atria and ventricles during the cardiac cycle.

Know the factors that contribute to the formation of cardiac sounds. Describe the timing and causes of the 1st and 2nd heart sounds.
Define stroke volume, cardiac output, cardiac index, and ejection fraction and give their normal values.
Explain the push-pull characteristic of the cardiac pump and the valve-plane mechanism. Describe the role of heart rate in altering the duration of systole and diastole.

Normal values: duration of the systole/diastole 270/530 ms (at 75 beat/min heart rate); left ventricular pressure (systole/diastole): 110/6-8 mmHg; right ventricular pressure (systole/diastole): 24/0-2 mmHg; left atrial pressure: 6-8 mmHg; right atrial pressure: 0-2 mmHg; heart rate at rest/at maximal work 70-180/min; stroke volume at rest/at maximal work: 70-80/125 mL; left ventricular end-systolic volume: 40-80 mL; left ventricular end-diastolic volume: 110-160 mL, left ventricular ejection fraction: 0.5-0.7; cardiac index: 3.2 L/min/m^2.

23. Factors determining the cardiac output. Regulation of the contractile force of the cardiac muscle. The Frank-Starling law of the heart.
Give the normal values of cardiac output at rest and during physical activity.
Compare the effect of sympathetic (β1 receptor) and parasympathetic (M2 receptor) autonomic nervous system on the heart rate. Define the terms: preload and afterload, what is their significance in the regulation of stroke volume.
Describe the factors that contribute to the increase in cardiac output during physical activity (enhance the cardiac pump function [preload↑ due to increased venous return, afterload↓ due to vasodilation of the vessels in muscles, sympathetic activation] and increase in heart rate [due to sympathetic activation]).
How do the following factors increase the power of contraction (positive inotropic) in the cardiac muscle: activation of the adrenergic receptors (homeometric control), increasing the length of muscle fibres (heterometric control), partial inhibition of the Na+-K+-ATPase and increasing the extracellular Ca^{2+}? Phrase the Frank-Starling law of the heart: mechanism, significance (Ca-sensitivity, sarcomer length).

Normal values: cardiac output at rest/maximal work: 5.5–24 L/min; cardiac index: 3.2 L/min/m^2; heart $AVDO_2$: more than double of the body average (114 mL/L).

24. The coronary circulation
List the blood vessels that supply the heart muscle (coronary vessels). Describe the characteristics of coronary blood flow during cardiac cycle. Contrast this cyclic variation in myocardial flow in the walls of the right and left ventricles. The resting tone of coronary vessels, their contribution to the cardiac output in rest and during physical activity. Enlist the possible reasons of alternations in the vascular tone. Give examples of substances eliciting vasodilation or vasoconstriction of coronary vessels.
Explain the mechanism whereby coronary blood flow is coupled to myocardial workload, and identify the humoral mechanisms (metabolites, NO) that cause coronary vasodilation and increased blood flow.
Explain how sympathethic stimulation alters cardiac activity and coronary vascular resistance.

Normal values: coronary blood flow at rest: 250 mL/min, 4-5% of resting cardiac output; heart $AVDO_2$: more than double of the body average (114 mL/L); table 1. and 2.

25. Blood viscosity and basic biophysical principles of circulation (Hagen–Poiseuille's law, Laplace's law, Bernoulli's law)
Define the term viscosity, list the factors that influence its value.
Define and compare flow and velocity of flow in terms of concept and unit. Understand the relationship between flow, velocity, and cross-sectional area (Bernoulli's law).
Understand the relationship between pressure gradient, flow, and resistance (Ohm's law) and explain these terms in the pulmonary and systemic circulation.
Understand the effects of adding resistance in series vs in parallel on total resistance and flow.
Explain the factors determining resistance using the Hagen Poiseuille's law. Explain the terms laminar –and turbulent flow. List the factors that shift laminar flow to turbulent flow. Describe the relationship between turbulent flow with the audible events, such as murmurs (blood pressure measurement).
Explain the concept of transmural pressure of blood vessels.
Explain the concept of vascular compliance, give the formula for its determination ($C=\Delta V/\Delta P$).

Explain the concept of critical closing pressure.
Describe the relationship among wall tension, transmural pressure, vessel radius and wall thickness using the equation of Laplace's law. Based on the relationship, in which vessel segment is the rupture of the vessel due to high wall tension most likely?

26. Hemodynamics: the function of the aorta and the arteries. The characteristics of the venous circulation.
Describe the structure of arteries, arterioles, capillaries, venules and veins, their contribution to the vascular resistance, and the value of blood pressure, total cross-section, flow velocity and blood volume across the different vessel regions.
Describe the methods of arterial blood pressure determinations. Give the definitions and normal values of arterial systolic, diastolic, mean, and pulse pressures. Describe the Windkessel function of the aorta.
Describe the role of muscular arteries and arterioles.
Characterize the structure of veins (wall distensibility). Explain why the volume of the venous system increases significantly with the changes of hydrostatic pressures related to standing up (orthostasis).
Describe the factors influencing venous return (heart pumping: „vis a tergo" and „vis a fronte", dynamic muscle pump, venoconstriction, respiratory pump, positive intraabdominal pressure, arterial pulsation, gravity, venous valves).

Normal values: perfusion pressure (pressure gradient) in the systemic / pulmonary circulation: 83 /6 mmHg, blood pressure drop in the systemic resistance vessels (arterioles): 60 mmHg, average flow velocity in the aorta: 22.5 cm/s, in the capillaries: 0,03 cm/s, cross sectional area of the aorta 4 cm^2, total cross sectional area of capillaries: 4000 cm^2, arterial systolic/diastolic/mean pressures: 110/70/83 mmHg; pulse pressure: 40 mmHg, central venous pressure: 0-2 mmHg.

27. The microcirculation: capillary solute exchange, lymphatic circulation and edema formation
Enlist the vascular segments that belong to microcirculation (terminal arterioles, metarterioles, precapillary sphincters – to control capillary blood flow; capillaries and postcapillary venules – exchange). Describe the main types of true capillaries: continuous, fenestrated and discontinuous endothelium. Describe the transports across the capillary wall.
Define osmotic, oncotic (colloidosmotic) and hydrostatic pressures, and give the normal values of these (the Starling forces) in both the capillary blood and the interstitial fluid compartments (special values: e.g. glomerular capillaries in the nephron, pulmonary capillaries – what are the consequences of these pressure values).
Define the Starling equation and discuss how each component influences fluid movement across the capillary wall.
Describe the lymphatics, and explain how the structural characteristics of terminal lymphatics allow the reabsorption of large compounds, such as proteins. Contrast the structure of lymphatic capillaries and systemic capillaries. What is the significance of the smooth muscle in the walls of lymphatic vessels?
Identify critical functions of the lymphatic system: clearance of proteins from the interstitium, reabsorption of filtered fluid, fat absorption, lymphocyte recirculation.
Describe the factors prompting lymphatic circulation: muscle pump, respiratory pump, venoconstriction, positive intraabdominal pressure, gravity, venous valves).
Define the term edema, which factors can lead to its development?

Normal values: average systemic capillary hydrostatic (blood) pressure: 17.3 mmHg, interstitial hydrostatic pressure: -3 mmHg, plasma oncotic (colloidosmotic) pressure: 28 mmHg, interstitial oncotic (colloidosmotic) pressure: 8 mmHg; average pulmonary capillary hydrostatic pressure: 10-11 mmHg, glomerular hydrostatic pressure:40–60 mmHg; lymph flow: 3-4 L/day.

28. The regulation of local blood flow. Autoregulation of blood flow, functional hyperemia, vasoactive mediators
Describe the role of the local regulation of blood flow. Describe the contribution of myogenic tone to local regulation of blood flow. Describe the Bayliss effect.
Enlist the vasoactive mediators released from vascular endothelium (NO, endothelin, eicosanoids). Describe the No actions on the vascular smooth muscle.
Describe how the theory of metabolic regulation of blood flow accounts for active hyperemia and reactive hyperemia.
Identify the role of P_{O2}, P_{CO2}, pH, adenosine, PGE_2, local temperature and K^+-ions in the control of local blood flow.
Define the autoregulation of blood flow – mention the areas where it has significant role (renal and cerebral circulation).
Humoral control of inflammatory hyperemia. Describe how histamine released from mast cells, bradykinin, prostanoids, and neuropeptides (SP, CGRP) released from polymodal nociceptors contribute to the inflammatory hyperemia.

Describe the triple response of the skin, and the contribution of the axon reflex to it.

Table 2.

29. Short-term control mechanisms of arterial blood pressure.
Describe the methods of arterial blood pressure determinations. Give the definitions and normal values of arterial systolic, diastolic, mean, and pulse pressures. Explain the factors determining blood pressure: cardiac pump function, circulating blood volume, total peripheral resistance.
Define the resting, neurogenic, basal and myogenic tone of resistance vessels. Describe the sympathethic vasomotor tone: its origin, the neurotransmitter and receptor responsible for the effect. What is the physiological significance of the sympathethic tone? Give examples to organ circulations where the sympathethic vasomotor tone is significant and where is negligible.
Characterize the reflex circuit elements of the high pressure baroreceptor reflex: 1. activity of the baroreceptors of the carotid sinus and the aortic arch along with their afferent nerves (CN IX and X), 2. the connections of the medullary neuronal groups playing a role in the central integration of the reflex (pressor and depressor area), 3. the activity of the sympathethic and the parasympathethic (CN X, vagus nerve) efferents, 4. the effects on the target organs (heart, arterioles, veins).
Describe the significance of the high pressure baroreceptor reflex. Explain the function of the baroreceptor reflex during postural changes (lying down, standing up).
Describe the role of chemoreceptors in the control of blood pressure.

Normal values: when standing up (orthostasis) the increase of venous blood volume in the lower extremity: 500 ml, Table 2.

30. Long-term control of arterial blood pressure. Volume regulation: The regulation of Na^+-metabolism and extracellular fluid volume.
Describe the methods of arterial blood pressure determinations. Give the definitions and normal values of arterial systolic, diastolic, mean, and pulse pressures. Explain the factors determining blood pressure: cardiac pump function, circulating blood volume, total peripheral resistance.
Define the role of sodium ion in maintaining extracellular fluid volume.
Describe the mechanisms involved in the monitoring of ECF volume (e.g., high-pressure baroreceptors, low-pressure cardiopulmonary stretch receptors, the juxtaglomerular apparatus, ANP producing atrial cardiomyocytes).
Explain the regulation of renin secretion. Diagram the activation of the renin-angiotensin system (RAS).
Identify the major mineralocorticoid hormone (aldosterone), describe its production, its target cells and its major biological actions.
List the physiological stimuli regulating aldosterone secretion. Contrast these stimuli with the effects of aldosterone on renal excretion of Na^+ and K^+, respectively.
Describe the causes and the consequence of reduced or elevated secretion of aldosterone (mineralocorticoid).
Explain the roles of cardiopulmonary (volume) receptors in the long-term control of arterial blood pressure.
Describe the effects of angiotensin II, vasopressin, and atrial natriuretic peptide (ANP) on arterial blood pressure: direct vascular and indirect renal mechanisms. Give the respective receptors and signal transduction mechanisms mediating the effects of these hormones.

31. Respiratory mechanics: Static mechanics of the lung and the chest. Spirogram. The rhythmogenesis of breathing.
Describe the functions of airways. Describe the mechanism of inspiration and expiration. Draw a diagram showing how pleural pressure, alveolar pressure, air flow, and long volume changes during the respiratory cycle.
Describe the forces responsible for the development of negative pleural pressure (elastic recoil of the lung, and expansion tendency of the chest wall). Describe the consequence of pneumothorax (air getting into the pleural space).
Define and explain anatomic and physiologic dead space, respiratory rate, minute ventilation and alveolar ventilation.
Draw a normal spirogram, indicating the various lung volumes. Explain how the different lung capacities are determined by the summation of lung volumes. Draw a spirogramm of a forced expiratory effort. Indicate the forced vital capacity (FVC), the forced expiratory volume in 1 second (FEV_1). Define the Tiffeneau-index (FEV_1/VC).
Define surface tension and the role of surfactant. Describe the source and the composition of surfactant. Explain the regulation of surfactant secretion.

Describe the control of airway diameter and secretory activity (sympathetic and parasympathetic effects): Define the term bronchomotor tone. Describe the effect of inflammatory mediators (histamine, prostanoids and leucotrienes). List the muscles used in quiet breathing, and the additional muscles involved in forced respiration. Describe the brainstem regions involved in the rhythmogenesis and regulation of breathing movements (DRG, VRG, pre-Bötzinger complex, Kölliker-Fuse nucleus).

Normal values: static lung volumes and capacities male/female (mL): TV: 500/500, IRV: 3100/1900, ERV: 1200/800, RV: 1200/1000, FRC: 2400/1800, VC: 4800/3200, TLC: 6000/4200; lung compliance: 0,2 L/cmH_20, chest+lung compliance 0,1 L/cmH_20, pleural pressure at the end of inspiration/expiration: -8/-5 cmH_20, alveolar pressure at the peak of inspiratory/expiratory flow: -1/1 cmH_20, airflow at the maximal intensity of inspiration/expiration: -0.5/0.5 L/sec Tiffeneau-index (FEV_1/VC): 75-80%, anatomic dead space: 150 ml, respiratory rate: 14 1/min, minute ventilation: 7 L/min, alveolar ventilation: 5 L/min, maximal hyperventilation capacity: 100-200 L/min.

32. Pulmonary gas exchange. Oxygen and carbon-dioxide transport in blood.
Give the normal values of partial pressures for oxygen and carbon dioxide in inspired air, alveolar air, arterial blood and mixed (central) venous blood?
Define the terms hypoventilation, hyperventilation.
Describe the O_2 transport (1. hemoglobin bound, 2. physically dissolved) and the CO_2 transport (1. physically dissolved, 2. chemically dissolved as bicarbonate anions, and 3. hemoglobin-bound with carbamino bonds) mechanisms in blood and the percentage contribution of these mechanisms to transport. Give the normal values for the bicarbonate concentration and the pH in arterial and mixed venous blood.
Draw the hemoglobin oxygen-dissociation curve. Explain the connections between pO_2, hemoglobin-saturation and blood O2 content, and give their normal values. Define P_{50} and give its normal value. Describe how the oxyhemoglobin dissociation curve is affected by changes in pCO_2 (Bohr-effect), plasma pH and red blood cell 2,3-DPG concentration. Explain the functional significance of these changes.
Describe the chemical structure of the hemoglobin molecule. Enlist and define special/pathological hemoglobin forms (HbF, methemoglobin, carboxy-hemoglobin, carbaminohemoglobin) and give their functional characteristics.
Describe the oxygen transport from the alveolus to the capillary blood.
Name the critical enzyme required for CO_2-transport, and its cellular location (carbonic anhydrase).
Explain the importance of chloride-shift (Hamburger-shift) in the blood CO_2-transport.

Normal values: partial pressure values (mmHg) of respiratory gases: inspired air / alveolar air / arterial blood / venous blood: pO_2: 149/100-104/95-98/40, pCO_2: 0,3/40/40/46; HbA P_{50}: 26 mmHg; arterial/mixed venous blood oxygen saturation: 97-98/75%; oxygen concentration in arterial/venous blood: 200/150 mL/L; arteriovenous oxygen difference ($AVDO_2$): 50 mL/L; resting oxygen uptake/metabolic rate: 250-280 mL/min, CO_2 concentration in arterial/venous blood: 480/520 mL/L; bicarbonate concentration arterial/venous blood: 24/27 mM; arteriovenous difference CO_2 ($AVDCO_2$): -40 mL/L; CO_2 production at rest: 210 mL/min, arterial and venous blood pH: 7.38–7.42.

33.Pulmonary circulation. The chemical control of ventilation. Ventilatory reflexes elicited from the lung.
Compare the pulmonary circulation with the systemic circulation: blood pressure values, vascular resistance and response to hypoxia. Describe the factors determining pulmonary circulation: neural effects (sympathetic, parasympathetic and sensory nervous sstem), vasoconstrictors (alveolar hypoxia, hypercapnia, low pH, serotonine, histamine, prostaglandines, angiotensin, leukotrienes, neuropeptides, endotheline) and vasodilatator substances (increased alveolar O2, prostacycline, NO, bradykinine, dopamine, histamine). Describe the ventilation-perfusion ratio in zone I-III in standing position.
Describe the anatomical locations of chemoreceptors monitoring the blood pO_2, pCO_2, and pH levels, explain their respective importance for detecting the changes in blood gases.
Describe the structure and function of peripheral chemoreceptors. Describe the function of central chemoreceptors.
Explain how alveolar ventilation is changed by changes in pO_2, pCO_2, or by combined changes.
Describe the driving force of ventilation after the adaptation of central chemoreceptors and explain what happens if such patient is administered pure oxygen.
Ventilatory reflexes elicited from the lungs: slow adaptation stretch receptors (inhalation inhibited, passive exhalation initiated, bronchodilation – Hering-Breuer reflex); fast adaptation irritant receptors (hyperpnoea, bronchoconstriction, mucus production, caughing); juxtacapillary chemoreceptors (short apne, bronchoconstriction, mucus production).

Normal values: maximal O_2 uptake: 4000 mL/min, maximal CO_2 production: 3200-4000 mL/min, maximal voluntary ventilation (MVV): 100-200 L/min, pulmonary artery systolic/diastolic/mean pressure: 24/9/14 mmHg, pulmonary artery pulse pressure: 15 mmHg, left atrial pressure: 6-8 mmHg, Tables 1 and 2.

34. Glomerular filtration: the factors determining the volume and composition of filtrate

Identify the following structures of the glomerular tuft: the afferent and efferent arterioles, glomerular capillary network, Bowman's capsule, and the juxtaglomerular apparatus (including the specialized juxtaglomerular arteriole cells and the macula densa).

Describe the three layers comprising the glomerular filtration barrier, and identify the capillary endothelium, the basement membrane and the podocytes. Which layer has the highest barrier function against filtration?

Define glomerular filtration rate (GFR), renal plasma flow (RPF), and filtration fraction (FF) and give their normal values. What kinds of substances are used to determine GFR and RPF values?

Given the capillary and Bowman's capsule hydrostatic and oncotic pressures, calculate the net filtration force (the effective filtration pressure) at the glomerular capillaries Define the factors determining GFR: characteristics of glomerular membrane (permeability, surface for filtration), effective filtration pressure, renal blood flow.

Normal values: GFR: 120-125 mL/min, RPF: 660 mL/min, FF: 0.2

35. Renal blood flow. The regulation of GFR and RBF.

Describe in sequence the blood vessels through which blood flows when passing from the renal artery to the renal vein, including the glomerular blood vessels, peritubular capillaries, and the vasa recta.

Define renal blood flow (RBF), including its normal value and its contribution to the cardiac output at rest. Describe the resting tone of renal vessels and the circumstances when it alters (physical activity, bleeding).

Describe the autoregulation of the RBF/RPF/GFR (autoregulation range). Describe the effect of change in the resistance of the afferent arteriole on GFR and RBF, and RPF.

Describe the role of the tubuloglomerular feedback, the local vasoactive metabolites (paracrine angitensin II, prostaglandins), and the myogenic response (Bayliss effect) in the process of autoregulation.

Describe the effect of low hydrostatic and high colloid osmotic pressures in peritubular capillaries on net proximal tubular fluid reabsorption.

Normal values: autoregulation range: 60-180 mmHg, RBF 1320 mL/min, RBF is 20-23% of resting cardiac output, Tables 1 and 2.

36. The general features of transport mechanisms in the renal tubuli (reabsorption and secretion). Renal clearance

Describe in sequence the tubular segments through which ultrafiltrate flows after it is formed at Bowman's capsule to when it enters the renal pelvis.

Identify each structure as being located in the renal cortex or renal medulla. Based on the glomerulus location and the length of the loop of Henle, distinguish between cortical and juxtamedullary nephrons.

Describe the contribution of the major nephron segments to the reabsorption of the filtered load of solute and water.

Define tubular reabsorption and secretion.

Explain the clearance principle. Use the clearance equation and appropriate compounds (inulin/creatinine, PAH) to determine the glomerular filtration rate, renal plasma flow, and renal blood flow.

Give the normal values of the clearance for inulin, creatinine, PAH, and glucose. The organic solutes reabsorbed with glucose-type reabsorption (monosaccharides, amino acids, ketone bodies). Glucose reabsorption: characterize the luminal and basolateral transport mechanisms.

Define the renal threshold of glucose and tubular maximum (Tmax) of glucose. Define glucosuria and describe the osmotic diuresis induced by glucosuria associated with diabetes mellitus Describe the fate of the filtered peptides and proteins in the proximal tubuli.

Describe the urea reabsorption in the proximal tubuli, and the urea recirculation in the distal nephron segments.

Normal values: inulin clearance=GFR, 120 mL/min, PAH-clearance=RPF=660 mL/min, renal threshold of glucose: 10 mM

37. Renal tubular transport of NaCl and water, production of the medullary osmotic gradient. The

concentration and dilution of urine. Osmoregulation. The regulation of K^+ metabolism.
Describe the luminal mechanisms of Na+-reabsorption in the proximal tubule (Na+-solute, Na+-H+- antiporter, paracellular mechanisms), in the thick ascending limb of the loop of Henle (Na+-K+-2Cl--symporter), in the distal convoluted tubulus (Na+-Cl--symporter) and the collecting duct (Na+-channel). Which transport is under hormonal control?
Characterize the renal tubular segments based on their water permeability. Describe the changes of osmolarity in the tubular fluid and in the interstitial fluid from the loop of Henle, and its importance for the dilution and concentration of urine.
Explain the countercurrent multiplier mechanism of the loop of Henle: what is the role of the countercurrent design and the different transport mechanisms in the descending and the ascending limbs in the production of the medullary hyperosmotic gradient (sodium and urea recycling)?
Describe the role of the countercurrent organization of renal medullary blood flow through the vasa recta on retaining the medullary osmotic gradient (countercurrent exchanger). Identify major routes and normal ranges for water intake and loss.
Localize the cells producing arginine-vasopressin (AVP), and describe the mechanism of neurosecretion from the posterior pituitary gland.
Describe the stimuli and mechanisms that control AVP secretion.
List the target cells for vasopressin and explain why AVP is also known as antidiuretic hormone (ADH).
Identify the tubular segment, where AVP increases water and urea permeability, and describe the cellular mechanism of its action (V_2-receptor, aquaporins and urea transporter). Explain how these affect urine concentration/dilution.
Distinguish between diabetes insipidus and explain the difference between the polyuria elicited by diabetes insipidus and by osmotic dieresis (urea content).
Define the role of extracellular K+ in maintaining normal nerve, heat muscle and skeletal muscle function.
Describe K+ distribution within the body (intra- and extracellular fluid compartment), and the role of insulin and aldosterone in the movement of K+ between intracellular and extracellular pools. Identify the tubular sites of K+ reabsorption and secretion.
Describe the factors that regulate K+ secretion in the collecting duct (i.e., aldosterone, plasma K+).

Normal values: maximal osmotic concentration in the outer medulla (short-loop nephron): 600 mosmol/L, in the inner medulla (long-loop nephron): 1200 mosmol/L; urine osmotic concentration: 70-1200 mosmol/L; urine specific gravity: 1001-1030 g/L (blood plasma 1012 g/L); diuresis and its interpretation: anuria: <100 mL/day; oliguria:100-600 mL/day; normal range: 600-2500 mL/day; polyuria: >2500 mL/day; in diabetes insipidus can reach 18-25 L/day!

38. The physiology of the urinary tract. Micturition reflex.
Describe the motor functions of the upper urinary tract.
Explain the visceral sensory, autonomic (sympathethic and parasympathethic) and somatic motor innervation of the urinary bladder and the urethral sphincters. Identify the structures critically important for urine continence as well as for micturition located in the lumbar and sacral segments of the spinal cord, and in the pons.
Describe the reflex arch of the micturition reflex (stimulus, receptor, center, efferent and response). Define the terms passive and active incontinence.

39. Thermoregulation, cutaneous blood flow.
Contrast the stability of body core with the variability of body shell (skin) temperature. Give the normal values of core body temperatures in humans, the circadian rhythm of core temperature and also the dependence of core temperature on the menstrual cycle. Define the thermoneutral comfort zone.
Diagram the thermal balance for the body, including metabolic heat production, heat exchange mechanisms (convection, conduction, radiation), and heat loss through evaporation. Metabolic heat production: the respective contributions of basal metabolic rate, physical exercise, and shivering to heat production. Non-shivering thermogenesis: the structure and function of brown adipose tissue, the control of its activity.
Describe the neuronal components of thermoregulatory reflexes: peripheral and thermal thermoreceptors, the neuronal regulation (hypothalamus). Define the thermoregulatory „set point".
Enlist the major physiologic mechanisms preventing from the development of either hypethermia or hypothermia (heat and cold adaptation process).
The control mechanisms of cutaneous blood flow: specific features of the microcirculation in acral and non-acral regions. Contrast local and neural control of cutaneous blood flow. Discuss the unique characteristics of skin blood flow

that are adaptive for body temperature regulation.
Describe the structure, function, and neuronal control of eccrine sweat glands. Describe the mechanisms of fluid secretion by the secretory coil and the ductal NaCl reabsorption.
Explain how the change in core temperature that accompanies exercise or passive heat accumulation differs from fever produced by infections (such as influenza), which alter the thermoregulatory set point.

Normal values: core body temperature: 37 °C (36.2-37.5 °C), thermoneutral zone (naked man): 25-27 °C.

40. Skeletal muscle blood flow. Sports physiology: the cardiovascular, respiratory and muscular effects of training. Factors determining performance in sports.
Give the contribution of skeletal muscle blood flow to the cardiac output at rest and during exercise.
Characterize the resting tone of vessels in the skeletal muscles, list the factors altering the vascular tone (Table 1).
Explain the importance of systemic neural and local control mechanisms in the skeletal muscle circulation. Give examples of vasodilator and vasoconstrictor mediators affecting these vessels.
Describe the redistribution of cardiac output during exercise to the CNS, coronary, splanchnic, cutaneous, and skeletal muscle vascular beds during sustained exercise (distance running) (Table 2). Characterize quantitatively the acute cardiorespiratory effects of exercise (heart rate, cardiac output, blood pressure, respiratory rate, ventilation and oxygen uptake (V_{O2})).
Contrast the effect of phasic and sustained skeletal muscle contraction. Explain the importance of the muscle pump.
Describe the possible energy sources, basic pathways of energy metabolism and hormonal regulation of metabolism of the exercising skeletal muscle (insulin, androgens, cortisol, GH, thyroid hormones).
Define fatigue and exhaustion and mention some of their possible underlying mechanisms.
Describe the cardiovascular, respiratory and muscular effects of training (heart rate, stroke volume, cardiac output, plasma volume, Vo_{2max}). (normal values).
List the factors determining performance in sports! (natural endowment = genetic factors, training, physiological status = neuromuscular and cardiorespiratory systems, psychological factors = motivation and tactics). Explain the impact of food and fluid intake (amount, composition and timing) in optimizing performance.

Table 1 and 2.

Normalvalues:

variable	untrained person	trained person	world class endurance runner
Heart rate HR_{rest} (beats/min)	75	65	45
Heart rate HR_{max} (beats/min)	185	183	174
Stroke volume SV_{rest} (mL)	60	70	100
Stroke volume SV_{max} (mL)	120	140	200
Systolic arterial BP at rest (mmHg)	135	130	120
Blood volume (L)	4,7	5,1	6
Max. ventilation V_{max} (L/min)	110	130	190
Max. blood lactate level (mmol/L)	7,5	8,5	9
Max. oxygen uptake Vo_{2max}(mL/bwkg/min)	40	50	80

Vessel region	Basal tone	Vasoconstrictor tone	Increase in tone following sympathetic activation
coronaries	+++++	-	-
brain vessels	+++++	-	-
vessels of skeletal muscle	++	++	+++
renal vessels	+	-	+++
splanchnic vessels	++	++	++++
acral vessels of the skin	-	++++	++++

Table 1: resting vascular tone at specific regions

Organ	Weight		Contribution from the resting cardiac output		O_2 consumption at rest		Contribution from the increased cardiac output (during exercise)		Maximal blood supply through maximal vasodilationa
	kg	%	mL/min	%	mL/min	%	mL/min	%	mL/min
Total	**70**	**100**	**5000**	**100**	**250**	**100**	**25000**	**100**	
Brain	1.4	2	750	15	45	18	750	3	1500
Heart	0.3	0.4	250	5	30	12	1250	5	1250
Splanchnic region	4	5.7	1000	20	55	22	750	3	9000
Liver	1.5	2.1	500	10					5000
Kidney	0.3	0.4	1000	20	17.5	7	750	3	1800
Skeletal muscle	35	50	800	16	50	20	21250	85	21250
Skin	2	2.9	250	5	10	4			3000
Adipose tissue	9	13	250	5	42.5	17	250	1	1800
Bone, etc	18	25.6	200	4					2000

Table 2: Circulatory redistribution

Learning Objectives 2nd semester

41. Acid-base balance

Define the term pH. Identify the normal range of blood pH values.
Define the term buffer, list them existing in the blood. Describe the role of buffers in maintaining pH, including the roles of the lungs and kidneys. List the parameters used for determining the acid-base status: st. bicarbonate, actual bicarbonate, buffer base).

Identify the major sites of $HCO3^-$ reabsorption (and $HCO3^-$ secretion) along the nephron, emphasizing the importance of H+ secretory mechanisms in this process. Describe the H+ secretory mechanisms in the proximal and distal nephron sites.

Describe the cellular mechanisms responsible for net transepithelial movement of $HCO3^-$.
Describe the importance of urinary buffers, and the production and excretion of ammonium. Explain the types and reasons of acid-base disturbances. Given a sudden increase or decrease in pH, identify the magnitude of the compensations that act to minimize change in pH of the body fluids, including a) buffers, b) respiratory adjustments, and c) renal adjustments.
Describe the renal and respiratory compensations of acid-base disturbances.

Normal values: arterial blood pH: 7,37-7,43, standard bicarbonate: 24 mmol/L, buffer base (BB): 44–49 mmol/L, urine pH: 4.0–8.0.

42. Principles of the regulation of the gastrointestinal tract. Special functional features of the gastrointestinal smooth muscle.

Describe the general functions of the gastrointestinal system (GIS) (motility, secretion, digestion, absorption). Starting from the oral cavity, describe where the above listed functions of the GIS are predominantly regulated by the central nervous system (oral cavity, salivary glands, esophagus, proximal stomach and rectum) or by local neural/humoral as well as by hormonal mechanisms (distal stomach, small intestine and colon)!
Describe the major anatomical characteristics of the enteric nervous system and the major cellular divisions of enteric ganglia (sensory nerves, interneurons, and motor neurons). Given a cross section of the bowel wall, identify the anatomical positions and major characteristics of the myenteric and submucosal plexi. Explain the interactions between the enteral nervous system and the sympathethic/ parasympathethic divisions of the autonomic nervous system.
Describe the vago-vagal reflex. Describe the main effects of GIS hormones: gastrin, secretin, CCK, GIP, GLP, and motilin.
Describe the characteristics of the spontaneous and stimulated electrical activity of GI smooth muscles (electrical slow waves, action potentials, and contraction).
Describe the anatomical locations and role of interstitial cells of Cajal as slow wave pacemakers and mediators of inputs from the enteric nervous system.
Describe major motor patterns in the GI tract and their functions: peristalsis and segmentation. Define the Bayliss-Starling law of the gut. Describe how extrinsic nerves (sympathetic and parasympathetic) affect motor patterns.

43. The splanchnic circulation

Give the percent contribution of splanchnic blood flow from the resting cardiac output. Name the components of the resting tone. Contrast the local and neural control of the splanchnic circulation (following exercise, blood loss, food intake).
Describe the role of the hepatic portal system in the function of the GIS. Describe the hepatic microcirculation, the morphological and functional features of the sinusoid capillaries.
Table 1 and 2.

44. Functions of the upper GI tract: chewing, salivation, swallowing.

Describe the motor mechanisms of food intake: sucking, biting and chewing (mastication).
Describe the volume and composition of salivary fluid coming from major salivary glands. Understand how acinar secretions are modified by duct cells to produce the final salivary fluid.
Describe the physiological functions and components of saliva.
Describe the stimuli and neural pathways involved in promoting salivary secretion. Explain why the composition of saliva will be different in response to sympathethic or parasympathethic stimulation.
Describe the swallowing reflex.
Understand the differences in the neural and muscular composition and function in the upper versus lower esophagus. Explicitly consider the upper and lower esophageal sphincters (UES and LES). Distinguish between primary and secondary

esophagus peristalsis.

45. Motor functions of the stomach. Vomiting (emesis). The mechanism and regulation of gastric juice secretion.

Describe the functional divisions of the stomach concerning gastric motility patterns.
Describe gastric filling: the short-loop and long-loop (vago-vagal) neural reflexes eliciting the receptive relaxation of the proximal stomach. Describe the mechanism of vomiting. List some stimuli that can trigger vomiting.
Describe the products of different cell types in the glands of the oxyntic area: the parietal cells (HCl, intrinsic factor), chief cells (pepsinogen), and mucosal cells (bicarbonate rich mucus) Describe the cellular mechanism of HCl production.
Explain the role of HCl in the digestion of proteins and carbohydrates. How is the activation of pepsinogen triggered?
What is the role of HCl in the defense against infections?
Describe the sympathetic/parasympathetic effect on the GI secretion. Enlist the neurotransmitter (Ach), the paracrine substance (histamine), and the hormone (gastrin) directly stimulating the parietal cells: their source, receptors, and signal transduction mechanisms.
Describe the role of GRP and somatostatin.
Describe the role of duodenal contents in regulating gastric secretion. Give the neuronal and hormonal mechanisms of the intestinal inhibition.
List the mechanisms contributing to gastric mucosal defense (prostaglandines, bicarbonate barrier).

Normal values: gastric juice secretion: 1-1.5 L/day; gastric juice H^+ concentration: 70-80 mmol/L; gastric juice pH: 1.10-1.15

46. The exocrine pancreas: secretion and regulation. The bile: secretion, storage, mobilization, regulation.

List the major components secreted by the exocrine pancreas and the principal cell types involved in this secretion.
Describe the main enzymes of the pancreas and the mechanism by which pancreatic zymogens are activated in the small intestine. Explain the role of the duodenal enteropeptidase (enterokinase). Describe the process of digestive enzyme synthesis and packaging and how this process maintains the integrity of the pancreas.
Describe the mechanisms by which HCO_3^- is secreted by pancreatic ductal cells.
Explain the neural (vago-vagal reflexes) and hormonal (secretin, CCK) control of secretion of the exocrine pancreas.
List the bile salt, bile pigments, phospholipids, cholesterol and bicarbonate components of bile as secreted by the liver and after modification by the gallbladder.
Explain the mechanisms stimulating gall bladder contraction and the secretion of bile through the sphincter of Oddi into the small intestine. Give examples for choleretic and cholekinetic factors.
Describe the role of bile salts in the digestion of fats.
Describe the enterohepatic circulation, including any different handling among primary and secondary bile salts and bile acids. Describe the cellular mechanisms for the hepatic uptake, conjugation, and secretion of bile salts and bilirubin.

Normal values: pancreatic juice production: 500-700 mL/day, bile secretion: 600 mL/day

47. The small intestine: motor function, digestion and absorption.

Describe the digestive motor function of the small intestine: segmentation, peristalsis, Bayliss-Starling law of the gut.
Explain the interdigestive motor patterns of small intestine: development and significance of migrating motor complex (MMC). Describe the significance of villi movements in the small intestine.
Characterize the surface of the small intestine and explain its role in absorption processes.
Describe the sequential digestion of ingested starch by enzymes of the salivary glands, pancreas, and the intestinal apical membrane. Membrane transport mechanisms for carbohydrates in the enterocytes.
Describe the sequential digestion of ingested proteins by gastric pepsin, pancreatic enzymes, and enzymes at the intestinal apical membrane. Membrane transport mechanisms in the absorption processes.
Describe the mechanisms for the uptake, processing and release of lipids by the small intestinal epithelium.
Describe the composition and formation of chylomicrons, their movement across the enterocyte basolateral membrane, and the route of entry into the cardiovascular system.
Describe the location and the mechanisms that mediate the intestinal trans-epithelial movement of water and the major electrolytes.

Normal values: pancreatic juice production: 500-700 mL/day, intestinal juice secretion: 3-4 L/day, intestinal fluid

reabsorption: 5-6 L/day

48. The functions of the colon: motor functions, digestion, absorption. Defecation reflex.
Describe the motility patterns in different regions of the colon: haustration, antiperistalsis, mass- peristalsis, defecation.
Explain how motility of the colon affects the reabsorption of water and electrolytes.
Describe the mechanisms, localization and regulation of colonic sodium, chloride and water absorption. Describe the mechanisms mediating colonic bicarbonate and potassium transport (aldosterone). Describe the role of the colon in forming the normal intestinal microbiota.
Defecation: Describe the defecation reflex and voluntary control of the reflex, define the terms passive and active incontinence.

Normal values: fluid reabsorption in the colon: 1.5-2 L/day, water-content of the faeces: 75-150 mL/day

49. Nutrition: energy metabolism, the role of macronutrients in energy intake.
Name the types of macronutrient compounds (carbohydrates, proteins and lipids) and characterize them according to the following aspects:
Dietary proteins: Describe sources and minimal daily allowance of proteins, importance of the essential amino acids (examples), biological value (grade) of the dietary proteins, their biological importance, and their contribution to the energy production of the body. Dietary carbohydrates: Describe types of carbohydrates (sources), biological importance, their anti- ketogenic effect, their contribution to the energy production of the body.
Dietary lipids: Describe the sources of lipids, essential fatty acids (examples), their biological importance, their contribution to energy production of the body.
Compare the energy content of the macronutrients - biological caloric values. Define the basal metabolic rate (BMR). Describe the standard conditions for measurement of the BMR. List the major factors affecting the BMR of individuals (age, gender, endocrine status).
Explain the effect of food ingestion on the metabolic rate (specific dynamic effect - diet-induced thermogenesis (DIT)). Describe the effect of protein-rich diet on the metabolic rate.
List the factors determining the daily energy expenditure (BMR+DIT+physical activity). Describe the effect of physical activity on the energy metabolism.

Normal values: conversion of Calorie/kcal values to Joule values: 1 Cal/kcal=4.2 kJ; biological caloric values of carbohydrates/proteins/lipids: 17.2/17.2/39 kJ/g; BMR adult male/female: 7100/6300 kJ/day; recommended daily allowance of proteins/carbohydrates/lipids: 60-80/300/50-150 g/day; WHO recommendation for optimal protein intake: 1-1.5 g/kg b.w./day

50. Nutrition: water, minerals, trace elements, vitamins, dietary fibers.
Give the normal range of dietary water intake, and the sources of water getting into the GIS.
Describe the concept and give the definition of trace elements. Explain the biological/biochemical significance of trace elements. List and describe the physiological role of some of the major trace elements such as Fe, Zn, Cu, Se, I, F etc.
Describe the vitamin concept, and give the definition of vitamins. List the major classes of the vitamins.
Describe the concepts of hypovitaminosis and hypervitaminosis. List the types, sources and biological significance of water and lipid soluble vitamins, and describe the symptoms of vitamin deficiencies.
Dietary fibers: Describe the sources, their biological role (gut motility, effects on the microbiota of the colon).

Normal values: dietary water intake: 1.5-2 L/day; secreted fluid volume in the whole GIS: 6-8 L/day; ascorbic acid (Vitamin C): 65-75 mg/day.

51. Nutrition: The internal control of food intake. The control of fluid and salt intake.
Describe how does energy intake and the metabolic rate affect the energy balance of the body and the deposition of fat into the fatty tissue. Name the major factors influencing the food uptake and catabolic processes.
Describe the evaluation of the body composition, evaluation of the grade of obesity (Body mass index BMI, lean body mass).
Name the hypothalamic centers involved in the regulation of food intake: localization and neurochemical phenotype of orexigenic and anorexigenic neuron groups. Name orexigenic and anorexigenic mediator substances (neuropeptides: NPY, MSH). Describe the role of central and peripheral glucose sensors.

Describe the peripheral signals affecting the central regulation: mediators released from the GI tract (ghrelin, CCK, insulin). Describe the role of the chemosensitive vagal afferents.
Explain the short and long-term control of food intake.
Describe the central regulation of water (thirst) and salt intake.

52. Principles of endocrine control systems.
Describe the basic structure of the endocrine system: locations of the hormone-producing cells/organs, the hierarchic arrangement (HPO axis), and the feedback mechanisms.
Define hormones and give examples for humoral communications between cells.
Classify the hormones based on their chemical structure (e.g. amino acid derivatives, peptides, proteins, steroids), solubility (water, lipid), and the transport type in the blood (freely or protein-bound). Understand the effects of plasma hormone binding proteins on access of thyroid hormones and steroid hormones to their sites of action and degradation and on the regulation of hormone secretion.
Describe the target organ hormone receptors (membrane receptors and intracellular receptors) and their signaling pathways. Give 1-1 example from each group. Explain the types of hormonal effects using 1-1 example (stimulatory, inhibitory, permissive effects).
Describe the synthesis of peptide and steroid hormones. Describe the secretory patterns of the hormones (continuous or intermittent (rhythmicity: episodic, pulsatile, circadian, longer-term periods)).
Explain the importance of patterns of hormone secretion, such as pulsatile, diurnal, and menstrual. Give examples.

53. Characterization of the hypothalamo-hypophyseal (neuroendocrine) system. Central integration of autonomic functions.
Overview of the anatomical features of the hypothalamus (location, nuclei). Characterization of the hypothalamo-hypophyseal neuroendocrine system.
Describe the anterior and posterior pituitary lobes concerning their anatomical connection to the hypothalamus.
Identify appropriate hypothalamic factors (releasing and inhibiting hormones) that control the secretion of each of the anterior pituitary hormones, and describe their route of transport from the hypothalamus to the anterior pituitary.
Describe the hormones of the anterior pituitary lobe (6). Understand negative feedback control of anterior pituitary hormone secretion at multiple levels.
Describe the hormones of the posterior pituitary lobe: identify their secretions, action mechanisms, and physiological significances (ADH, oxytocin).
Describe the integrative functions of the hypothalamus: autonomic reflex, hierarchy in the autonomic nervous system, central integration of sensory, autonomic functions, and behavior.

54. Hormone synthesis in the adrenal cortex. The glucocorticoids: biosynthesis, regulation and physiological effects. Stress and general adaptation syndrome. Sex steroids of the adrenal cortex.
Identify the functional zones (one medullary and three cortical zones) and the principal hormones secreted from each cortical zone (glucocorticoids, mineralocorticoids, androgens).
Describe the components of the neuroendocrine (hypothalamo-pituitary-adrenal, HPA) axis that control glucocorticoid secretion. The corticotroph cells of the anterior pituitary. POMC.
Understand the differential regulation of cortisol versus aldosterone release. Describe the trophic effect of ACTH on the adrenal cortex and its significance concerning drug therapies involving glucocorticoid treatments.
Understand the cellular mechanism of action of adrenal cortical hormones (receptors).
Identify the major physiological and pharmacological actions of glucocorticoids on energy metabolism, on the carbohydrate, fat and protein metabolism, on the cardiovascular system, on the immune system, on the central nervous system, an on other endocrine systems that complement the metabolic effects to promote survival of the organism (gastrointestinal tract, surfactant, bone metabolism and growth). List the permissive effects of cortisol.
Identify the consequences of a) over-secretion and b) under-secretion of glucocorticoids.
Give the definitions of stress and stressor. Describe the 3 phases of the general adaptation syndrome (GAS) during the stress response.
Describe the interactions of adrenal medullary and cortical hormones in response to stress (Cannon's fight and flight response).
Describe the role of sex steroids secreted by the adrenal cortex.

55. Thyroid hormones: biosynthesis, regulation and physiological effects.
Describe the enteral absorption and the uptake of iodide in the thyroid gland.
Identify the steps in the biosynthesis, storage, and secretion of tri-iodothyronine (T3) and thyroxine (T4).
Describe the function of the hypothalamus-anterior pituitary-thyroid gland axis, the negative feedback regulation of T4/T3 secretion. Describe the trophic effect of TSH on the thyroid gland.
Describe the plasma transport proteins involved in blood transport of thyroid hormones. Explain the importance of thyroid hormone binding in blood on free and total thyroid hormone levels.
Understand the significance of the conversion of T4 to T3 in extra-thyroidal tissues, give the name of the enzyme responsible for the conversion.
Describe the localization of thyroid hormone-receptors, the molecular mechanism of ligand-receptor interaction.
Describe the physiologic effects and mechanisms of action of thyroid hormones on: energy metabolism, carbohydrate, fat and protein metabolism, cardiovascular system, central nervous system, gastrointestinal functions, respiratory system, growing and sexual functions. Understand the causes and consequences of a) over-secretion (hyperthyroidism) and b) under-secretion (hypothyroidism) of thyroid hormones. Explain what conditions can cause an enlargement of the thyroid gland (goiter).

56. The endocrine pancreas. The integrated endocrine control of metabolism.
Identify the normal range of plasma glucose concentrations, and list the chemical forms and anatomical sites of storage pools for glucose and other metabolic substrates.
Identify the major hormones secreted from the endocrine pancreas (insulin, glucagon, somatostatin, pancreatic polypeptide, amylin), their cells of origin, and their chemical nature (Langerhans islet).
Describe the insulin receptor. List the major target organs or cell types for insulin, the major effects of insulin on each, and the consequent changes in concentration of blood transport nutrients.
Understand the relationship between blood glucose concentrations and insulin secretion. Define the term ,,incretin" and give examples (GLP-1, GIP). Describe the roles of neural input and gastrointestinal hormones on insulin secretion.
Describe the consequences of over-secretion or under-secretion of insulin. Diabetes mellitus: types, symptoms, complications (high blood glucose - hypergylcaemia, ketoacidosis, hypovolemia).
Describe the control of glucagon secretion.
List the target organs or cell types for glucagon and describe its principal actions on each.
Identify the hormones (growth hormones, catecholamines, thyroid hormones, glucocorticoids) that promote the influx and efflux of glucose, fat, and protein into and out of energy storage pools and their impact on the uptake of glucose by tissues.

57. The development and physiology of the male reproductive system. The physiology of the sexual act
Define chromosomal, gonadal and somatic sex.
Describe the physiological functions of the internal and external components of the male reproductive tract.
Describe spermatogenesis and the role of Sertoli cells, Leydig cells and the basement membrane in this process. Describe the blood-testis barrier.
Describe the endocrine regulation of testicular function: the role of the GnRH pulse generator, FSH, LH, testosterone, and inhibin.
Describe the, biosynthesis, mechanism of transport within the blood of testosterone and related androgens.
List the major target organs and cell types for testosterone and other androgens. Describe the effects and cellular action mechanisms of testosterone and related androgens.
Define the term: puberty. Identify the consequences of over-secretion and under-secretion of testosterone for a) prepubertal and b) postpubescent males.
Describe the neural, vascular, and endocrine components of the erection, emission and ejaculation response.

Normal values: volume of semen: 1.5-5.0 mL, sperm concentration >15 (20-40) million/mL, >60% motile

58. The physiology of the female reproductive system: sexual steroids, ovarian and endometrial cycle, the physiology of the sexual act.
List the internal and external components of the female reproductive system. Describe the hormonal regulation of estrogen and progesterone biosynthesis and secretion by the ovaries (HT-HP-ovary axis). Describe the ovarian and

endometrial cycle, describe oogenesis and its relationship to changes in the ovarian follicle. Explain the roles of FSH, LH, estradiol, and inhibin in oogenesis and follicular maturation. Describe ovulation and the formation and decline of the corpus luteum and the roles of hormones in each of these processes.
Graphically illustrate the timing of changes in blood levels of FSH, LH, estradiol, and progesterone, and correlate these with structural changes in the endometrium (proliferative and secretory phases) and the ovary (ovarian cycle) seen during the menstrual cycle. Describe the change in core temperature during the cycle.
List the major target organs and cell types for estrogen action and describe its effects on each.
List the principal physiological actions of progesterone, its major target organs and cell types, and describe its effects on each.
Describe the physiology of the sexual act in female.

Normal values: length of menstrual cycle is 25-30 days; length of menstruation 4-6 days; duration of LH surge: 10-12 hours.

59. Fertilization and implantation. The neuroendocrine control of pregnancy, parturition and lactation.
Describe the process and location of fertilization. Give the time and location of implantation. List the hormones secreted by the placenta and describe the role of human chorionic gonadotropin (hCG) in the rescue of the corpus luteum in maintaining pregnancy early post- implantation. Explain the hormonal basis of pregnancy tests.
Describe further hormonal systems determining intrauterine development of the fetus (insulin, thyroid hormones).
Discuss the roles of sex steroids, oxytocin, relaxin, and prostaglandins in the initiation and maintenance of parturition.
Explain the role of hormones in mammary gland development during puberty, pregnancy, and lactation (estrogen, progesterone, prolactin, oxytocin).

Normal values: duration of oocyte migration 1-2 days; implantation of the blastocyst: 7 days after ovulation, length of pregnancy: 40 weeks

60. The regulation of Ca^{2+} and phosphate metabolism. The role of the bones in the Ca-homeostasis. Physiology of bones
Physiology of bones: types and structure of bones. Mechanism of bone tissue remodeling (osteoblast-induced osteoclast activation – RANKL, OPG).
Identify the major storage pools and major routes of Ca^{2+} and phosphate loss from the body. Identify the tubular transport mechanisms that are hormonally regulated.
Know the cells of origin for parathyroid hormone (PTH). Describe the regulation of PTH secretion and the role of the Ca^{2+}-sensing receptor. List the target organs and cell types for PTH and describe its effects on each.
Understand the consequences of a) over-secretion, and b) under-secretion of PTH. Explain the symptoms of hypocalcemia.
Identify the sources of vitamin D and diagram the biosynthetic pathway and the organs involved in modifying it to the biologically active 1,25(OH_2)D3 (1-25 dihydroxycholecalciferol, calcitriol). Identify the target organs, effects and cellular mechanisms of action for calcitriol. Describe the consequences of vitamin D deficiency.
Describe the negative feedback relationship between PTH and calcitriol.
Name the stimuli that can promote secretion of calcitonin, its actions, and identify which (if any) are physiologically important.
Enlist other hormones taking part in calcium homeostasis and bone metabolism.

61. Physiology of growth and puberty (hormonal changes)
List the hormones that play an important role in extrauterine somatic growth (growth hormone, IGF1, sex steroids, calcitriol, thyroid hormones, glucocorticoids, insulin).
Describe the relationship between growth hormone and the insulin-like growth factors in the regulation of growth.
Describe the metabolic and growth promoting actions of growth hormone.
Describe the consequences of growth hormone overproduction a) before (gigantism) and b) after the cessation (acromegaly) of longitudinal bone growth. Describe the symptoms of growth hormone under-secretion.
What is the effect of hypothyroidism (dwarfism) or stress on somatic growth?
Describe developmental changes in the male and female reproductive systems during puberty.
Describe the stages of puberty in females: adrenarche, thelarche, pubarche, menarche. What do these expressions mean?
What are the effects of sex steroids on somatic growth?

62. The control of cerebral blood flow, the cerebrospinal fluid, barrier systems of the brain.
Give the normal value of cerebral blood flow, and its percentage to the resting cardiac output. Describe the mechanism of the autoregulation of cerebral blood flow. Monroe-Kelly's principle. Explain the Cushing reflex.
Contrast the significance and mechanisms of local and systemic neural control of cerebral blood flow.
Discuss the relative importance of PO2, PCO2, pH and blood glucose level in regulating cerebral blood flow.
Describe formation, reabsorption and role of cerebral spinal fluid (CSF). Describe the normal pressure, flow, and volume of the CSF.
Describe the structural components of the blood brain barrier and how this barrier impedes the movement of various substances from the blood to neurons. Locate and identify the brain regions outside the blood-brain barrier, and describe the function of circumventricular organs.

Normal values: cerebral blood flow (adult): 750 mL/min, 15% of resting cardiac output. CSF volume: 140 mL; CSF secretion rate: 500 mL/day. CSF pressure: 5 mmHg (8-10 cmH_2O)

63. The peripheral nervous system: primary sensory neurons
Make a schematic figure of a primary sensory neuron and indicate and characterize its major parts: peripheral axon, central axon, cell body. Give the anatomical location of primary sensory neurons (spinal dorsal root ganglia, and the sensory ganglia of cranial nerves).
List the major neurotransmitters released from the primary sensory neurons.
Define the terms: receptor sensitivity, receptor specificity (modality), and receptive field.
Group the somatosensory receptors based on the origin of the sensory stimulus (extero-, intero-, and proprioceptors) and on their modality (mechano-, thermo, uni- and polimodal nociceptors). Define the term adaptation: slow-adapting and fast-adapting receptors. Explain how the axonal diameter and myelinisation determines the action potential propagation in sensory axons. Group the sensory axons according to the Lloyd-Hunt (Ia, Ib, II, III and IV)-, and the Erlanger-Gasser classification (Aα, Aβ, Aδ, and C). Define the terms secondary and tercier sensory cell. Give at least one example.

64. The somatosensory nervous system: the dorsal column (medial lemniscus system) pathways
Describe the submodalities of somatic sensibility (fine touch, proprioception) subserved by the Dorsal Column-Medial Lemniscus system.
Describe the cutaneous mechanoreceptors (localization, adaptation properties) and their functions: Pacinian corpuscles, Meissner's corpuscles, Ruffini endings, Merkel cell and free nerve endings.
Describe the topographic representation of the body at the level of the somatic sensory cortex (sensory homunculus).
Explain how peripheral innervations density influences the size of the representation area in the postcentral gyrus.
Define the concept of a dermatome and explain the dermatomal organization of the head and body.

65. The somatosensory nervous system: the anterolateral pathways. Exteroceptive spinal reflexes. Inflammatory pain. Hyperalgesia. The endogenous control of pain, the physiological background of pain management.
Describe the concepts of nociceptor and nociception. Definition of pain. Describe the cellular mechanisms of nociceptor activation. Differentiate between fast and slow pain and identify the peripheral nerve fibers and central connections that account for these different types of pain.
Describe the submodalities of somatic sensibility (pain/temperature/coarse touch) subserved by the spino-thalamic system.
Describe the ascending sensory pathways and their connections with the cerebral cortex conveying nociceptive, thermal and tactile (coarse touch) sensory information.
Describe the difference between the modality specific and wide dynamic range type interneurons/projection neurons in the spinal dorsal horn.
Describe the reactions of the body evoked by noxious stimulation (motor and autonomic responses, affective reactions).
Describe the reflex arc of the flexor-extensor reflex.
Inflammatory pain: inflammatory mediators and their receptors, symptoms of inflammation. Explain the terms hyperalgesia and allodynia.
Describe the components of the descending pain control (endogenous analgesic) system (PAG, LC, raphe nuclei, spinal gate control mechanisms). List the types of neurotransmitters involved. Describe how endogenous opiates may modulate the pain experience.

Describe the key features of visceral nociception. Describe the mechanism of referred pain of visceral origin. Describe the concept of Head zones, list 3 characteristic localizations of referred visceral pain.

66. The visual system: protection of the eye, image formation, refraction errors. The function of the photoreceptors, retinal signal processing. The visual field and the visual pathways. Cerebrocortical mechanisms. Binocular vision, color vision.

Describe the function and importance of tear secretion, the composition of tear, the control of tear secretion (innervation).
Describe the gross anatomical structure of the eye and basic physiological optics.
Describe the refraction of light as it passes through the eye to the retina, identifying the eye components that account for refraction of light.
Describe the process of accommodation to near vision. List the components of the accommodation triad. Define the "near point".
Explain the method of measuring visual acuity including the normal value of visual acuity (visus).
Describe the refractive deficits that account for myopia, hyperopia, presbyopia, astigmatism and their correction.
Explain the production, circulation and absorption of the vitreous humour. Give the normal value of intraocular pressure. Explain glaucoma.
List the structure and cell types of the human retina. Explain the properties of the different photoreceptor types: number, distribution in the retina, chromatic and luminance properties (scotopic and photopic vision).
Describe the basic biochemistry of the photo-transduction process, the "dark current", and the photoreceptor response to capturing a photon.
Trace the projections of the visual hemifields onto the retina (nasal/temporal), describe the retino-thalamo-striate pathway. Explain how the crossing of optic nerve fibres accounts for visual field representations at each stage.
Describe the extrageniculate projections (suprachiasmatic nucleus, superior colliculus, pretectum) of retinal ganglion cells and their importance.
Review the midbrain path for the pupillary light reflex. How do you interpret the presence / absence of the direct and consensual reflex?
Describe binocular disparity and its relationship to stereopsis (depending on the diastance). Explain the neuronal mechamism for colour vision. Cues supporting spatial vision.

Normal values: visus: 5/5 (m) or 20/20 (feet), spatial resolution: 1', total refractory power of the eye: 60 D, refractory power of the cornea: 40-43 D, refractory power of the lens (far accommodation): 17-20 D, near point: 7-10 cm, physiologic astigmia: 0.5 D, intraocular pressure: 10-20 mmHg (mean: 16 mmHg)

67. Hearing: the function of the outer, the middle and inner ear. Hearing tests. The auditory pathways

Define the following categories: pure (basic) tone, sound (musical tone), noise, frequency, loudness and intensity of the sound, propagation of the sound, sound pressure level (dB).
Describe the function of the outer and middle ear structures in the mechano-electrical transduction process of sound energy into nerve impulses. Describe the acustic impedance matching.
Describe the differences between bone and air conduction.
Describe the muscles in the middle ear and explain their role (tympanic reflex). Define the difference between conductive, sensory and neural loss of hearing, and name the tuning fork tests examining them.
Explain the frequency analysis performed by the cochlea on the basis of its physical properties (Békésy theory, tonotopy).
Identify the neuronal elements of the organ of Corti. Explain the function of inner and outer hair cells.
Explain how deformations of the basilar membrane are converted into action potentials in auditory nerve fibers.
Describe the auditory pathway. Describe the role of frequency code and population code in hearing.

Normal values: frequency range of human hearing: 20-20000 Hz, sound pressure level of human hearing: 0-120 dB, reference sound pressure level: 20 μPa, threshold of human hearing: 0 dB, frequency range of human speech: 250-4000 Hz, reference frequency of the phon scale: 1000 Hz

68. The physiology of olfaction and taste sensation.

Describe the location and structure of smell receptors.
Describe the olfactory cilium and the family of olfactory receptors housed in its membrane.
Explain how olfactory receptors are activated and explain the mechanism of olfactory transduction.

Explain the term functional topography in the olfactory system (e.g. olphactory bulb epitope map). Describe the olfactory pathways.
Define the following terms: anosmia, hyposmia, dysosmia.
Describe the location, structure, and afferent pathways of taste receptors. Describe the cells of a taste bud.
Name the basic taste sensations, i.e., identify the five distinct gustatory modalities.
Explain how taste receptors are activated and explain the mechanism of taste transduction for each taste quality.
Identify the three cranial nerves that transmit taste information to the cerebral cortex. Describe the structure and function of the central taste centers.

69. The motor reflex. The structure and function of muscle proprioceptors. The myotatic and the inverse myotatic spinal reflex. The gamma fusimotor servomechanism (gamma-loop).
Describe the reflex arc from stimuli to reflex actions.
What is the difference between exteroceptive and proprioceptive reflexes?
Define the notion of proprioception and describe the proprioceptors. Define the main functions of muscle spindles and Golgi tendon organs. Delineate the localization, structure, and sensory/motor innervation of muscle spindles and Golgi tendon organs. Describe the intrafusal and extrafusal muscle fibers and provide a classification for intrafusal fibers.
Define the structure and function of gamma and alpha motoneurons.
Explain how the activity of gamma motoneurons is able to compensate the changes in the structure and sensitivity of muscle spindles due to the contraction of the extrafusal muscle fibers (alpha- gamma coactivation).
Define the notion of myotatic and inverse myotatic reflexes, describe the receptors and the adequate stimuli.
Trace the path of neuronal activity during the knee-jerk (patellar) reflex and describe the reflex arc. Compare the reflex arc of the knee-jerk reflex with that of the inverse myotatic reflex.
Describe the agonist and antagonist muscles and the mechanism of reciprocal innervation.
What is the Jendrassik maneuver? What are hyporeflexia, hyperreflexia and areflexia?

70. The control of muscle tone and body posture. The vestibular system.
Define the notion of muscle tone and explain the role of alpha and gamma motoneurons in the regulation of muscle tone.
Enlist the brainstem neuronal structures participating in the regulation of muscle tone (nucl. ruber, nucl. vestibularis Deitersi, pontin and medullar reticular formation) and explain their role in flexor and extensor tone.
What is the effect of cortical and cerebellar lesion on muscle tone?
Enlist the sensory mechanisms implicated in the control of posture and gait (vestibular, proprioception, visual).
Delineate the elements of the vestibular system (semicircular canals and otolith organs).
Explain the function of hair cells. Define: endolymph, perilymph, receptor potential and the activity of the vestibular nerve. Compare the functions of the semicircular canals and otolith organs.
Define and describe the types of nystagmus: optokinetic, rotatoric, postrotatoric, and caloric nystagmus and their mechanisms.

71. The consequences of spinal cord hemisection and transection. The cerebrocortical control of movements. Cerebellum and basal ganglia in motor control
What is the spinal shock? What are the sensory, motor, and vegetative consequences of the total
spinal cord transection?
Enlist the functions that can and cannot be recovered after spinal shock in humans.
What is the lower (alpha) motoneuron? What is atrophy?
Enlist the parts, the localization and function of the motor cortex (primary motor, premotor, and supplementary motor cortex).
Describe the functions of the primary motor cortex. Define somatotopic organization and plasticity.
Describe the origin, path and function of the corticospinal tract. Enlist the consequences of corticospinal tract lesions (Babinski sign).
Enlist the main parts of the cerebellum (vestibulo-, spino-, cerebrocerebellum and describe their main roles.
Mention a few symptoms caused by the lesion of the cerebellum (nystagmus, ataxia, dysdiadochokinesis, dysmetria, hypotonia, telegraphic speech).
Enlist the parts of the basal ganglia (neostriatum, pallidum, nucl. subthalamicus and substantia nigra).
Describe the main neurochemical systems in the basal ganglia (glutamate, GABA, dopamine, acetylcholine, peptide cotransmitters).

Discuss the sensory, motor, and cognitive functions of the basal ganglia. Describe the clinical conditions associated with Parkinsonism.

72. Electroencephalogram (EEG) and the physiology of sleep-wake cycles. The circadian rhythm and the pineal gland.

Describe the origin (the electrophysiological basis) of the electroencephalogram.
Describe the EEG waves (frequency ranges, amplitude) of the EEG, and identify the brain states typically associated with these different waveforms.
Characterize the non-REM and REM sleep phases: Describe how respiration, cardiovascular, renal, gastrointestinal, eye movement, muscle tone, and endocrine function change from wake to NREM and REM states.
Define and describe the most important features of circadian rhythms (biological changes that are 1) genetically determined, 2) generated by an internal self-sustaining pacemaker that can be entrained (synchronized) by external signals, and 3) have an app. 24h periodicity).
Give examples of physiological changes characterized by circadian rhythmicity (body temperature, growth hormone secretion, cortisol secretion etc.).
Explain the features of the suprachiasmatic nucleus (SCN) that make this nucleus suitable to function as a circadian pacemaker (Zeitgeber).
Describe the role of the retinohypothalamic pathway in synchronizing SCN activity with the light-dark cycling.
What is our current understanding of the physiological functions of melatonin (melatonin receptors, endocrine circadian transducer)?