

Dear Students,

The learning objectives below summarize the study material tested during all types of exams in Medical Physiology. They consist of three parts: 1. Title, 2. Guidelines, 3. Normal values. The title corresponds to the topic titles of the oral exams. The guidelines consist of questions and tasks, but in many cases, they also contain useful references regarding the answers. The questions used for the entry exam are the objectives and normal values marked in **bold RED**. Insufficient knowledge of these objectives or normal values results in an automatic fail (1) for the exam, either during the entry test or during the oral topic examination. Normal values usually appear upon their first occurrence in the curriculum, but they may be important for discussing any subsequent topic. The normal values are quantitative data comprising parameters with homeostatic regulation, also typical values found in healthy young adult individuals, and even nutritional recommendations. For the normal values where a range is provided, the examinee is expected to give a value WITHIN the physiological range along with the correct unit of measurement during the oral exam. These normal values should aid the student to understand the physiological mechanisms contained in the respective learning objective. Please note that the normal values marked also with yellow are the **laboratory reference ranges** of these parameters as reported by Department of Laboratory Medicine, and the Department of Pathophysiology will require the precise knowledge of these ranges in the Pathophysiology exams (next year). Note that during oral exams, the chosen topic will disclose ONLY the title, not the detailed objective. The examinee is expected to know the material of the topic by then.

On behalf of the Department's teaching faculty, I wish you successful exam preparation with the help of these objectives!

Best regards,

Ferenc Domoki

1. Control Theory

Define the concept of the "internal environment" and explain why its regulation is necessary. **What is meant by homeostasis and the concept of a homeostatic parameter?** Explain the difference between guidance and control. Describe the theoretical mechanisms available for control (humoral, neural). **Describe the basic components and functions of a neural control loop (reflex arc):** receptor, afferent branch/pathway, center, set point, efferent branch/pathway, effector. **Explain the meaning of and provide examples for negative feedback, positive feedback, and feedforward processes.** Describe the differences between endocrine, paracrine, and autocrine communication based on the site of mediator release and the pathway to the target tissue. What is meant by "behavioral control" and why is it necessary? Give examples. How can the efficiency of control systems be measured? **Define the concept of gain.** Define the term servo-control mechanism?

Normal values: core temperature: 37 °C (36.2–37.5 °C), resting heart rate: 60–100 beats/min, arterial blood pressure (systole/diastole): 120/80 mmHg, **plasma glucose conc (fasting): 3.3–5.6 mM**, respiratory rate: 14–16 breaths/min.

2. Passive Transport Processes of the Cell Membrane

Describe and illustrate the molecular structure of the cell membrane (fluid mosaic model). Explain the significance of the distribution of phospholipids and proteins regarding the selectivity of membrane permeability, focusing on the passage of ions, hydrophobic, and hydrophilic substances. Describe the phenomenon of lateral diffusion in the membrane. Define solution concentration concepts and compare the following units: mM, mEq/l, mosm/kgH₂O. Describe simple transmembrane diffusion, the role of driving forces (along chemical and electrical gradients, and at equilibrium), and membrane properties. **Define Fick's law of diffusion applied to biological membranes.** Outline the role of **aquaporins** in water movement across membranes. Define the following terms: osmosis, osmole, osmolarity, osmolality, and tonicity. Define the "rejection fraction" and explain the development of osmotic pressure due to differential membrane permeability to water and solutes. **Characterize facilitated diffusion.** Define transporter types (uniport, symport, antiport). Define transport maximum, saturation, competitive, and non-competitive inhibition.

Normal values: **blood plasma osmolality: 275-295 mosm/kgH₂O**

3. Active Transport Processes of the Cell Membrane

Define primary and secondary active transport. Outline the utilization of energy derived from ATP hydrolysis in transporting Na⁺, K⁺, Ca²⁺ and H⁺ against their electrochemical potentials using examples. Explain how cells utilize the movement of Na⁺ and K⁺ down their electrochemical gradients to drive the uphill transport of other solutes (e.g., Na⁺/glucose cotransporter, Na⁺/Ca²⁺ exchanger). Interpret the mechanism and significance of ABC transporters using examples. **Define vesicular transport: endocytosis, exocytosis, and transcytosis.** List examples of substances specifically and non-specifically transported via these pathways.

4. Receptors and Signal Transduction Mechanisms

Describe mediator types: paracrine and autocrine signaling molecules, hormones, neurotransmitters, and neurohormones. Define receptor, ligand, agonist, and antagonist (competitive, non-competitive). **Classification of receptors:** 1. by location (membrane, cytosolic, nuclear, and intracellular membrane receptors (IP₃, ryanodine)), 2. by function (ionotropic, metabotropic, receptor enzymes, enzyme-linked receptors). Ionotropic receptors: selective and non-selective, cation and anion channels; give an example for each. Outline signaling pathways, signal transduction elements, and their intracellular significance. Metabotropic receptors: types (G-protein-coupled receptors, receptor tyrosine kinases, etc.). Heterotrimeric G-proteins: structure, types (G_s/G_i/G_q) and function. **Define secondary messengers and describe the most vital ones** (cAMP, cGMP, calcium, IP₃/DAG). Discuss the significance of post-translational modifications (e.g., phosphorylation) on cellular protein function. **Demonstrate receptor enzymes and enzyme-linked receptors through examples.** Intracellular receptor signaling: describe cytosolic and nuclear receptor structure and function through examples. Describe membrane-bound receptor processes: activation, inactivation, internalization, up-regulation, down-regulation, sensitization, and desensitization.

5. Resting Membrane Potential of the Cell

Explain the origin of the resting membrane potential, including chemical and electrical driving forces acting on ion diffusion. **Write the Nernst equation for calculating diffusion potential** and calculate the K^+ equilibrium potential (E_{K^+}). Based on the Nernst equation, determine the direction of ion movement if the membrane potential is: a) equal to, b) higher than, or c) lower than the ion's equilibrium potential. **Write the Goldman-Hodgkin-Katz equation.** Explain how decreased permeability to Na^+ , K^+ , and Cl^- affects membrane potential. State typical resting membrane potentials for skeletal muscle (-90 mV), smooth muscle (-60 mV), and neurons (-70 mV). Characterize the steady-state condition. Use the interplay between passive ion fluxes (Na^+ , K^+) and the ion pump (**$Na^+/K^+-ATPase$**) as an example to explain their role in maintaining membrane potential and cell volume. **Consequences of Na^+/K^+ -pump inhibition.**

Normal values:

	Extracellular conc.	Intracellular conc.
Na^+	136–145 mM	12 mM
K^+	3.5–5.2 mM	155 mM
Cl^-	98–106 mM	4 mM
HCO_3^-	23–29 mM	8 mM
Ca^{2+} (ionized)	1.5 mM	10^{-5} mM

6. Electrical Properties of the Neuronal Membrane

Define the following ion channel terms: selectivity, gating, activation, inactivation. Compare gating mechanisms of intracellular/extracellular ligand-gated, voltage-gated, and mechanically-gated ion channels. **Define and compare electrotonic (local, graded) potential and action potentials** (direction of potential change, graded nature, propagation speed, amplitude changes during propagation). Name the neuronal membrane regions where these arise. **Draw the neuronal membrane potential over time during an action potential (e.g., squid giant axon) and mark its phases.** Interpret threshold potential and the "all-or-none" law. Characterize voltage-gated Na^+ , K^+ , Ca^{2+} channels functionally (gating, activation, inactivation). Describe their roles in action potential phases (depolarization, overshoot, repolarization, hyperpolarizing afterpotential). Interpret absolute and relative refractory periods. Consequences of voltage-gated Na^+ channel blockade (lidocaine).

Normal values: neuronal action potential duration: 1 ms

7. Action Potential Propagation in Nerve Fibers. Axon Classification

Describe action potential propagation in myelinated vs. unmyelinated axons. Characterize saltatory conduction. Define membrane capacitance and explain its impact on propagation speed in myelinated and unmyelinated axons. Action potential propagation in mixed peripheral nerves: The compound

(extracellular recorded) action potential. Determine how axon diameter and myelination influence conduction velocity within a peripheral nerve. **Group nerve fibers according to the Erlanger-Gasser classification.**

Normal values:

Erlanger-Gasser class	Conduction velocity
A α	100 m/s
A β	50 m/s
A γ	20 m/s
A δ	15 m/s
B	7 m/s
C	1 m/s

8. Neurotransmission

Characterize electrical synapses, including gap junction structure and function. **Compare electrical and chemical transmission** (directionality, speed). Describe sequential events in chemical neurotransmission (from presynaptic membrane depolarization to postsynaptic potential generation). **Describe the ionic base of local potentials: excitatory postsynaptic potential (EPSP), inhibitory postsynaptic potential (IPSP), end-plate potential (EPP), and receptor potential.** Describe spatial and temporal summation of PSPs and their role in action potential generation. **Describe the characteristics of classical neurotransmitters.** Group classical and non-classical neurotransmitters by their chemical structure: 1. acetylcholine, 2. amino acids (glutamate, glycine, GABA), 3. biogenic amines (dopamine, norepinephrine, epinephrine, histamine, serotonin), 4. gases (NO, CO), 5. lipids (endocannabinoids), 6. peptides (endorphins, enkephalins, dynorphins, substance P, CGRP, VIP). **Characterize major neurotransmitters by synthesis, inactivation, receptors, and signaling pathways. Define ionotropic and metabotropic receptors.** Role of intraneuronal (axonal) transport in intercellular communication. Non-synaptic transmission and volume transmission.

Normal values: synaptic delay: 1–1.5 ms.

9. Peripheral Nervous System: Primary Sensory Neurons

Draw a primary sensory neuron; label and describe its peripheral axon, central axon, and cell body. Anatomically localize primary sensory neuron cell bodies (dorsal root ganglia of spinal nerves, sensory ganglia of cranial nerves). Indicate likely sites of receptor potential origin, action potential initiation, and transmitter release. **Define receptor sensitivity (activation threshold), specificity (modality), and receptive field. Classify somatosensory receptors by origin (extero-, intero-, proprioceptors) and modality (mechano-, thermo-, uni-, and polymodal nociceptors).** Describe sensory transduction and

action potential generation steps for mechano-, thermo-, and nociceptors. List major neurotransmitters released by primary sensory neurons. Define slowly vs. rapidly adapting receptors. Determine how sensory axon diameter and myelination affect conduction velocity in peripheral nerves. Group sensory nerve fibers by Lloyd-Hunt (Ia, Ib, II, III, IV)- and Erlanger-Gasser A α , A β , A γ , A δ , B, C) systems. Define secondary sensory cells and their relationship to primary sensory neurons; provide at least one example.

10. Peripheral Nervous System: Parasympathetic Nervous System

Characterize the anatomical structure of the parasympathetic system: localization of preganglionic and postganglionic neuronal cell bodies and axons. Classify autonomic nerve fibers in peripheral nerves using Erlanger-Gasser criteria (B, C). **Characterize synapses between preganglionic fibers and autonomic ganglion cells.** Define the autonomic ground plexus. Describe the structure and function of postganglionic varicosities. **Explain acetylcholine synthesis, release, target organ receptor mechanisms, and degradation. Give examples of parasympathetic effects mediated by cholinergic receptors.** Mention additional neurotransmitters released from parasympathetic nerves and their actions. Define the autonomic tone.

11. Peripheral Nervous System: Sympathetic Nervous System and Adrenal Medulla

Characterize the anatomical structure of the sympathetic system: localization of preganglionic and postganglionic cell bodies and axons. Sympathetic adrenergic system: explain norepinephrine and epinephrine biosynthesis, norepinephrine release, and clearance. List adrenergic receptor types on effector organs and their associated signal transduction pathways. Give examples of tissue effects produced by each receptor type. Characterize adrenal medulla anatomy and hormonal secretion control. Describe catecholamine transport, elimination, and degradation. Sympathetic cholinergic and non-adrenergic, non-cholinergic (NANC) sympathetic actions.

12. Peripheral Nervous System: Motoneurons and Neuromuscular Junction

Draw a motoneuron, labeling dendrites, axon, axon hillock, and cell body. Localize cell bodies anatomically (ventral horn of spinal cord, motor cranial nerve nuclei) and classify peripheral motoneuron axons via Erlanger-Gasser criteria (A α , A γ). Mark sites of IPSP, EPSP, action potential generation, and transmitter release on your diagram. **Draw the skeletal muscle neuromuscular junction and order the sequential steps of a neuromuscular transmission.** Compare end-plate potential (EPP) properties with skeletal muscle action potentials. List neuromuscular junction inhibitors (curare, succinylcholine, botulinum toxin), specifying exact sites and mechanisms of action. **Define the motor unit;** explain the size principle of motor recruitment during varying muscular effort.

13. Skeletal Muscle Function: Structure, Excitation-Contraction Coupling, and Biochemistry

Name skeletal muscle components from whole muscle down to sarcomere molecular organization (bundle of fibers, fibers, myofibrils, myofilaments, sarcomere). Characterize thick and thin filaments; list their constituent proteins. Diagram a myosin molecule, labeling subunits (heavy and light chains) and state

their functions. Describe the roles of troponin and tropomyosin in contraction. **Describe the steps of the electromechanical coupling in striated muscle**, describing roles played by sarcolemma, T-tubules, sarcoplasmic reticulum, thin filaments, and Ca^{2+} . **Describe chemical and mechanical steps of cross-bridge cycle, explaining how this produces muscle shortening. The sliding filament theory.** Describe relaxation mechanisms. Summarize ATP functions in contraction and relaxation. Explain the mechanism behind rigor mortis (postmortem rigidity).

14. Skeletal Muscle Function: Mechanics and Energetics

Define and compare isometric, isotonic, and auxotonic contractions. Explain relationships between preload, afterload, and total load during isotonic contraction. **Draw skeletal muscle length-tension curves; explain active, passive, and total tension alongside their molecular origins** (sarcomere length vs. active tension profile). Explain length-tension and force-velocity relationships. Contrast single muscle twitches with tetanus. Explain why single twitches produce less peak force. **Explain contraction summation mechanisms** and how increasing stimulation frequency converts twitches into tetanus. **Define incomplete and complete tetanus.** Define muscle fatigue; list intracellular factors contributing to it. Compare structure, energetics, and function across the three main muscle fiber types (fast glycolytic, fast oxidative, slow oxidative). Describe energy sources in working muscle, ranking them by speed and yield of ATP production; highlight differences among fiber types.

15. Smooth Muscle Function

Define and compare single-unit and multi-unit smooth muscle. Outline intracellular steps involved in smooth muscle contraction and relaxation. Explain the difference between electromechanical and pharmacomechanical coupling. Compare actin-myosin regulation in smooth vs. skeletal muscle, noting structural similarities. **Describe Ca^{2+} sources, flux, and roles during smooth muscle contraction/relaxation. Explain G_q pathway roles in contraction, G_s pathway roles in relaxation, and NO roles in relaxation.** Explain Ca^{2+} -sensitization and desensitization of smooth muscle myofilaments. Explain how smooth muscle generates and sustains tension with much lower ATP consumption than striated muscle. Contrast post-contraction relaxation with stress-relaxation. Pharmacological strategies for smooth muscle relaxation (e.g., phosphodiesterase inhibitors).

16. Body Fluid Compartments. Blood Plasma

Define extracellular and intracellular fluid compartments, including extracellular subdivisions. Describe the indicator dilution method and its use in measuring plasma, blood, extracellular, and total body water volumes (principles of fluid therapy). Describe blood fractions formed following centrifugation (formed elements vs. plasma). **Classify plasma components (organic/inorganic). Define hematocrit. Name plasma protein fractions** and explain their measurement via electrophoresis, **illustrating each with examples.** Name and characterize plasma lipoproteins.

Normal values: total body water: ~60% of body weight (intracellular: 40%, extracellular: 20%), interstitial fluid volume: 11 L, total blood volume: 5–6 L (80 mL/kg), plasma volume: 3 L, hematocrit (female/male): 0.35–0.45/0.4–0.5, plasma osmolality: 275–295 mosm/kgH₂O, plasma Na^+ : 136–145 mM,

plasma K^+ : 3.5–5.2 mM, total plasma Ca^{2+} : 2.2–2.6 mM, free/ionized Ca^{2+} : 1.5 mM, plasma Cl^- : 98–106 mM, plasma HCO_3^- : 23–29 mM, plasma glucose (fasting): 3.3–5.6 mM, plasma urea: 2–11 mM, plasma bilirubin: <21 μ M, total plasma protein: 60–87 g/L, plasma albumin: 34–48 g/L, total plasma cholesterol: <5.2 mM, total plasma lipids: 4.5–10 g/L.

17. General Characteristics of Red Blood Cells (RBCs)

State RBC parameters: count, size, shape, lifespan. Organelles of mature RBCs. **Define and state formulas for MCH, MCHC, and MCV.** Describe the Price-Jones curve. Define anemia (Hb cc < 130 g/L in males or < 120 g/L in females) and its categories: microcytic, normocytic, macrocytic. Characterize RBC osmotic fragility. Describe erythrocyte sedimentation rate (ESR): mechanisms, measurement, clinical value, and normal values. Characterize the RBC membrane and name three major membrane proteins.

Normal values: RBC count (female/male): 4.2–5.3/4.6–6 million/ μ L (4.2–5.3/4.6–6 T/L), RBC diameter: 7–8 μ m, RBC lifespan: 120 days, ESR (female/male): 1–20/1–12 mm/h, hemoglobin concentration (female/male): 115–150/130–165 g/L, MCV: 82–98 fl, MCH: 27–32 pg, MCHC: 316–349 g/L, RBC osmotic fragility: 0.45–0.50% NaCl solution.

18. Erythropoiesis

Characterize red bone marrow and list primary erythroid progenitor stages. **Define reticulocytes and their clinical value. List essential endogenous and exogenous substances for RBC production, plus consequences of deficiency: iron (microcytic anemia), B12/folate (macrocytic anemia), EPO (normocytic anemia). Characterize iron metabolism:** absorption (ferroportin), transport (transferrin), storage (ferritin, hemosiderin), regulation (hepcidin). **Systemic B12 and folate dynamics and roles in hematopoiesis. Erythropoietin (site of production, triggers, function).** Additional hormonal influences on erythropoiesis (e.g., growth hormone, testosterone).

Normal values: plasma iron: 7–28 μ M, iron RDA: 10–20 mg, daily iron loss: 1–3 mg, vitamin B12 RDA: 1–2 μ g, folate RDA: 200 μ g, relative reticulocyte count: 0.9–1.5%

19. Hemoglobin Degradation and Bile Pigments

Describe aged RBC removal, hemoglobin release, plasma binding proteins, and macrophage uptake. Describe hemoglobin breakdown steps: fate of iron, globin chains, and porphyrin ring. **Macrophage release of bilirubin, plasma transport, hepatic uptake, conjugation, and biliary secretion. Define indirect (unconjugated) and direct (conjugated) bilirubin. Bilirubin fate in the gut, enterohepatic circulation, and excretion. Formation of urobilinogen (UBG) and significance of urinary detection.** Define jaundice/icterus (plasma bilirubin > 35 μ M).

Normal values: plasma bilirubin: <21 μ M

20. White Blood Cell Physiology

State normal WBC count and sites of leukopoiesis. **Define and describe differential WBC count preparation. State morphological features and normal percentages of WBC types in differential counts.** Describe functional properties of major WBC categories. Describe phagocytosis: roles of monocyte/macrophage system and neutrophil granulocytes. **Describe lymphocyte types and functions.** Define antigens and outline antigen presentation. **Describe immunoglobulin structure, classes, and functions.** Describe main elements and functions of the complement system. Define leukocytosis and leukopenia.

Normal values: total WBC count: 5000–10000 cells/ μ L (5-10 G/L), neutrophils: 67–75%, lymphocytes: 15–50%, monocytes: 5–13%, eosinophils: 0–8%, basophils: 0–1%

21. ABO and Rh Blood Groups

Characterize ABO antigens and circulating antibodies (Landsteiner's rule). Characterize ABO inheritance patterns. Which proteins are encoded by genes responsible for blood group inheritance? Why do natural antibodies develop? **Characterize Rh antigens and Rh inheritance patterns.** Which proteins are encoded by genes responsible for Rh inheritance? Why doesn't Landsteiner's rule apply to the Rh system? State ABO and Rh phenotype frequencies. **Describe blood typing procedure (Serafol card).** Pre-transfusion testing (major crossmatch, minor crossmatch, Serafol card, bedside test / biological trial). Describe Rh isoimmunization / sensitization (prophylaxis, erythroblastosis fetalis). Define agglutination vs. hemolysis, including processes and consequences.

22. Primary Hemostasis

Distinguish between hemostasis and blood coagulation. Compare white and red thrombi. Thrombopoiesis. State normal platelet count; define thrombocytopenia and thrombocytosis. Describe platelet morphology, size, and granule types. Describe primary hemostasis and its sequential events. **Describe platelet adhesion, aggregation, and activation**, including molecular mechanisms (von Willebrand factor, membrane glycoproteins, activation mediators, receptors, signaling pathways). Outline endothelial roles in hemostasis. Pharmacological inhibition of platelet aggregation (COX inhibitors, ADP receptor antagonists, GP IIb/IIIa inhibitors).

Normal values: platelet count: 150000–400000 cells/ μ L (150-400 G/L), bleeding time (Ivy method): 3–5 min.

23. Secondary Hemostasis: Blood Coagulation

Define clotting factors, activation mechanisms (limited proteolytic cascade), synthesis sites, and nomenclature. **Describe the extrinsic pathway, intrinsic pathway, and contact activation phase. Describe the common pathway and stable fibrin mesh formation. Describe vitamin K's role in synthesizing vitamin K-dependent factors. Define blood clot and describe clot retraction mechanisms.** Define blood serum; compare serum with plasma. Compare prothrombin time (PT) and clotting time.

Define INR, its calculation, and clinical significance.

Normal values: **prothrombin time: 12-17 s**, **INR: 0.8–1.2**, clotting time (Lee-White method): 5–8 min, plasma fibrinogen: 3 g/L.

24. Fibrinolysis and Anticoagulation (In Vitro and In Vivo)

Describe the plasmin system activation and regulation. Describe thrombomodulin/protein C/protein S and heparin/antithrombin regulatory systems. **List in vitro-only anticoagulants (EDTA, citrate) and mechanisms of action. List in vivo anticoagulants and fibrinolytic drugs, detailing mechanisms of action (heparin, vitamin K antagonists, plasminogen activators).**

25. Respiratory Mechanics 1: Static Mechanics of the Lungs and Chest

Draw a normal spirogram labeling static lung volumes. State which volumes constitute different capacities. Indicate which volumes/capacities cannot be directly measured by spirometry. Draw static transpulmonary pressure-volume curves from residual volume to total lung capacity (inflation/deflation). **Define lung compliance;** give two clinical examples where compliance is abnormally low or high. Draw transmural pressure-volume (compliance) curves for lung, chest wall, and combined respiratory system on the same axes; explain resting equilibrium points. Define factors determining total lung capacity, functional residual capacity, and residual volume. Describe forces generating negative intrapleural pressure (lung collapse tendency vs. chest wall expansion tendency); explain pneumothorax mechanics. **Define surface tension and its impact on lung mechanics**, alveolar stability, and surfactant action. Define atelectasis and surfactant's role in prevention. What is alveolar interdependence? **State surfactant source, components, and regulatory control.**

Normal values: static lung volumes/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/cmH₂O**, **chest + lung compliance: 0.1 L/cmH₂O**.

26. Respiratory Mechanics 2: Ventilation

Draw the pleural pressure, alveolar pressure, airflow, and volume changes during normal quiet breathing, marking start/end of inspiration and end of expiration. Describe how pressure gradients drive air movement. **Define dynamic resistance factors** (airway resistance and tissue viscous resistance). Explain why upper airways and large bronchi account for most airway resistance based on bronchial tree dimensions, total cross-sectional area, and laminar vs. turbulent flow. **Define anatomical and physiological dead space, respiratory rate, total minute ventilation, dead space ventilation, and alveolar minute ventilation.** Explain physiological dead space measurement. **Draw a forced expiratory spirogram; define FEV₁ and Tiffeneau index (FEV₁/VC). What and how much is the Maximum Voluntary Ventilation (MVV)?** Draw a flow-volume loop of a forced expiratory maneuver, labeling forced vital capacity (FVC), peak expiratory flow (PEF), and FEF₂₅₋₇₅ (maximum expiratory flow rate between the 25 and 75% of the VC). Which parameter best reflects small airway resistance?

Normal values: intrapleural pressure (end inspiration/expiration): -8/-5 cmH₂O, intra-alveolar pressure (peak inspiration/expiration): -1/+1 cmH₂O, airflow (peak inspiration/expiration): -0.5/0.5 L/s, max expiratory pressure: 100 cmH₂O, PEF: 10 L/s, **Tiffeneau index (FEV₁/VC): 75–80%, anatomical dead space: 150 mL, respiratory rate: 14-16 breaths/min, minute ventilation: 7 L/min, alveolar ventilation: 5 L/min, MVV (female/male): 80-120/140-180 l/min, maximal voluntary ventilation (MVV): 100–200 L/min**

27. Oxygen Transport in Blood

Define the partial pressure of gases. Describe oxygen diffusion dynamics from alveoli to capillaries; define capillary reserve time. Describe hemoglobin chemical structure. Describe special/pathological hemoglobin variants (HbF, methemoglobin, carboxyhemoglobin) and functional properties. **Draw the oxygen-hemoglobin dissociation curve. Explain relationships between pO₂, hemoglobin saturation, and blood oxygen content. Define P50 and state its normal value.** Compare bound vs. physically dissolved oxygen quantities. **State hemoglobin oxygen-binding capacity (Hüfner factor). Describe effects of temperature, pCO₂ (Bohr effect), pH, and 2,3-DPG on the dissociation curve and their physiological significance.** List five causes of hypoxia. Hypoxia categories: 1. hypoxic hypoxia (low inspired pO₂, alveolar hypoventilation, impaired diffusion), 2. anemic/transport hypoxia (anemia, methemoglobinemia, CO poisoning), 3. ischemic/stagnant hypoxia (low cardiac output, vascular occlusion), 4. histotoxic hypoxia (cellular toxins). **Define cyanosis** (deoxygenated Hb > 50 g/L). Explain how anemia and CO poisoning alter the oxygen dissociation curve, paO₂, and SaO₂.

Normal values: inspired air / alveolar air / arterial blood / venous blood pO₂: 149/100–104/95–98/40 mmHg; HbA P50: 26 mmHg; arterial/mixed venous O₂ saturation: 97–98/75%; Hüfner factor: 1.34 mL/g; arterial/venous O₂ concentration: 200/150 mL/L; arteriovenous oxygen difference (AVDO₂): 50 mL/L; resting oxygen consumption: 250–280 mL/min.

28. Carbon Dioxide Transport in Blood

Describe modes and percentages of CO₂ transport in blood: 1. physically dissolved, 2. chemically bound as bicarbonate, 3. carbamino-bound to hemoglobin. Name the critical enzyme for CO₂ transport and state its localization. Explain the chloride shift (Hamburger shift). Describe the effect of oxygen unloading on CO₂ binding (Haldane effect).

Normal values: partial pressures of CO₂ (inspired/alveolar/arterial/venous): 0.3/40/40/46 mmHg; arterial/venous CO₂ content: 480/520 mL/L; arterial/venous bicarbonate content: 24/27 mmol/L; arteriovenous CO₂ difference (AVDCO₂): -40 mL/L; resting CO₂ production: 210 mL/min.

29. Respiratory Rhythmogenesis and Pulmonary Reflexes

Describe the muscles involved in quiet vs. forced breathing and respiratory motoneuron localizations (C3–C5, T1–T11). Describe motoneuron activity patterns across respiratory cycles (inspiratory, post-inspiratory, expiratory). **Describe brainstem regions governing respiratory rhythmogenesis and**

regulation: DRG, VRG, pre-Bötzinger complex (and its role), PRG (medial parabrachial nucleus, Kölliker-Fuse nucleus). Describe three pulmonary receptor reflexes regulating tidal volume and rate, including reflex arcs: 1. **Hering-Breuer reflex**, 2. irritant receptor reflexes, 3. J-receptor juxtacapillary chemoreflexes. Define: hypoventilation, hyperventilation, eupnea, hypopnea, hyperpnea, dyspnea, tachypnea, and bradypnea. Define abnormal breathing patterns: Kussmaul, Cheyne-Stokes, apneustic, gasping, Biot's respiration.

30. Chemical Control of Respiration

Locate sensory receptors detecting blood pO₂, pCO₂, and pH; describe their importance in sensing gas changes. **Structure and function of peripheral vs. central chemoreceptors.** Describe how changes in pO₂ and pCO₂ alter alveolar ventilation independently and combined. When does carbon dioxide narcosis occur? Describe primary respiratory drive following central chemoreceptor adaptation and consequences of oxygen administration in such patients. Describe changes in alveolar ventilation: 1. immediately upon high altitude ascent, 2. after two weeks of acclimatization, 3. immediately upon returning to sea level. Describe feedforward ventilatory control during exercise and exercise effects on arterial pO₂, pCO₂, and pH.

Normal values: maximum oxygen uptake: 4000 mL/min, maximum CO₂ production: 3200–4000 mL/min.

31. Airway Biology, Metabolic, and Endocrine Functions of the Lung

Nasal conchae function. Sneezing and coughing reflexes. **Define mucociliary clearance.** Airway host defense: alveolar macrophages, Clara cells, tissue mast cells. **Regulation of airway diameter and secretion: bronchomotor tone, adrenergic actions.** Inflammatory mediators (histamine, prostanoids, leukotrienes). Describe vasoactive clearance during pulmonary transit. Give examples of substances almost completely cleared (local mediators: leukotrienes, prostaglandins, bradykinin, VIP, endothelin, serotonin) vs. those unaffected (circulating vasoactive hormones: epinephrine, vasopressin). Pulmonary vascular endothelial role in angiotensin II synthesis (ACE expression).

32. Cardiac Pacemaking and Conduction

Describe ionic mechanisms generating spontaneous diastolic depolarization (pacemaker potential) in pacemaker cells. Trace impulse conduction through the cardiac conduction system starting from the SA node. What is the effect of hyperkalemia on cardiac excitability? Why is the AV node / Bundle of His the sole physiological link between atrial and ventricular syncytia? Functional significance of slow AV nodal conduction velocity. Compare sympathetic vs. parasympathetic effects on impulse generation and conduction. Define positive/negative chronotropic and dromotropic effects, detailing cellular mechanisms at the SA and AV nodes.

Normal values: cardiac action potential duration: 200–300 ms, intrinsic SA node pacemaker rate: 100 AP/min.

33. Structural and Functional Properties of Cardiac Muscle

Compare cardiac vs. skeletal muscle fibers regarding fiber size, intercellular connections, and myofilament architecture. **Characterize gap junctions in establishing a functional syncytium. Compare action potential and refractory period durations between cardiac and skeletal muscle. Draw time-aligned action potential and contraction curves for both tissue types. Use your diagram to explain why cardiac muscle cannot undergo tetanic contraction. Describe steps of excitation-contraction coupling and relaxation in cardiac muscle. Identify Ca^{2+} sources contributing to cytosolic elevation and explain Ca^{2+} 's role in force regulation. Draw fast response (ventricular muscle) and slow response (pacemaker) action potentials, labeling time and voltage axes accurately. Explain underlying ionic currents for each phase. How do differing ion channel populations explain variations between these action potentials? Mechanism and functional significance of the long plateau phase.**

34. The Mechanical Cardiac Cycle. Jugular Venous Pulse

Draw left atrial, left ventricular, and aortic pressure profiles alongside left ventricular volume and valve positions across the cardiac cycle; label cycle phases. Define stroke volume, cardiac output, cardiac index, and ejection fraction, stating normal values for healthy adults. Explain origin of heart sounds; state timing and causes of first and second heart sounds. Describe suction-pump characteristics of the heart and the base-plate mechanism. Describe atrial pressure waves during the cardiac cycle and conditions producing visible jugular venous pulses.

Normal values: systolic/diastolic duration: 270/530 ms (at HR 75 bpm), left ventricular pressure (systole/diastole): 120/6–8 mmHg, right ventricular pressure (systole/diastole): 24/0–2 mmHg, left atrial pressure: 6–8 mmHg, right atrial pressure: 0–2 mmHg, heart rate resting/max exercise: 70–180 beats/min, stroke volume resting/max exercise: 70–80/125 mL, left ventricular end-diastolic volume: 110–160 mL, left ventricular end-systolic volume: 40–80 mL, left ventricular ejection fraction: 0.5–0.7, cardiac output resting/max exercise: 5.5–24 L/min, cardiac index: 3.2 L/min/m².

35. Regulation of Cardiac Contractility

Plot and compare passive and active length-tension curves of a single cardiac fiber against the pressure-volume loop of an intact ventricle. Correlate fiber length, tension, and contraction velocity with end-diastolic/end-systolic volumes, pressures, and dP/dt . Superimpose a ventricular function curve onto a pressure-volume diagram. **Define preload** (maximal wall stress BEFORE systole). Why are end-diastolic ventricular pressure, atrial pressure, and central venous pressure used to estimate preload, and why is ventricular pressure most reliable? **Define afterload** (maximal wall stress DURING systole). Why is systolic arterial pressure used to estimate afterload? **State Frank-Starling's Law of the Heart.** Significance of Frank-Starling's law in matching left and right ventricular stroke volumes. **How do adrenergic stimulation, increased fiber length (heterometric regulation),** partial $\text{Na}^+\text{-K}^+\text{-ATPase}$ inhibition, and elevated extracellular Ca^{2+} enhance contractile force (positive inotropy)? What is meant by a positive lusitropic effect via adrenergic receptor stimulation?

36. Electrocardiography (ECG)

Define electric dipole and dipole vector. Biophysical basis of ECG generation. **Describe bipolar and unipolar ECG leads, detailing exact electrode placements and polarities. Illustrate a typical 12-lead ECG tracing. Name all waves, segments, and intervals, stating their normal durations and corresponding cardiac electrical events.**

Normal values: standard paper speed: 25 mm/s (1 mm = 40 ms), standard amplitude: 1 cm = 1 mV, P wave: <100 ms, PQ interval: 120–200 ms, QRS complex: 80 ms (<100 ms), QT interval: 320–390 ms.

37. Interpretation of the ECG

Describe systematic ECG evaluation steps: rhythm origin, regularity, rate, electrical axis, wave/segment/interval analysis. Determine origin of excitation on a tracing; state underlying criteria. **Determine regularity and rate. Define normocardia, bradycardia, and tachycardia.** Explain theoretical concepts behind calculating cardiac electrical axis; determine electrical axis. Define normal axis, right deviation, and left deviation. Describe normal P wave, QRS complex, and T wave features (amplitude, duration, morphology) in specific leads. Significance of T wave concordance. **Describe key segments and intervals (PQ, QT, ST).** Define the isoelectric line and its reference baseline. Why must QT intervals be corrected for heart rate? How is the corrected QT calculated (Bazett, Fridericia formulas)?

Normal values: normal electrical axis: 30–60°.

38. Cardiac Work, Metabolism, and Coronary Circulation

Describe factors determining external cardiac work (volume-pressure work vs. kinetic work) and mechanical efficiency. Characterize metabolic substrates utilized by myocardium and state myocardium's share of resting total oxygen consumption. **Describe coronary blood flow patterns across the cardiac cycle. Compare flow dynamics between right vs. left ventricles and subendocardial vs. subepicardial regions of the left ventricle. State myocardial oxygen extraction rate and arteriovenous oxygen difference (AVDO₂), emphasizing functional significance compared to other organs.** Describe relationship between coronary blood flow and myocardial workload. Characterize humoral mechanisms causing coronary vasodilation. **Explain how sympathetic stimulation affects cardiac function and coronary vascular resistance.** Significance of direct vs. indirect vascular effects of sympathetic drive during exertion.

Normal values: resting coronary blood flow: 250 mL/min (4–5% of resting cardiac output); myocardial AVDO₂: 114 mL/L (more than twice the systemic average).

39. Hemodynamics: Biophysical Principles

Define volumetric flow rate and velocity, stating units. State relationships between flow rate, flow velocity, and vessel cross-sectional area. Which factors determine total fluid energy (Bernoulli's principle)? **State relationships between pressure head (gradient), flow, and hydraulic resistance (Ohm's law of circulation); perform calculations given two parameters. Describe systemic and pulmonary circulations**

connected in series; write Ohm's law for both circuits. **List factors determining hydraulic resistance based on the Hagen-Poiseuille equation.** Are theoretical conditions for Hagen-Poiseuille's law strictly fulfilled in the vascular system? Contrast laminar and turbulent flow; state factors promoting turbulence. Reynolds number. Relationship between turbulent flow and auscultatory heart sounds/murmurs.

40. Hemorheology

Define shear stress, shear rate, and viscosity, and their units. Newton's law of viscosity; **define Newtonian fluids**. Anomalous viscosity of blood: **which factors influence blood viscosity?** (Hematocrit, shear rate, Fåhræus-Lindqvist effect). Describe mechanisms reducing viscosity at higher shear rates (disruption of RBC aggregates, RBC alignment). Describe RBC aggregation (rouleaux formation) in relation to plasma protein composition. Flow adaptation phenomena: axial streaming, orientation, deformation. How does blood viscosity change in microvascular beds? The Fåhræus-Lindqvist effect: phenomena and underlying mechanisms.

41. Hemodynamic Characteristics of Vascular Segments

Define transmural pressure. **Define vascular compliance** ($C = \Delta V / \Delta P$). Which two main factors determine compliance? (Wall distensibility and initial volume). Characterize vascular segments by compliance. Define critical closing pressure. State relationship between transmural pressure, vessel radius, and wall tension: Laplace's law. Where is vessel wall rupture most likely according to Laplace's law in the circulatory system? Define hydraulic resistance and conductance. Describe how in series vs. parallel vascular arrangements impact total resistance. **Characterize contributions of arteries, arterioles, capillaries, venules, and veins to total peripheral resistance, as well as profiles for blood pressure, total cross-sectional area, flow velocity, and blood volume across vascular beds.**

Normal values: **systemic / pulmonary perfusion pressure: 92/6 mmHg**; total peripheral resistance (resting): 16.5 Hgmm $\times$ min/l; pulmonary vascular resistance: 1.5 Hgmm $\times$ min/l; pressure drop across systemic resistance vessels: 60 mmHg; mean velocity in aorta: 22.5 cm/s, in capillaries: 0.03 cm/s; aortic cross-sectional area: 4 cm²; capillary total cross-sectional area: 3000 cm².

42. Arterial System Function

Describe invasive (catheter + transducer) and non-invasive (sphygmomanometry) arterial blood pressure measurements. Draw the aortic blood pressure waveform. Define systolic, diastolic, mean, and pulse arterial pressures, giving normal adult values. **Describe aortic Windkessel function.** Show effects of changing a) stroke volume, b) arterial compliance, and c) total peripheral resistance on systolic, diastolic, mean, and pulse pressures. Propagation of arterial pressure pulses; pulse wave contour changes during peripheral propagation. Flow pulses. **Palpable arterial pulse qualities.**

Normal values: **arterial systolic/diastolic/mean pressure: 120/80/93 mmHg; pulse pressure: 40 mmHg.**

43. Microcirculation: Capillary Exchange

Describe microcirculatory components: arterioles, metarterioles, precapillary sphincters, capillaries, venules. **Describe capillary types: continuous, fenestrated, discontinuous/sinusoidal, and blood-organ barrier endothelium.** Describe fluid and solute movement across capillary walls using Fick's law. Compare capillary permeability to small solutes vs. plasma proteins using reflection coefficients (σ). Define osmotic, oncotic (colloid osmotic), and hydrostatic pressures; state normal Starling forces in capillary blood and interstitium. **Write the Starling equation, detailing how individual components govern fluid filtration/absorption.** According to Starling forces, what primarily protects pulmonary circulation from edema?

Normal values: mean capillary hydrostatic pressure: 17.3 mmHg, interstitial hydrostatic pressure: -3 mmHg, **plasma oncotic pressure: 28 mmHg**, interstitial oncotic pressure: 8 mmHg; pulmonary capillary hydrostatic pressure: 10–11 mmHg.

44. Microcirculation: Lymphatic System and Edema Formation

Characterize the lymphatic system, comparing lymphatic capillaries with blood microvessels; explain how lymphatics reabsorb macromolecules (e.g., proteins). Role of smooth muscle elements in lymphatic vessels. **Characterize key lymphatic functions:** returning filtered protein/fluid to circulation, fat absorption, immune surveillance. Graph relationships between interstitial pressure, interstitial volume, and lymph flow. Explain why rising tissue pressure normally PREVENTS edema. **Explain edema development in: a) venous occlusion, b) lymphatic obstruction, c) increased microvascular permeability, d) malnutrition/hypoalbuminemia.**

Normal values: lymph flow rate: 3–4 L/day

45. Characteristics of Venous Circulation

Characterize veins, comparing them with corresponding arteries in number and compliance. Explain why venous volume changes dramatically during postural hydrostatic pressure shifts. **Characterize factors facilitating venous return** (cardiac pumping: *vis a tergo* and *vis a fronte*, skeletal muscle pump, respiratory pump, venoconstriction). Explain why venous valve incompetence impairs muscle pump effectiveness. **Describe sympathetic vasoconstrictor innervation of veins. Define venomotor tone.**

46. Regulation of Local Blood Flow

Define the autoregulation of blood flow. Characterize short-term and long-term autoregulatory responses. Role of myogenic tone in local regulation (Bayliss effect). Endothelium-derived vasoactive mediators. **Describe nitric oxide synthesis pathways and action mechanisms on vascular smooth muscle.** Describe active vs. reactive hyperemia using metabolic regulatory theories. Describe roles of common metabolic factors: pO_2 , pCO_2 , pH, adenosine, PGE_2 , and K^+ ions. Describe steps and triggers of angiogenesis starting from postcapillary venules. Role of angiogenesis in long-term matching of tissue metabolic demand with blood flow. Humoral regulation during inflammatory hyperemia. Vasoactive actions of mast

cell histamine, bradykinin, and neuropeptides from polymodal primary sensory neurons. **Triple response of Lewis (cutaneous reflex); axon reflex.**

47. Determinants of Cardiac Output; Guyton Diagrams

Describe cardiac output measurement techniques: Fick principle, indicator dilution, thermodilution. Plot the cardiac output curve; describe how contractility changes shift this curve. **Define mean circulatory filling pressure**, state its normal value, and list factors altering it. Define venous return; state determinants of venous resistance and flow. **Plot the vascular function curve, indicating how total peripheral resistance, blood volume, and venous compliance alter its shape.** Explain how the intersection of cardiac output and vascular function curves sets steady-state cardiac output and central venous pressure. Use your diagram to explain cardiac output shifts following hemorrhage, autonomic stimulation, and exercise.

Normal values: mean circulatory filling pressure: 7 mmHg, central venous pressure: 0–2 mmHg.

48. Short-Term Regulation of Arterial Blood Pressure

Define resting, neurogenic, basal, and myogenic vascular tones. **Describe origin and nature of sympathetic vasomotor tone, detailing involved neurotransmitters and receptors.** Physiological significance of sympathetic tone. Give examples of organs with significant vs. negligible arteriolar sympathetic tone. **Characterize high-pressure baroreceptor reflex arc elements:** 1. carotid sinus / aortic arch baroreceptor firing and afferent fibers, 2. medullary neuronal integration, 3. efferent sympathetic/parasympathetic output, 4. effector responses (heart, arterioles, veins). Importance and operation of baroreceptor reflexes during postural changes (orthostasis). Neural blood pressure control during emergencies: 1. outline circulatory reflexes triggered by hypoxia/hypercapnia, 2. characterize central ischemic (Cushing's) reflex.

Normal values: venous pooling in lower limbs upon standing (orthostasis): ~500 mL.

49. Long-Term Regulation of Arterial Blood Pressure

Significance of extracellular fluid volume and blood volume control in long-term pressure regulation compared to carotid reflexes. Describe pressure diuresis. Describe low-pressure cardiopulmonary receptors and neurohumoral reflexes triggered by sudden central venous pressure changes: afferents, hypothalamic integration, renal effectors. **Effects of angiotensin II, vasopressin (ADH), and atrial natriuretic peptide (ANP) on arterial pressure: direct vascular vs. indirect renal actions, target receptors, and second messenger systems.**

50. Pulmonary Circulation

Factors influencing gas diffusion between alveolar air and capillary blood: apply Fick's law; define diffusion-limited vs. perfusion-limited transport. Define diffusing capacity. Compare pulmonary and systemic circulations regarding pressures, resistances, and hypoxic responses. Determine normal ventilation-perfusion ratio (V/Q); explain how vertical position affects V/Q distribution. **Describe regional**

vascular dynamics in an upright human. Explain West zones (I, II, III) based on pulmonary arterial, alveolar, and venous pressures. Describe pulmonary vascular resistance variations with cardiac output and pulmonary arterial pressure (recruitment and distension). Describe pulmonary vascular resistance variations across lung volumes, explaining extra-alveolar vs. alveolar vessel dynamics. **Consequences of hypoxic pulmonary vasoconstriction (Euler-Liljestrand reflex) on flow distribution.** Effects of inhaled nitric oxide on resistance and hypoxic vasoconstriction. Characterize bronchial circulation.

Normal values: pulmonary artery systolic/diastolic/mean pressure: 24/9/14 mmHg, pulmonary artery pulse pressure: 15 mmHg, left atrial pressure: 6–8 mmHg, ventilation-perfusion ratio (V/Q): 0.9–1.1.

51. Thermoregulation: Skin, Adipose Tissue, and Muscle

Thermal neutral zone concept. Thermal balance conditions; physical mechanisms of heat production, gain, and loss: metabolism, radiation, conduction, convection, evaporation. Core temperature stability vs. shell temperature variability. **Skin blood flow control:** acral vs. non-acral microvascular properties. Contrast systemic neural vs. local regulation in skin. Vasomotor adaptation to thermal demands. **Sweat gland structure, function, and neural control.** Secretory mechanisms in acini and NaCl reabsorption in ducts. **Primary physiological defenses against hypothermia and hyperthermia.** Metabolic heat production: basal metabolic rate, physical work, shivering thermogenesis. Van 't Hoff's law. Non-shivering thermogenesis: brown adipose tissue architecture, regulation, and function.

Normal values: core temperature: 37 °C (36.2–37.5 °C), thermal neutral zone: 25–27 °C.

52. Central Mechanisms of Thermoregulation

Normal core body temperature, circadian rhythms, and menstrual cycle variations. Neural circuitry in thermoregulatory reflexes: peripheral/central thermoreceptors, preoptic area, hypothalamus, brainstem/spinal neuronal networks, and negative feedback loops. Define set-point. **Contrast passive hyperthermia, exercise-induced hyperthermia, and fever during infectious disease (e.g., influenza).** Physiological adaptations during acclimatization to hot vs. cold environments.

53. Exercise Physiology

Energy substrates in working muscle, hormonal regulation, and main ATP synthesis pathways. Metabolic classification of muscle fibers. **Explain dynamic shifts in metabolic pathways and fuel sources based on exercise intensity and duration. Describe the aerobic-anaerobic continuum. Systemic neural vs. local vascular control in active skeletal muscle.** Lactate metabolism and lactate's role as an energy substrate. Define exercise terms: lactate threshold, oxygen deficit / EPOC, VO_2max , Fick principle. Acute cardiorespiratory adjustments during dynamic endurance exercise (heart rate, stroke volume, cardiac output, blood pressure, ventilation, oxygen uptake) and thermal impact. Cardiac output redistribution during sustained performance (e.g., long-distance running) across organs (brain, coronaries, splanchnic, skin, skeletal muscle). Contrast phasic/dynamic vs. static contractions on vascular compression, venous return, and central venous pressure. Exercise diagnostic tools (spiroergometry, blood lactate, heart rate monitoring). Chronic adaptations to endurance training (cardiovascular, respiratory, skeletal muscle,

increased VO₂max and lactate threshold). Fatigue mechanics and recovery/regeneration in athletic performance.

Typical values:

Parameter	Sedentary person	Athlete (eg marathon runner)
Resting heart rate (beats/min)	60–80	40–50
Maximal heart rate (beats/min)	175-185	175-185
Resting Stroke volume (mL)	70	100
Maximal Stroke volume (mL)	120	200
Maximal Cardiac output (L/min)	20-22	30–40
Maximal Ventilation (L/min)	90-110	180–200
Maximal Blood lactate (mmol/L)	7.5	9
VO ₂ max (mL/kgbw/min)	35–45	80

54. Nutrition: Energy Balance and Macronutrients

Describe macronutrients (carbohydrates, proteins, fats) as energy sources: state and compare physiological caloric values. **Methods for measuring energy expenditure**: direct vs. indirect calorimetry. Define respiratory quotient (RQ) and caloric equivalent of oxygen; state values for macronutrients and mixed diets. **Define basal metabolic rate** (BMR) and state measurement conditions. Determinants of BMR (age, sex, thyroid status). **Diet-induced thermogenesis** (DIT / specific dynamic action). Which macronutrient produces the highest DIT? Total daily energy expenditure components (BMR+DIT+ physical activity). Effect of physical activity on energy expenditure; define "leisure rate". Upper limits of daily human energy expenditure. Describe macronutrient categories: **Proteins: sources, minimum requirements**, essential amino acids (examples), biological values, functional roles, contribution to caloric needs. Carbohydrates: sources, biological functions, contribution to caloric needs. Fats: sources, essential fatty acids (examples), biological functions, contribution to caloric needs.

Normal values: 1 kcal = 4.2 kJ; **BMR adult female/male: 6300/7100 kJ/day**; leisure rate female/male: 8400/9600 kJ/day (approx. 100-115 W); **WHO optimal protein intake recommendation: 1–1.5 g/kg body weight/day**.

Parameter	Carbohydrate	Fat	Protein	Mixed Diet
Physiological caloric value (kJ/g)	17.2	39	17.2	—
RQ	1.0	0.7	0.8	0.82

Caloric equivalent of O₂ (kJ/L)	21.2	19.2	19.7	20.2
Recommended daily intake (g/day)	300	50–100	60–80	—

55. Nutrition: Water, Minerals, Vitamins, and Dietary Fiber

Daily volume and sources of fluid entering the gastrointestinal tract. Define trace elements; explain their physiological importance and list key examples (Fe, Zn, Cu, Se, I, F etc.). **Define vitamins**; classify them. Define provitamins and antivitamins, noting clinical significance. Define hypovitaminosis, hypervitaminosis, and RDA. **State RDAs, primary functions, and deficiency states for water-soluble vitamins: thiamine (B₁), niacin (B₃), folate (B₉), ascorbic acid (C), and cobalamin (B₁₂).** List fat-soluble vitamins, sources, and biological roles. Vitamin A: RDA, primary functions, deficiency, and toxicity. **Vitamin D and Vitamin K deficiency states.** Sources of non-digestible dietary fiber; roles in maintaining gut motility and normal intestinal microflora.

Normal values: daily fluid intake: 1.5–2 L/day, GI secretions: 6–8 L/day; thiamine RDA: 1–1.5 mg; niacin RDA: 15–25 mg; ascorbic acid RDA: 65–75 mg; vitamin A RDA: 0.8–1.1 mg, Vitamin B9 RDA: 200–300 µg, Vitamin B12 RDA: 1–2 µg