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End-terms Medical Physiology

Task Force Group on Physiology Education of the Federation of European Physiological Societies (FEPS)

Dear colleagues,

In a modern approach there is a strong tendency to formulate general end-terms of a curriculum such as medicine in the form of competencies, like in the CanMEDs*. Such competencies are built from integrated knowledge, skills and attitudes learned throughout the curriculum. Although this approach is very relevant for assessing the overall development of the medical student at the end of his/her education, there is still an underlying necessity for thorough knowledge and understanding of the basic sciences, such as Physiology. It is well appreciated that basic sciences support sound clinical reasoning, and therefore need to be defined properly. As such, a description of required knowledge in medical Physiology in the form of end-terms is completely valid. What is presented in the present document must be seen as the minimal required mastery (knowledge and understanding) of (patho) physiology at the end of the medical curriculum, i.e. at the end of the master phase, when applicable.

We did not intend to suggest in which part of the curriculum the knowledge, c.q. competence has to be acquired. The responsibility for this lies in the faculties of the individual European countries. Therefore the terms can be used as an underlying blueprint at any stage of the development of a medical curriculum. Our point of view was that the end-terms should be formulated as such that they are concrete, assessable, and attainable. The approach for organizing them follows the major body systems.

We are also fully aware of the fact that several teaching forms are applied throughout the universities of the European countries, ranging from classical, discipline-based, teacher-centered curricula with a clear separation between physiology and pathophysiology, to a more student-centered interdisciplinary approach such as used in problem-based curricula. Aside from that, we recognize that some medical faculties have already adopted the Bologna rules and organize their medical curricula embedded in a bachelor and master phase, while others have kept the classical approach of an integral curriculum. It is obvious that the attention for such basic sciences as Physiology will be highest in the initial (bachelor) phase of medical education. This does not exclude that – aside from rehearsing study material from the bachelor phase – also new material can be learned in the later (master) phase of the medical education.

The FEPS offers this overview to any of the national societies as a directive and is willing to support any specific request of these societies. At the end of the document we also provide a non-exhaustive list of Physiology textbooks, which we consulted throughout our preparatory work. This however does not mean that we advise the use of any particular book. The market is broad and many valuable textbooks are available. We have chosen for qualitative, general approachable, English written, textbooks.

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For information on the CanMEDs see http://rcpsc.medical.org/canmeds/CanMeds-summary_e.pdf

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1. Central and peripheral nervous system and skeletal muscle system

1.1. Organization of the central nervous system

1.1.1. Student has sufficient knowledge of location, constitution and the functional characteristics of the central nervous system (CNS) and is able to

- describe the location of the CNS, including membranes and spaces within the bony environment
- produce a scheme of the function of the human body, in terms of motor, sensory and integrative functions in relation to the structure of the CNS
- name the cranial nerves and their relation with the function of their target organs
- describe the role and function of cortical and subcortical structures, brain stem, midbrain, basal ganglia, thalamus and limbic system
- explain, using examples, how and by which way information from the periphery enters and leaves the spinal cord
- describe the specific functions of the spinal nerves

1.2. Global function of the central nervous system

1.2.1. Student has insight into the input-elaboration-output model and into the way by which the various components of the CNS communicate and is able to

- describe the processes within the CNS using the input-elaboration-output model
- point out the differences in architecture and function between the somatic and autonomic nervous system
- indicate how the various parts of the CNS communicate with each other

1.3. Functions of the neuron

1.3.1. Student has insight into the transmission of information and is able to

- describe the processes necessary for maintaining the resting membrane potential
- explain which processes are critical for the occurrence and transmission of the nervous impulse and call the factors which influence these processes
- explain the electrical basis of the occurrence of the action potential

1.3.2. Student has insight into the transmission of information from the neuron to the various neighboring cells and is able to

- describe the difference between direct and indirect impulse transmission and explain the respective mechanisms of transmission
- describe the synthesis and degradation of neurotransmitters
- call and explain factors which strengthen and weaken impulse transmission between neurons

1.4. Sensory perception

1.4.1. Student has insight into the specific characteristics of various sensors and is able to

- explain the processes and structures fundamental to vision
- explain the relationship between the specific functional mechanisms of the various parts of the eye ball, as well as of the integrated function of this structure
- name and explain the mechanisms by which the eye is able to adapt to changes in the environment

- explain the processes and structures fundamental to hearing and equilibrium
- explain the relationship between the architecture and specific working mechanisms of the various parts of the auditory system and the equilibrium system
- explain which processes and structures are fundamental to smell and taste and locate the various receptors
- describe the functional mechanism of these receptors
- describe the nature, architecture and function of various sensory receptors in the skin

1.5. Somato-sensory system

1.5.1. Student has insight into the structures and processes which are involved in the input of sensory triggers, and is able to

- divide sensory input in terms of sensor type, conduction pathways, speed and end points
- describe the meaning of propioception, extero- and interoception, and its function in the sensory system as a whole

1.5.2. Student has insight into the structures and processes which are involved in sensory perception, and is able to

- describe the origin and nature of pain triggers and indicate which stimulatory and inhibitory systems are involved in the elaboration of pain stimuli
- indicate the brain pathways and domains which are involved in the various types of sensory perception

1.6. Blood/brain barrier and liquor

1.6.1. Student has insight into the importance of the blood/brain barrier for the normal function of the organisms and is able to

- describe the structure and function of the blood/brain barrier
- describe the composition and function of the liquor within the CNS

1.7. Reflexes

1.7.1. Student has insight into the appearance and functional significance of reflexes as well as of the fundamental structures and is able to

- explain the functional mechanism of the reflex circle and its clinical importance
- explain structure and function of simple and complex reflex circles, as well as of exteroceptive and proprioceptive reflex circles, using illustrative examples

1.8. Integrated and coordinated processes

1.8.1. Student has insight into the action and underlying structures in the CNS for integrated and coordinated processes and is able to

- distinguish the various integrated and coordinated processes, responsible for:
    - consciousness (specific stages: alertness, rest, sleep)
    - cognitive processes (i.e. memory, attention, learning)
    - subjective processes (i.e. emotions, behavior)
- explain the relationship between the structures and function of the brain involved in the these integrative processes
- elaborate on how communication between the three integrative processes occurs

1.9. Motor system

1.9.1. Student knows the microstructure of the skeletal muscle fiber, has insight into the process of muscle fiber contraction, and is able to

- describe the different structures constituting skeletal muscle fibers as well as of their individual function and the differences between different skeletal muscle fiber types
- describe the excitation-contraction coupling, contraction and relaxation and how energy for these processes is generated
- indicate the differences between isotonic and isometric contractions
- explain the effects of muscle excitation and indicate by which mechanisms contraction force can be influenced
- describe the mechanisms for muscle adaptation to load on the short term (aerobic versus anaerobic) and on the long term (training, hypertrophy, atrophy)

1.9.2. Student has insight in the various types of movement, its regulation and into the related structures with the CNS and is able to

- describe the organization of the motor control system, including cortical areas, thalamus, basal ganglia, cerebellum and spinal cord
- divide the motor system into three functional components:
    - posture of the body
    - locomotion of the body
    - fine motor functions
- relate for each of the three components between the regulation of the motor function and the various related structures of the CNS

2. Respiration

2.1. Airways

2.1.1. Student has insight into the (macroscopic and microscopic) architecture and function of the structures within the respiratory system, from nasal cavity to alveoli) and is able to

- describe the structure and function of the airways
- describe the structure and function of the lungs and pleurae
- explain the forces which determine the flow of respiratory gases

2.1.2. Student has insight into the mechanical properties of the lung and chest wall and is able to

- explain how passive and active respiratory movements occur
- indicate the composition and function of the surfactant in relation to surface tension
- explain the relationship between the respiratory force, lung volume and interpleural pressure
- explain static and dynamic compliance and apply it in practical situations
- name and quantify the various lung volumes and lung capacities
- explain the influence of respiratory pattern on pleural pressure and respiratory labor

2.1.3. Student has insight into the mechanisms of ventilation of the dead space and alveolar space and is able to

- distinguish between anatomical and physiological dead space and name the factors which determine the volume of both compartments

- explain the influence of respiratory volume and respiratory frequency on the composition of the air in the alveolar space and in the expiratory air

2.2. Lung circulation and gas exchange

2.2.1. Student has insight into the factors which affect the finally attained values of partial pressures for oxygen and carbon dioxide in the blood after passage through the lung and is able to

- name the factors which determine the rate of gas exchange in the lung
- explain the local differences in ventilation/perfusion in the vertical and horizontal body position
- explain the connection between alveolar ventilation and gas exchange
- explain changes in blood gas tensions during exercise
- explain changes in blood gas tensions after prolonged stages at high altitude and during diving

2.2.2. Student has insight into the factors which determine the amount of blood in the pulmonary circuit and is able to

- explain the autoregulatory mechanisms which determine the ventilation/ perfusion ratio
- explain the cause(s) of lung edema

2.2.3. Student has insight into the interaction between the function of the heart and the lungs and is able to

- point out the relationship between cardiac output and gas transport
- predict the changes in the function of the heart and circulation during insufficient pulmonary function

2.2.4. Student has insight into the transport of oxygen from the alveolus to the capillary and is able to

- explain which factors determine the diffusion capacity, and the way by which this can be measured
- describe the course of changes in oxygen tension in the lung capillaries
- explain the meaning of the pressure gradient for oxygen transport, as well as the factors which affect this gradient (mountain sickness, diving)
- explain the influence of unequaled ventilation and perfusion on the arterial oxygen tension

2.2.5. Student has insight into the transport mechanism of oxygen from the blood to the tissues and is able to

- indicate the relationship between the oxygen tension and saturation of the blood
- explain the physiological meaning of the S-formed dissociation curve of oxyhemoglobine and indicate which factors affect the position of this curve (pH, temperature, pCO_2)
- indicate the relationship between the molecular structure of hemoglobin (Hb) and its function as oxygen carrier

2.2.6. Student has insight into the connection between the oxygen and carbon dioxide tension in the blood passing the tissues and is able to

- point out how oxygen is delivered to the tissue
- explain the physiological advantages of the Haldane-effect and Bohr-effect on the transport of oxygen and carbon dioxide
- relate between the respiratory quotient and gas exchange

2.2.7. Student has insight into the transport of carbon dioxide from the tissues to the blood and is able to

- indicate the forms in which carbon dioxide is transported and how this is achieved
- describe the connection between the carbon dioxide tension and content in the blood and explain in global terms the importance for the acid-base balance
- explain the functional meaning of carbon dioxide anhydrase for the transport of carbon dioxide

2.3. Regulatory mechanisms

2.3.1. Student has insight into the regulation of the respiration and is able to

- indicate in global terms localization, function and functional organization of the related regulatory centers, as well as of the central and peripheral sensors
- explain the effects of chronic hypercapnia
- describe the respiratory changes during stress and exercise
- predict the effect of reduced excitability of the respiratory centers
- explain the respiratory changes during stay at high altitude

3. Blood and circulation

3.1. Composition and function of the blood

3.1.1. Student has insight into the transport and composition of liquids in the body and is able to

- describe the various body fluid compartments
- point out the volume of these compartments
- indicate globally the processes responsible for exchange of ions and liquid between the compartments
- indicate globally the factors which regulate the volume of the compartments

3.1.2. Student has knowledge of the composition of the blood and of the synthesis and degradation of corpuscular elements and is able to

- indicate the various blood components and their percentage occurrence in the blood
- explain the hematocrit concept
- describe the synthesis of erythrocytes and leucocytes and the hormonal regulation of it

3.1.3. Student has knowledge of the most important molecular mechanisms which determine the function of the erythrocyte and is able to

- explain the role of the erythrocyte in the transport of gas
- globally point out the most important metabolic pathways, i.e. of glycolysis, DPG-shunt, pentose phosphate way, role of hemoglobin reductase
- globally point out the fundamental basis of oxygen toxicity and the protective mechanisms of the erythrocyte

3.1.4. Student has insight into the heme and iron metabolism and is able to

- name the constituents, the key reaction and the reaction scheme for heme synthesis and heme degradation
- describe the localization and regulation of the heme synthesis and degradation within the body
- describe the model for uptake and (re)circulation of iron in the body and well as the most important related proteins

3.1.5. Student has insight into the molecular mechanisms and processes fundamental for hemostasis and its regulation and is able to

- indicate the function of platelets, calcium ions, thrombin, vitamin K-antagonists and fibrinogen
- indicate the difference between the intrinsic and extrinsic activation of hemostasis
- explain the action of anti-coagulating drugs
- explain the principle of measurements of duration of clotting
- indicate the factors which affect the duration of clotting

3.1.6. Student has insight into the mechanisms of humoral and cellular immunity and is able to

- name the various plasma components involved in immunity
- describe formation and role of lymphocytes in various immunity reactions
- explain the difference between innate and adaptive immunity
- explain the difference between groups of blood type groups, as well as of the principle of blood-type antagonism and consequences for blood transfusion

3.2. The heart

3.2.1. Student has insight into the function of the heart as a pump, as well as of the large connecting blood vessels, and is able to

- globally describe the relationship between the morphology and function of the systemic and pulmonary circulation
- indicate the differences between systemic and pulmonary circulation
- describe the functional mechanism of the heart valves and the functional consequences of insufficient closure and/or opening
- describe graphically the sequential variations in pressure and volume in the various heart chambers during one heart cycle
- apply relevant parameters for cyclic changes in pressure and volume parameters in simple calculations

3.2.2. Student has insight into the coronary circulation and its regulation and is able to

- describe the course of coronary blood vessels
- describe the course of the coronary flow pattern during a heart cycle
- name the factors which determine coronary flow
- point out the principles of coronary flow regulation
- point out the principles of coronarography

3.2.3. Student has insight into the depolarization and repolarization of cardiac tissue and into the global electrophysiology of the heart and is able to

- describe the characteristics of the cardiac action potential, the pacemaker function of the sinus node and the normal conduction of the action potential through the heart wall
- describe the mode of registration of the electrical cardiac activity
- explain the interpretation of the electrocardiogram of a healthy individual
- name the various mechanisms underlying the normal variation in cardiac rhythm (for instance respiratory arrhythmia)

3.2.4. Student has insight into the mechanisms by which the cardiac function adapts to the body requirements and is able to

- distinguish between intrinsic (autoregulation) and extrinsic (extracardiac) regulation, including the Frank-Starling mechanism
- describe the way by which intrinsic mechanisms work
- describe the way by which extrinsic mechanisms work
- indicate the relationship between venous return and cardiac function
- indicate the most important indices for cardiac work
- explain the way by which cardiac work can be determined

- show insight in physiological and pathological consequences of cardiac hypertrophy

3.3. Systemic circulation

3.3.1. Student has insight into the functional structure of the circulatory system and is able to

- relate between the architecture and function of the specific parts of the circulation
- indicate the differences between resistance and capacitance vessels, as well as the functional meaning of these differences

3.3.2. Student has insight into the factors responsible for maintaining blood flow throughout the body and is able to

- apply Poiseuille's law for the relationship between pressure and peripheral resistance in the circulation
- explain the relationship between cardiac function, blood vessel filling, blood pressure and blood flow
- name the factors maintaining adequate venous return to the right and left half of the heart both in resting conditions and during exercise
- describe the architecture, location, and functional meaning of specific circulatory systems such as in liver, heart, brain, lungs, kidneys and skin

3.3.3. Student has insight into the microcirculation and the related endothelial function and is able to

- describe the structure of the microcirculation and name the characteristics of the various vessel types in this area
- name the factors responsible for vasoconstriction and vasodilatation
- relate between changes in the microcirculation and the regulation of the systemic blood pressure
- describe the specific role of the smooth muscle cells in the blood vessel wall

3.3.4. Student knows the fetal circulation and the changes in this system during and immediately after birth and is able to

- explain how the oxygen delivery to the fetus occurs
- indicate the function of the ductus arteriosus and the foramen ovale and the meaning of the closure after birth
- describe the circulatory function of the placenta
- explain the role of fetal hemoglobin and changes after the partus

3.4. Capillary exchange

3.4.1. Student has insight into the processes of capillary filtration and absorption between the vascular and interstitial compartments and is able to

- describe the mechanisms responsible for ion transport through the capillary wall and indicate how this process can be affected
- name the factors which determine the liquid balance in the interstitium
- name and explain disturbances in liquid balance in the interstitium

3.4.2. Student knows the structure and function of the lymphatic system and is able to

- explain the formation, composition and flow of lymph
- name and explain the disturbances caused by changes in the function of lymph vessels
- describe the morphology of primary and secondary lymphoid organs
- explain the relation between structure and function of primary and secondary lymphoid organs

3.4.3. Student has insight into the composition and function of blood plasma and lymph and is able to

- indicate the function of the individual components of plasma and lymph

3.5. Blood pressure regulation

3.5.1. Student has insight into the regulation of the blood pressure and is able to

- describe the role of baroreceptors
- explain the regulation of peripheral resistance
- explain the role of the renin-angiotensine-aldosteron system
- explain the phenomenon of shock

4. Water, salt, and kidneys

4.1. Water and electrolyte balance

4.1.1. Student has insight into the process of exchange of water and electrolytes between the various body compartments and is able to

- describe the fundamental mechanisms responsible for the exchange of water and electrolytes between the various body compartments

4.1.2. Student has insight into the maintenance of the balance of water and electrolytes and is able to

- describe the effect of water and electrolyte intake from the milieu exterieur on the balance of water and electrolytes
- describe the effect of loss of water and electrolytes into the milieu exterieur on the balance of water and electrolytes
- describe the role of the kidney in maintaining the balance between uptake and loss of water and electrolytes
- describe the mechanisms of autoregulation of the renal blood flow in association with the regulation of the glomerular filtration rate (GFR)
- explain the concept of diuresis - antidiuresis

4.2. Acid-base balance

4.2.1. Student has insight into the maintenance of the acid-base equilibrium and is able to

- indicate which acids, bases and buffers play a role in maintaining the acid-base equilibrium
- explain the effects of respiration on the acid-base equilibrium
- describe the metabolic and renal influences on the acid-base equilibrium in various circumstances
- interpret different acid-base balances
- explain the relationship between the balance of water and electrolytes on the one hand and the acid-base equilibrium on the other hand
- understand causes and compensatory mechanisms of metabolic and respiratory acidosis and alkalosis (Astrup)

4.3. Regulation of excretion

4.3.1. Student knows the location and structure of the kidneys, the excretory system and the bladder, has insight into the regulation of water- and electrolyte homeostasis by the kidney and is able to

- explain how urine is formed
- describe the regulation of the function of the kidney
- describe the methods used to quantify the kidney function
- describe the mechanism of miction (urine release from the bladder)
- relate the composition of the urine to that of the blood

5. Endocrinology

5.1. Function of endocrine organs

5.1.1. Student has insight into the localization, architecture and function of the following endocrine organs: hypothalamus, pituitary gland, adrenal cortex, adrenal medulla, thyroid and parathyroid gland, endocrine part of the pancreas, pineal organ, reproductive organs and thymus, and is able to

- explain the concept of positive and negative feedback
- relate between the (microscopic) structure of the organs and their function
- describe which hormones are produced by these organs and how this production is regulated
- describe which physiological processes are affected by the various synthesized hormones

5.2. The hypothalamic-pituitary system

5.2.1. Student has insight into functional role of the hypothalamic-pituitary system and is able to

- explain the relations between the hypothalamus, pituitary gland, and peripheral endocrine target organs
- distinguish between the various possibilities of hormonal excretion
- explain the function of the autonomous nervous system and the related role of the pituitary gland
- to explain with an example the relation between the various parts of the hypothalamus-pituitary gland system

5.2.2. Student has insight into the non-endocrine functions of the pituitary gland and is able to

- relate with examples between the individual behavior and the coordinating role of the pituitary gland
- explain the importance of the pituitary gland for the regulation of the uptake of water and nutrients and for the regulation of osmolarity
- explain the role of the pituitary gland in the genesis of the diurnal rhythm

5.3. Hormones

5.3.1. Student has insight in the biochemical action of hormones and is able to

- describe the different types of hormones and their mode of action
- describe the hormonal regulation of stress
- describe the receptors involved, as well as the second messengers and biochemical actions
- explain the activation of adenylate-cyclase via G-proteins
- explain the phosphatidylinositol-cascade

5.3.2. Student has insight into the role of corticosteroids in the metabolism and is able to

- describe the effects of glucocorticosteroids on the carbohydrate metabolism

- explain the effects of glucocorticosteroids on the global metabolism
- explain the effects of anabolic steroids on the protein synthesis
- explain the function of mineralocorticoids in the salt homeostasis

5.3.3. Student has insight into the endocrine function of various organs, such as

- the heart
- the digestive system
- the lungs
- the kidneys

6. Reproduction

6.1. The female genital system

6.1.1. Student has insight into the gametogenesis in the female, as well as in the follicular development, ovulation and formation of the corpus luteum. The student has insight into the endocrine regulation of these processes and is able to

- describe the various stages in the female life in association with the reproductive physiology (childhood, puberty, sexual maturity and menopause)
- relate between architecture and function of the female gonads
- describe the processes of formation and development of the oocytes in the ovarium
- describe the processes occurring in the ovarium immediately before, during and after ovulation
- describe the endocrine regulation of these processes
- relate the ovarian changes before and after ovulation to gravidity

6.1.2. *Student has insight into the female genital tract and menstrual cycle and is able to*

- describe the course and endocrine regulation of the menstrual cycle
- describe how the menstrual cycle can be influenced by external factors
- describe the principles of hormonal anticonception
- indicate which functional morphological changes in the female genital system occur during the menstrual cycle and gravidity

6.2. The male genital system

6.2.1. Student has insight into the gametogenesis in the male. The student has insight into the endocrine regulation of these processes and is able to

- describe the various stages in the male life in association with reproductive physiology (childhood, puberty, sexual maturity, senescence)
- explain the male gametogenesis from spermatogonium to spermatozoa
- describe the process of maturation of semen during transport through the genital system
- explain the regulation of activity of the accessory reproductive organs
- describe the endocrine regulation of these processes

6.3. Coitus, fertilization and fetal growth

6.3.1. Student has insight into the mechanisms of coitus and fertilization and is able to

- describe the phases of coitus
- describe the amount of ejaculate, location of delivery of sperm, and transport of sperm to the location of fertilization
- explain the process of fertilization and development of the zygote, in relation to the transport of the zygote to the uterus
- explain the principle of in-vitro fertilization

6.3.2. Student knows the process of fetal growth and has insight into the physiological birth process, and is able to

- describe the function of the placenta during pregnancy
- describe the role of placental hormones
- indicate the maternal changes during pregnancy
- explain the development of the various fetal organ systems
- describe the phases of normal birth
- describe the changes in the neonate immediately and shortly after birth
- describe the processes enabling lactation

7. Gastro-intestinal system

7.1. General function

7.1.1. Student has insight into the architecture and function of the gastro-intestinal system and is able to

- describe the general structure of the wall of the gut and the structures within this wall
- indicate the function of each of these structures
- describe the mechanisms of movements in the gastro-intestinal tract (peristalsis, antiperistalsis)
- describe the chemical processes involved in digestion
- describe the mechanisms of absorption of the main nutrients, including vitamins
- describe the storage and conversion of energy

7.1.2. Student knows the principles of neural and humoral regulation of transport, secretion and absorption, and is able to

- describe the function of the enteric nervous system and its relation to the autonomic nervous system
- describe the function of the most important digestive hormones, including their origin of production and target cells
- show insight into the nervous and hormonal communication between various parts of the gastrointestinal tract

7.2. Function of the oral cavity and esophagus

7.2.1. Student has insight in the function of the salivary glands, and is able to

- localize and describe the architecture of the salivary glands, and describe the regulation of secretion
- indicate the function of saliva

7.2.2. Student knows the function of mastication and is able to

- describe in a global way the architecture of teeth, as well as the differences between teeth in children (milk teeth) and adults
- explain the process of mastication

7.2.3. Student knows the various structures involved in swallowing and is able to

- describe the oral, pharyngeal and esophageal phase of swallowing, as well as its regulation
- name the involved nerves and the location of the neural centers
- describe the specific transport function of the esophagus and the meaning of the cardia
- describe the role of the upper and lower esophageal sphincters in swallowing

7.3. The stomach

7.3.1. Student knows the function of the stomach and is able to

- describe the motor and secretion functions of the stomach
- explain the functional differences between the proximal and distal part of the stomach during filling, emptying and inter-digestive phase
- explain the process of acid secretion and protection of the gastric surface
- explain the feedback processes which influence the motor and secretion function of the stomach
- describe the degradation process of carbohydrates, proteins and fat in the stomach
- describe the mechanism and meaning of the physiological vomiting reflex

7.4. Small and large intestines

7.4.1. Student has insight into the general architecture of the intestinal tract (duodenum, jejunum, ileum, cecum, colon, rectum, canalis analis), related to the specific functions in the process of digestion and absorption of nutrients, and is able to

- describe the role of the major digestive glands, liver and pancreas for the intestinal digestion of carbohydrates, fat and proteins
- explain the function of the entero-hepatic circulation
- describe how carbohydrates, fat and proteins are degraded to end products to be absorbed
- explain how the absorption of end products occurs
- explain the function of microbial fermentation in the large intestines
- describe the secretion and resorption in the large intestines, resulting in the formation of feces
- explain how diarrhea and constipation can occur

8. Metabolism

8.1. Storage of nutrients

8.1.1. Student has insight into the (regulation of) storage and use of carbohydrates, proteins and fat in the body and is able to

- describe in global terms the transport routes (origin – destination) of the main nutrients, degradation products and signal molecules

- indicate which micronutrients and micro-elements are necessary for proper function of organs
- indicate how and which nutrients are delivered to specific organs from the gastrointestinal tract
- explain why and how glucose, fatty acids and amino acids are stored in the body
- indicate the role of the liver, fat tissue, muscle tissue and brain in the storage and use of nutrients
- explain how and when these products are liberated from their stores
- indicate the relationship between the metabolism of carbohydrates, fat and proteins as related to their storage (metabolic pool)
- explain the regulation of food intake
- explain the regulation of body weight (obesity and starvation)

8.1.2. Student has insight into the energy metabolism of the body and is able to

- indicate how ATP can be generated from carbohydrates, proteins and fat
- indicate the differences between aerobic and anaerobic energy conversion
- describe in a global manner the metabolic pathways used for energy conversion
- explain the meaning of glycolysis, gluconeogenesis, glycogenolysis, glycogenesis, β-oxidation and ketogenesis and indicate under which circumstances each of them is important

8.2. Metabolism and hormonal regulation

8.2.1. Student has insight into the hormonal regulation of the energy metabolism and is able to

- indicate the role of the thyroid gland in the metabolism
- describe the role of the pancreatic hormones insulin and glucagon in the metabolism
- indicate the role of catecholamines and glucocorticoids in the metabolism
- explain the interaction between the regulation of the various hormones involved in the metabolism

8.3. Adaptation to exercise

8.3.1. Student has insight into the metabolic adaptations during exercise and physiological training and is able to

- describe the changes in energy metabolism during exercise, depending on the relative intensity and type of physical load
- describe the general effects of training on the energy metabolism and specifically on the skeletal muscle
- describe the meaning of VO_2 max and respiratory quotient in exercise physiology.
- explain oxidative stress and the role of antioxidants

9. Thermoregulation

9.1. Processes and balance

9.1.1. Student has insight into thermoregulation and is able to

- describe the role of the thermoregulatory center and the central and peripheral sensors
- describe which hormones play a role in the regulation of body temperature
- differentiate between normal and deviating body temperatures, such as hypothermia, hyperthermia and fever

9.1.2. Student knows the regulation of the heat balance in the body and is able to

- describe the short term as well as long term adaptive mechanisms when a sudden transition to an extremely warm or cold environment occurs
- indicate how the equilibrium between the production and delivery of heat is maintained in various climates
- indicate how this equilibrium changes during exercise
- explain the relation between heat loss and water balance
- indicate which factors determine the level of heat production, how this is regulated and how various organs participate in the generation of heat

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