General histology – schemes

List for the final exam

A. Cell biology

1. Draw and label cell membrane:

- cross-section of cell membrane: phospholipid bilayer, cholesterol,
- transmembrane protein, ion channel, transporter, and receptor proteins, glycocalyx,
- drawing of phospholipid molecule: highlight hydrophilic (phosphatidic acid) and hydrophobic portion (fatty acids).

2. Draw and label (animal) cell and its organelles:

- cell membrane, cytoskeleton (microfilaments, microtubules),
- nucleus in interphase (membrane, pores), nucleolus, cytoskeleton (intermediate filaments),
- endoplasmic reticulum smooth and rough (including ribosomes), Golgi complex, transport vesicle,
- lysosome, mitochondria.

3. Draw and label intercellular junctions in relation to cell polarity:

- draw two adjacent cells and their junctions, highlight apical and basolateral poles of cells,
- zonula occludens,
- zonula adherens,
- desmosome,
- nexus (gap junction).

4. Draw and label nutrition uptake by cells:

- pinocytosis: small molecules (cell drinking),
- phagocytosis: ingesting larger particles (*e.g.* bacteria), pseudopodia,
- transcytosis: transport of vesicles.

5. Draw and label nucleus of the eukaryotic cell, endoplasmic reticulum, Golgi complex, and mitochondria with its membranes:

- nuclear envelope: two layers of membrane, nuclear pore, heterochromatin, and euchromatin,
- smooth and rough endoplasmic reticulum + Golgi complex,
- outer and inner mitochondrial membrane, cristae, the localisation of respiratory complex proteins in the inner membrane.

6. Draw and label basement membrane:
- basal lamina consisting of lamina densa (dense layer) et lucida (clear layer): collagen type IV, glycoprotein laminin,
- fibroreticular lamina: collagen type III, collagen type VII,
- basis of the cell attached to lamina lucida by hemidesmosomes.

7. Draw and label the cell cycle; what is the regular sequence of the phases; distinguish the phases of mitosis:
- G1 (G0) – S – G2 – M,
- interphase nucleus in G1 – S – G2 phases,
- draw schemes of individual mitotic (M) phases (position of chromosomes, mitotic spindle, cell division): prophase, metaphase, anaphase, telophase,
- cytokinesis.

8. Draw and label protein synthesis starting with DNA and RNA:
- transcription of DNA into the molecule of RNA,
- mRNA translation into protein sequence, ribosome, the relation between codon-mRNA, and anti-codon-tRNA, synthesized protein,
- small and large subunit of the ribosome.

B. Epithelial tissue

9. Draw and label specializations of the cell apical pole including their size, and details of their structure; give an example for each modification:
- microvilli: cytoplasm processes about 1 µm long, a base formed by actin microfilaments, top of microvilli covered by glycocalyx; complex of microvilli and glycocalyx = brush (microvillous) border, *e.g.* duodenum, gallbladder, proximal tubule of kidney,
- stereocilia: branched variety of microvilli, also formed by actin microfilaments, 7 µm long, *e.g.* epididymis, hair cells of inner ear,
- kinocilia: motile processes of the cells, 2-10 µm long, microtubules in arrangement 9+2 = axonema, dynein (molecular motor), pairs of microtubules (microtubule doublets) joined by nexin, anchored in the basal bodies, *e.g.* trachea, bronchi, fallopian tube.

10. Draw and label simple epithelia; give examples:
- simple squamous epithelium: single layer of uniform flat cells, flat nuclei, *e.g.* pulmonary alveoli, parietal layer of the Bowman capsule,
- simple cuboidal epithelium: single layer of uniform cuboidal cells, rounded nuclei, *e.g.* thyroid gland follicles,
- simple columnar epithelium: single layer of uniform columnar cells, oval nuclei, *e.g.* stomach, small and large intestine, gallbladder, and uterine mucosa (endometrium),
- pseudostratified columnar ciliated epithelium: basal parts of all cells rest on the basement membrane, nuclei in different distances from the basement membrane, *e.g.* trachea and bronchi.

11. Draw and label stratified squamous epithelia; give examples:

- stratified squamous epithelia non-keratinized: nuclei present in superficial cells, *e.g.* oral cavity, oesophagus,
- stratified squamous epithelia keratinized, thin type of the skin: stratum basale, str. spinosum, str. granulosum, (str. lucidum – only in thick type of the skin), str. corneum, str. disjunctum, *e.g.* axilla,
- stratified squamous epithelia keratinized, thick type of the skin – in addition str. lucidum, *e.g.* planta, palma.

12. Draw and label stratified columnar epithelium, stratified cuboidal epithelium, and transitional epithelium; give examples:

- stratified cuboidal epithelium: several layers of cuboidal cells, *e.g.* large ducts of glands,
- stratified columnar epithelium: basal cuboidal layer, above few layers of columnar, cells, *e.g.* conjunctiva,
- transitional epithelium: 2 schemes according to the functional state of the organ (depending on the state of its filling); flattened and high epithelium, changing shapes of cells, umbrella cells, *e.g.* bladder, ureters.

13. Draw and label Goblet cell in the context of two epithelia in which is present; give examples:

- unicellular intraepithelial mucous gland,
- nucleus located in the basal part, surrounded by rough endoplasmic reticulum, large Golgi apparatus, secretory granules in the apical segment of the cell,
- within a simple columnar and pseudostratified columnar ciliated epithelium, *e.g.* trachea, intestine.

14. Draw and label classification of multicellular exocrine glands according to the structure of the ducts and the secretory compartments; give examples:

- simple tubular glands: *e.g.* intestinal crypts, endometrial glands; simple tubular coiled glands: *e.g*. sweat glands; simple tubular branched glands: *e.g.* gastric glands,
- compound tubular glands: *e.g*. duodenal Brunner´s glands,
- simple alveolar glands: *e.g*. sebaceous glands; compound alveolar glands: *e.g*. lactating mammary gland,
- compound acinar glands: *e.g*. pancreas, parotid gland,
- compound tubuloalveolar glands: *e.g*. sublingual or submandibular glands.

15. Draw and label skin glands according to the classification based on the mechanism of secretion; give examples:

- merocrine/eccrine gland: *e.g*. sweat gland,
- apocrine gland: *e.g*. aromatic (sweat) gland,
- holocrine gland: *e.g*. sebaceous gland.

16. Draw and label differences between serous, mucous, and seromucous glands; give examples:

- serous cells: pyramidal shape of the cell with zymogen granules, round nuclei, basophilic cytoplasm, abundant rough endoplasmic reticulum, *e.g.* pancreas, parotid gland,
- mucous cells: columnar cell with flattened nucleus on the cell base, granules with mucin, *e.g.* Brunner´s glands,
- seromucous (mixed) gland: two types of secretion units, mucous cells in tubular part of gland, serous cells in acinar part, serous demilune of Gianuzzi, *e.g.* submandibular and sublingual gland.

C. Connective tissue

17. Draw and label resident cells of the connective tissue proper:

- fibroblast: oval nucleus with nucleoli, rough endoplasmic reticulum, Golgi apparatus, mitochondria, secretory vesicles, production of extracellular matrix,
- fibrocyte: less cytoplasm and cell processes compared to a fibroblast,
- reticular cell: star-shaped cell, oval nucleus, production of reticular fibres,
- adipocyte (fat cell): multilocular (nucleus in the centre, a number of mitochondria, lipid droplets) and unilocular (spherical shape with one large fat droplet, eccentric nucleus, and thin layer of cytoplasm),
- pigment cell (melanocyte): cytoplasmic protrusions, nucleus, melanin granules (melanosomes).

18. Draw and label wandering cells of the connective tissue proper:

- macrophage (histiocyte): round to oval shape, irregular eccentrically placed dark nucleus, Golgi apparatus, and endoplasmic reticulum, phagocytic vesicles, lysosome, phagosome, peptide-MHC complex on the surface,
- plasma cell (plasmocyte): round or spherical shape, nucleus with heterochromatin in a “cartwheel” nuclear pattern, rough endoplasmic reticulum, Golgi apparatus, secretory vesicles, immunoglobulin’s synthesis,
- mast cell (mastocyte, heparinocyte): oval shape, small nucleus, secretory granules with heparin and histamine.

19. Draw and label biosynthesis of collagen; draw and label reticular and elastic fibres:

- collagen fibre: procollagen, triple helix of tropocollagen, and their overlapping within microfibrils, cross striations of fibrils, collagen bundle,
- shape of reticular fibres, their arrangement among fibrocytes or reticular cells,
- elastic fibres: oxytalan microfibrils surrounding the elastin core.

20. Draw and label mesenchyme and mucous tissue; give an example:

- mesenchyme: mesenchymal undifferentiated cells (star-shaped), fibroblasts, reticular fibres, ground substance,
- *e.g.* embryonal connective tissue proper (mesenchyme),
- mucous tissue: fibroblasts, reticular fibres, hyaluronic acid in ground substance,
- *e.g.* umbilical cord and pulp of young teeth

21. Draw and label loose (collagen) connective tissue; give an example:
- collagen and elastic fibres,
- fibroblast, macrophage, mastocyte,
- capillaries, nerve fibres,
- *e.g.* connective tissue layer of the mucosa (lamina propria mucosae), tunica adventitia.

22. Draw and label regular and irregular dense connective tissue; give an example:
- irregular dense connective tissue: collagen fibres running in various directions, fibroblasts, fibrocytes,
- *e.g.* reticular layer of the corium, fibrous capsules of organs,
- regular dense connective tissue: collagen fibres running in parallel bundles, fibroblasts, fibrocytes,
- *e.g.* tendon.

23. Draw and label hyaline cartilage; give an example:
- chondrocytes in lacunae with basophilic capsules, forming isogenous groups,
- extracellular matrix with ground substance and type II collagen fibrils,
- perichondrium: outer layer (stratum fibrosum) – fibroblasts, collagen connective tissue, blood and lymphatic vessels, nerves; inner) layer (stratum chondrogenicum) – chondroblasts,
- *e.g.* trachea.

24. Draw and label elastic cartilage; give an example:
- individual chondrocytes or small isogenous groups,
- extracellular matrix with ground substance, elastic fibres, and type II collagen fibres,
- perichondrium: outer layer with fibroblasts, collagen connective tissue, vessels, and nerves; inner layer with chondroblasts,
- *e.g.* auricle, epiglottis.

25. Draw and label fibrous cartilage; give an example; draw and label ultrastructure of chondrocyte:
- transition of cartilage into the dense collagen connective tissue at the periphery,
- separated chondrocytes or chondrocytes in linear groups,
- eosinophilic extracellular matrix with type I collagen fibres in form of irregular bundles or parallel bundles,
- chondrocyte ultrastructure: nucleus, rough endoplasmic reticulum, Golgi apparatus, exocytosis of matrix,
- *e.g.* intervertebral discs (annulus fibrosus), articular menisci.

26. Draw and label histology of compact bone:
- lamellae forming Haversian systems (osteons), interstitial lamellae, Haversian canal inside osteon,
- osteocytes with projections running through bone canaliculi, transverse and oblique canals of Volkmann,
- periosteum with collagen connective tissue, Sharpey's fibres, and fibroblasts,
- endosteum on the inner bone surface.

27. Draw and label histology of trabecular (spongy, cancellous) bone:
- branched bony trabeculae composed of lamellar bone,
- osteons in thick trabeculae,
- osteocytes, osteoblasts, osteoclasts,
- spaces among the trabeculae contain either red or yellow bone marrow (adipocytes).

28. Draw and label intramembraneous (desmogenous) ossification; give an example of bone formed via the desmogenous ossification:
- ossification centres with reticular fibres and fibroblasts gradually differentiate into osteoblasts on the surface of newly formed bone trabeculae, production of unmineralized bone matrix (osteoid), osteocytes surrounded by the bone matrix,
- connective tissue proper among the bone trabeculae, blood vessels,
- osteoclasts in erosion (Howship´s) lacunae on the surface,
- *e.g.* flat cranial bones, upper and lower jaw.

29. Draw and label ossification of a long bone as a whole – stages of long bone formation:
- cartilaginous model, subperiosteal collar bone of intramembranous origin in the extent of the diaphysis,
- primary ossification centre in diaphysis, blood vessels in diaphysis,
- secondary ossification centres in epiphyses, blood vessels in diaphysis,
- epiphyseal plates between the diaphysis and the epiphyses,
- ossification of the epiphyseal cartilage and termination of the bone growth.

30. Draw and label zones of epiphyseal growth cartilage; give an example of bone formed via chondrogenous ossification:
- resting zone of hyaline cartilage,
- proliferation zone with rapidly divided chondroblasts forming columns,
- hypertrophic zone with huge chondrocytes,
- calcification zone,
- erosion zone/line with blood capillaries, chondroclasts, and osteoprogenitor cells,
- ossification zone with newly formed bone trabeculae, osteoblasts producing bone matrix,
- *e.g.* bones of upper and lower limbs, vertebrae, ribs, pelvic bones.

D. Blood

31. Draw (including their appropriate staining) and label erythrocytes – morphology (including their size) and number in men and women in peripheral blood:
- size: 7.5 µm x 2.5 µm, morphology: biconcave disc without a nucleus,
- 4.0-5.8 millions/mm^3 in men; 3.8-5,2 millions/mm^3 in women,
- eosinophilic cytoplasm.

32. Draw (including their appropriate staining) and label granulocytes – morphology (including their size) and differential count (the percentage ranges given for each type of leukocyte):
- neutrophils (45-70%), size: 10-12 μm, morphology: granules smaller then in basophils and eosinophils with limited affinity to stain, segmented nucleus,
- eosinophils (0-5%), size: 10-15 μm, morphology: bilobed nucleus, large red granules (take up reddish/orange colour),
- basophils (0-2%), size: 8-10 μm, irregular shape of nucleus, large basophilic granules.

33. Draw (including their appropriate staining) and label agranulocytes – morphology (including their size) and differential count (the percentage ranges given for each type of leukocyte); draw and name 1 type of macrophage:
- lymphocytes (20-45%), size: 6-18 μm, morphology: large nucleus almost fills the cell, thin rim of cytoplasm,
- monocytes (2-10%), size: 12-20 μm, morphology: kidney-shaped nucleus, azurophilic granules (lysosomes),
- macrophage: osteoclasts, microglial cells, or wandering cell of connective tissue proper.

34. Draw and label thrombopoiesis and blood platelets – morphology (including their size) and number in peripheral blood:
- oval-shaped thrombocyte without nucleus, size: 2-4 μm, morphology: hyalomere and granulomere, tubular system,
- thrombopoiesis: hematopoietic stem cells/hemocytoblast (25 μm, rounded nucleus, nucleoli), megakaryoblast, megakaryocyte, thrombocyte,
- 150 000-400 000/mm^3 of peripheral blood.

35. Draw (including appropriate staining and size) and label erythropoiesis:
- hematopoietic stem cells (HSC)/hemocytoblast: 25 μm, rounded nucleus, nucleoli,
- proerythroblast: 15-20 μm, purple cytoplasm, nucleus, nucleolus,
- basophilic erythroblast: 12-15 μm, blue cytoplasm, ribosomes,
- polychromatophilic erythroblast: 8-10 μm, purple to pink cytoplasm,
- orthochromatophilic (eosinophilic) erythroblast: 6-8 μm, pinkish to reddish cytoplasm,
- reticulocyte: remnants of organelles (ribosomes, endoplasmic reticulum), no nucleus,
- erythrocyte: 7,5 μm, eosinophilic.

36. Draw and label lymphopoiesis:
- hematopoietic stem cells (HSC)/hemocytoblast: 25 μm, rounded nucleus, nucleoli,
- lymphoblast,
- T- and B-lymphocytes (plasma cells differentiating from B-lymphocytes), NK cells.

37. Draw and label monopoiesis (monocytopoiesis):
- hematopoietic stem cells (HSC)/hemocytoblast: 25 μm, rounded nucleus, nucleoli,
- monoblast,
- monocyte,
- macrophage in tissue.

38. Draw and label granulopoiesis (granulocytopoiesis):
- hematopoietic stem cells (HSC)/hemocytoblast: 25 µm, rounded nucleus, nucleoli,
- myeloblasts,
- promyelocytes with azurophilic granules,
- myelocytes with specific granules,
- metamyelocytes,
- neutrophils, eosinophils, basophils.

E. Muscle tissue

39. Draw and label smooth muscle cell, 2 schemes with a longitudinal and a cross-section:
- longitudinal section: long, spindle-shaped cell and nucleus, nucleus in central position, caveolae, microtubules,
- free ribosomes, rough endoplasmic reticulum, mitochondria, gap junctions,
- cross section: smooth muscle cell with 1 central nucleus.

40. Draw and label skeletal muscle fibre, 2 schemes with a longitudinal and cross-section:
- longitudinal section: sarcolemma, myofibrils, sarcomere, nuclei situated on the periphery,
- cross striation, alternation of anisotropic and isotropic bands,
- cross section: skeletal muscle fibre with nuclei on periphery.

41. Draw and label ultrastructure of skeletal muscle fibre including scheme of a sarcomere and a triade:
- Z lines bordering the sarcomere, actin anchored to Z-lines, myosin,
- A-band, I-band, M-line,
- a triade consisting of T-tubule invaginating towards the terminal cisterns of sarcoplasmic reticulum,
- nuclei on the periphery, mitochondria in sarcoplasm.

42. Draw and label cardiac muscle, 2 schemes with a longitudinal and cross section:
- longitudinal section: cardiac muscle cells, intercalated discs, central position of nucleus, lipofuscin granules near the poles of nuclei, mitochondria,
- endomysium with very dense capillary network,
- cross section: cardiac muscle cell with central nucleus.

43. Draw and label ultrastructure of the intercalated disc:
- maculae adherentes (desmosomes): make tissue coherent,
- zonula adherens (adhesive belt): connected to actin filaments,
- gap junction (nexus): two connexons of adjacent cells with a channel inside; each connexon consisting of six molecules of connexin protein.

44. Draw and label cardiac conducting system including histology of the terminal part of this system:
- sinoatrial and atrioventricular node,
- bundle of His, right and left bundle branch,
- Purkinje fibres: histology: less myofibrils, lighter sarcoplasm – glycogen around the nucleus, larger diameter then normal cardiomyocytes.

E. Nerve tissue

45. Draw and label a neuron:
- nerve cell body (perikaryon), nucleus, nucleolus, Nissl's substance (rough endoplasmic reticulum), mitochondria,
- dendrites, axon, initial segment,
- myelin sheath, node of Ranvier, Schwann cells, terminal arborisation – branching of the axon on the effector.

46. Draw and label types of neurons according to the number of processes. Label neuron processes in all schemes. Give examples:
- apolar: embryonic neuroblasts,
- bipolar: second neurons of the retina,
- pseudounipolar: sensitive neurons in spinal ganglia,
- multipolar: spinal motor neurons in ventral horns.

47. Draw and label histological structure of peripheral nerve:
- epineurium, perineurium, endoneurium,
- axons and dendrites, myelin sheath, Schwann cells, nuclei of Schwann cells,
- vasa nervorum, nervi nervorum.

48. Draw and label myelinated and unmyelinated axons in peripheral nerve system, development of myelin sheath (3 schemes) and longitudinal section of myelinated axon:
- development: axon, Schwann cell, and its membrane wrapped around the axon, myelin formation,
- longitudinal section: axon, Schwann cells, layers of myelin, node of Ranvier,
- multiple axons enfolded by Schwann cell.

49. Draw and label histological structure of monosynaptic reflex arc:
- receptor, afferent sensory fibre, spinal ganglion with pseudounipolar neuron, dorsal spinal horn,
- interneuron of the spinal cord, large multipolar motoric neuron in the ventral horn,
- efferent motor fibres, effector (muscle).

50. Draw and label motor end plate (neuromuscular junction):
- axon, myelin,
- axon terminal of motoneuron, synaptic vesicles with neurotransmitter acetylcholine,
- presynaptic and postsynaptic membrane, synaptic cleft, sarcolemma of skeletal muscle.

51. Draw and label synapse and neurotransmitter circulation:

- axon, microtubules, microfilaments, mitochondria,
- synaptic vesicles with transmitter, synaptic cleft,
- presynaptic and postsynaptic membrane.

52. Draw and label neuroglia of central nervous system (CNS) and their function:

- fibrous (in white matter) and protoplasmic (in gray matter) astrocytes; processes, perivascular pedicles, blood-brain barrier,
- oligodendrocytes: produces myelin in CNS,
- ependymal cells lining CNS cavities, tanycyte
- microglial cells: inactivated microglia and activated glia (*i.e.* macrophage).

53. Draw and label tissues of meninges:

- periosteum, dura mater: dense collagen tissue,
- arachnoid: loose trabecular connective tissue, arachnoid villi (granulations) protruding to the venous sinuses,
- pia mater: loose collagen connective tissue with blood vessels, its inner side covers the surface of the CNS.

Embryology – schemes

List for the final exam

A. Progenesis

54. Draw and label folliculogenesis:
- primordial ovarian follicle with primary oocyte and follicular cells,
- primary unilaminar and multilaminar follicle,
- secondary follicle, forming cavities, growing oocyte with zona pellucida,
- tertiary (Graafian) follicle, antrum folliculi, theca folliculi, granulosa membrane, cumulus oophorus, corona radiata,
- ovulation with free oocyte surrounded by zona pellucida and cumulus oophorus.

55. Draw and label mitosis and meiosis during oogenesis and spermatogenesis; note control checkpoints with developmental arrest during oogenesis; state the ploidy of cells:
- mitotic division of oogonium, 1st meiotic division and 1st meiotic arrest (2n),
- oocyte maturation: re-initiation of meiosis and 2nd meiotic arrest, matured oocyte (n) in metaphase II and extruded polar body,
- mitotic division of spermatogonia, 1st spermatocytes (2n),
- 1st meiosis leading to 2nd spermatocytes (n), 2nd meiosis and four haploid spermatids,
- mark the asymmetry of division during oogenesis and the symmetry of division during spermatogenesis.

56. Draw and label spermatogenesis including spermiohistogenesis; note ploidy of cells:
- spermatogonia in testicular seminiferous tubules, adjacent Sertoli cells,
- mitotic division of spermatogonia leading to primary spermatocytes (2n),
- first meiotic division giving rise to secondary spermatocytes (n),
- second meiotic and spermatids,
- spermiohistogenesis – morphological transformation of spermatids into spermatozoa,
- Spermatozoon: flagellum, midpiece, condensed heterochromatin, acrosome.

57. Draw and label the fertilization, acrosomal and cortical reactions, genesis of a zygote:
- sperm capacitation, spermatozoa penetrating through the cumulus oophorus, corona radiata, and zona pellucida,
- polyspermy block: exocytosis of cortical granules, zona hardening, perivitelline space extension,
- extrusion of 2nd polar body as a mark of the fertilization,
- genesis of maternal and paternal pronucleus, fusion of pronuclei in the zygote.

58. Draw and label the cleavage till blastocyst hatching, including the implantation; state where and when the embryo in different stages of development occurs:

- day 1: mitotic division of the zygote (1st cleavage) toward blastomeres enclosed in zona pellucida, fallopian tube,
- day 2-3: mitotic division of blastomeres, embryonic genome activation (eight-cell), passing through the fallopian tube,
- day 3-4: morula formation, descending down the fallopian tube,
- day 4: blastocyst formation and hatching out of the zona pellucida in uterus,
- day 5: blastocyst attachment to the endometrium.

59. Draw and label blastocyst formation and the implantation in three schemes – free blastocyst, onset of implantation, and finalized implantation:

- formation of blastocoel and blastocyst expansion, hatching, free blastocyst,
- nidation of blastocyst into the endometrium, differentiation of trophoblast and embryoblast,
- syncytiotrophoblast formation and the invasion into the endometrium, vascular lacunae in the endometrium, chorion laeve et frondosum, operculum.

60. Draw and label the development of chorionic villi – primary to tertiary villi. Describe differences between villi of the mature and immature placenta:

- differentiation of trophoblast: cytotrophoblast and syncytiotrophoblast, primary chorionic villi,
- secondary chorionic villi with extraembryonic mesenchyme,
- tertiary villi equipped with fetal capillaries and the extraembryonic mesenchyme,
- tertiary villli of the mature placenta (reduction of syncytiotrophoblast and extraembryonic mesenchyme).

61. Draw and label the development of implanted blastocyst; amniotic vesicle and yolk sac, gastrula, layers of amnion and chorion:

- blastocyst with embryoblast and trophoblast,
- syncytio- and cytotrophoblast, epiblast and hypoblast, primary mesoderm, Heuser's membrane,
- amniotic vesicle, yolk sac and their mutual contact; origin of exocoelomic cavity,
- chorion (primary mesoderm + cytotrophoblast + syncytiotrophoblast),
- amnion (primary mesoderm + amniotic ectoderm).

62. Draw and label embryonic disc – dorsal view and sagittal sections:

- ectodermal primitive streak and primitive (Hensen's) node,
- notochordal process,
- luminization of the notochordal process along with the origin notochordal canal,
- entodermal prechordal plate,
- neurenteric canal, oropharyngeal and cloacal membranes, allantois.

63. Draw and label the formation of mesoderm and chorda dorsalis – dorsal view, sagittal and transversal sections:

- dorsal view: primitive streak and primitive node,
- sagittal section: notochordal canal related to amniotic cavity and yolk sac,
- transversal section: migration of ectodermal cells and origin of mesoderm, differentiation of paraxial mesoderm, intermediate mesoderm, and lateral mesoderm.

64. Draw and label origin of somites and intraembryonic coelom in gastrula, basic segmentation of mesoderm – transversal views:

- fate of paraxial mesoderm and origin of somites,
- intermediary mesoderm, lateral mesoderm with somatopleura and splanchnopleura, coelom,
- relation of somites to the neural tube, neural crest, chorda dorsalis, and paired aortae; relation to the nephrogenic cord.

B. Nerve system

65. Draw and label the development of neural plate, neural groove, and neural tube – dorsal view and transverse sections:

- the relation of primitive streak and neural plate, anterior and posterior neuropores,
- ectoderm, coelom, prechordal plate, and neural plate,
- neural folds, neural groove, basis of neural crest,
- neural tube related to chorda dorsalis, neural crest, and somites.

66. Draw and label head part of neural tube, division to brain vesicles, describe further development of vesicles:

- the stage of three brain vesicles: prosencephalon, mesencephalon, rhombencephalon,
- prosencephalon divided to telencephalon and diencephalon,
- rhombencephalon divided to metencephalon (future pons Varoli and cerebellum) and myelencephalon (future medulla oblongata),
- lateral brain vesicles (telencephalon), 3rd (diencephalon) and 4th (metencephalon) brain vesicle.

67. Draw and label histogenesis of central nervous system:

- neural tube: dorsal roof (alar) plate and ventral floor (basal) plate, sulcus limitans; neural crest,
- dorsal (afferent) and ventral (motoric) spinal root, spinal ganglia, sensitive and motor neurons,
- glial external and internal limiting membrane, ependymal cells, neuroblasts, and spongioblasts.

68. Draw and label neural crest and its derivatives:

- neural crest and the relation to the neural tube,
- division of neural crest, cells migrating from the crest, melanocytes,
- spinal ganglia, ganglia of the autonomic nervous system, the enteric nervous system, and medulla suprarenalis,
- placodes of the cranial nerves.

69. Draw and label development of the eye and nervus opticus:

- optic vesicle growing from the diencephalon, ectodermal lens placode,
- optic nerve and bilayered optic cup with inner neural layer and outer pigmented layer; invagination of the lens vesicle, cornea,
- eye mesenchyme: choroidea, corpus ciliare, iris, sclera,
- arteria hyaloidea, arteria centralis retinae,
- vasa centralia retinae enclosed in nervus opticus.

70. Draw and label development of the inner ear, origin of the middle ear cavity and the outer ear:

- inner ear: invagination of otic placode, otocyst, cochlea, primordial saccule, primordial utricle, endolymphatic duct, semicircular duct,
- middle ear cavity: originating from the 1st entodermal pharyngeal pouch; malleus, incus, and stapes originating from the mesenchyme of 1st and 2nd branchial arches,
- outer ear: external auditory meatus from the 1st ectodermal cleft, pinna from 3 auricular hillocks on the mandibular and 3 hillocks on the hyoid pharyngeal arch, eardrum.

C. Circulation

71. Draw and label formation of blood islands and primitive extraembryonic bloodstream:

- blood islands in the extraembryonic mesenchyme of the yolk sac, connecting stalk, and chorionic villi,
- angioblasts, differentiating into erythroblasts, and endothelial cells,
- extraembryonic vitelline vessels.

72. Draw and label embryonic circulation from primitive bilateral circulation to unification of paired blood vessels; highlight direction of the blood flow:

- distinguished embryonic and extraembryonic (vitelline) circulation, followed by the unification of them,
- umbilical vein (draining the chorionic villi), common cardinal vein (tributaries: pre- and postcardinal vein, draining somite areas), vitelline vein (from the extraembryonic circulation),
- heart, internal carotid artery, aorta, vitelline artery, umbilical artery.

73. Draw and label the formation of heart tube:
- fusion of paired heart tube,
- six venous tributaries: paired common cardinal veins, umbilical veins, vitelline veins,
- sinus venosus and atria, sino-atrial aperture, atrio-ventricular canal,
- ventricular space, heart bulbus, truncus, and aortic arches.

74. Draw and label the formation of the heart loop:
- sinus venosus, sino-atrial opening, atrioventricular canal, ventricles,
- heart bulbus, truncus, and aortic arches,
- heart loop formation and separation of future right and left atrium and ventricle.

75. Draw and label atrial septation. Highlight the establishment of atrial septum before and after the birth:
- sinu-atrial orifice and septum spurium,
- septum intermedium,
- septum primum and foramen (ostium) primum,
- fusion of septum primum and septum intermedium; origin of foramen (ostium) secundum,
- septum secundum and foramen ovale, separation of right ventricle from left one,
- after the birth – closing the foramen ovale, septum primum is pressed against septum secundum.

76. Draw and label septation of heart ventricles and the separation of large arteries:
- septum intermedium and septum interventriculare with foramen interventriculare,
- membranous and muscular parts, closing of interventricular foramen,
- bulbar ridges, aortico-pulmonary septum,
- separated aorta and pulmonary trunk.

77. Draw and label development of arteries of the aortic arches:
- remnants of the 1st arch artery – maxillary artery,
- remnants of the 2nd arch artery – stapedial artery,
- 3rd arch – common and internal carotid artery,
- 4th arch – aortic arch (on the left) and right subclavian artery (on the right),
- 5th arch – no developed,
- 6th arch – pulmonary trunk, a. pulmonalis dx. et sin., and ductus arteriosus (on the left).

78. Draw and label patens foramen ovale (foramen ovale apertum) after birth:
- septum primum, septum secundum,
- blood flowing to the left atrium via pulmonary veins, left-to-right shunt from the left to the right atrium through the foramen ovale, overload of the right atrium and right ventricle,
- right ventricular hypertrophy, pulmonary artery hypertrophy,
- reduced hypotrophic aorta.

79. Draw and label patens (persistent) ductus arteriosus including postnatal flow of blood; draw and label types of aortic coarctation:

- arcus aortae, pulmonary trunk, ductus arteriosus,
- direction of blood flow to pulmonary trunk via persistent duct,
- preductal, ductal, and postductal coarctation,
- mechanism of the coarctation.

80. Draw and label tetralogy of Fallot:

- ventricular septal defect with irregular division of the bulbus,
- aorta connected to both the right and the left ventricle,
- pulmonary stenosis,
- right ventricular hypertrophy.

D. Digestive system

81. Draw and label the origin of the primitive gut:

- relation of the amniotic sac and the yolk sac,
- delimitation of the primitive gut due to expansion of the amniotic sac over the yolk sac,
- oral (oropharyngeal) and cloacal membrane,
- yolk vesicle connected to the gut via the vitelline (omphaloenteric) duct.

82. Draw and label development and the fate of ectodermal pharyngeal clefts – frontal view:

- oropharyngeal membrane,
- mandibular arch, hyoid arch, three pairs of tubercles (pinnas) as a primordium of external ear, first pharyngeal cleft developing into the meatus acusticus externus, tympanic membrane,
- operculum closing the space of sinus cervicalis.

83. Draw and label development and derivatives of entodermal pharyngeal pouches, including primordium of the tongue:

- position of tuberculum impar and copula, thyroid gland, and larynx,
- 1st pouch – tympanic (middle ear) cavity and auditory (Eustachian) tube,
- 2nd pouch – tonsillar sinus and palatine tonsil,
- 3rd pouch – thymus and inferior parathyroid gland,
- 4th pouch – superior parathyroid gland, ultimobranchial body (parafollicular cells of the thyroid gland).

84. Draw and label skeleton of the pharyngeal arches, note the examples of muscles:

- 1st arch – Meckel's cartilage, malleus, incus, sphenomandibular ligament; masticatory muscles, *e.g.* mylohyoid muscle, anterior belly of the digastric muscle, tensor tympani muscle,
- 2nd arch – upper part of hyoid bone body, lesser cornua, stylohyoid ligament, styloid process, stapes; mimic muscles, platysma, further *e.g.* posterior belly of the digastric muscle, stylohyoid, and stapedius muscle,
- 3rd arch – lower part of the body of the hyoid bone, greater cornua; *e.g.* stylopharyngeus muscle,
- 4th arch – thyroid cartilage, cuneiform cartilages; pharyngeal and laryngeal muscles,
- 6th arch – cricoid, corniculate cartilages; pharyngeal and laryngeal muscles.

85. Draw and label nerves of the pharyngeal arches:

- 1st arch – trigeminal nerve,
- 2nd arch – facial nerve,
- 3rd arch – glossopharyngeal nerve,
- 4th arch – vagus nerve,
- 6th arch – recurrent laryngeal nerve (vagus nerve).

86. Draw and label development of the tongue and thyroid gland:

- the borderline between the ectoderm and entoderm – oropharyngeal membrane,
- ectodermal origin of tuberculum impar and lateral lingual swellings of the mandibular arch – the body of the tongue,
- entodermal origin of copula the root of the tongue,
- thyreoglossal duct, right/left/pyramidal lobe of the thyroid, foramen caecum.

87. Draw and label development of the hypophysis:

- stomodeum (ectoderm), oropharyngeal membrane, pharynx (entoderm),
- Rathke's pouch in the roof of the stomodeum; infundibulum of the 3rd ventricle from the diencephalon,
- adenohypophysis originating from the Rathke's pouch; neurohypophysis growing from the infundibulum.

88. Draw and label development of dental lamina, teeth primordia, and tooth development:

- labiogingival groove separating the lip from the gingiva,
- dental lamina (at the gingiva) and the segmentation to five buds forming the primordia of the primary teeth; 8 primordia of the secondary teeth growing in the palatal/lingual direction in each quadrant,
- enamel organ in the bud stage, cap stage, and bell stage,
- mesenchymal dental follicle as a base of tooth pulp, primordium of a secondary (permanent) tooth.

89. Draw and label histogenesis of the crown and root of a tooth:

- enamel organ, enamel-producing ameloblasts, sheath of Hertwig,
- dental pulp, odontoblasts, Tomes' fibres, predentine, dentine,
- cementoblasts, periodontal ligaments, and alveolar bone around the root.

90. Draw and label development of trachea and lungs, tracheo-oesophageal fistula; distinguish fetal canalicular stage and terminal sac stage of developing lungs:

- larynx separated by laryngotracheal groove from the ventral part of the oesophagus,
- fistula – communication between oesophagus and trachea (or another organ),
- fetal canalicular stage (week 16-26): terminal and respiratory bronchiole lined by simple cuboidal epithelium; vessels separated by mesenchyme from bronchiole,
- terminal sac stage (week 26 onwards): ductus alveolares, saccus alveolaris, alveoli with simple squamous epithelium and tightly adjacent to capillaries.

91. Draw and label the rotation of the oesophagus and stomach, migration of the liver primordium and the relationship to the coelomic cavity – transversal views:

- relations of stomach, coelomic cavity, dorsal and ventral mesentery,
- rotation of the stomach – right side towards the dorsal wall of coelom, left side towards the ventral wall of coelom; greater curvature shifted to the left side, lesser curvature shifted to the right,
- liver primordium shifted to the right within the ventral mesentery.

92. Draw and label the development of liver and pancreas:

- hepatic diverticulum growing out of the gut, branching to the bile duct system, and hepatic cords,
- dorsal and ventral pancreatic primordium,
- rotation of the ventral pancreas and ductus choledochus to the dorsal direction, fusion of ventral and dorsal pancreas,
- major pancreatic duct and part of the head of pancreas originating from the ventral primordium; accessory pancreatic duct, the body and the tail originate from the dorsal primordium.

93. Draw and label the rotation of the midgut and hindgut; explain the origin of Meckel´s diverticulum and faecal fistula formation:

- Midgut rotation around superior mesenteric artery,
- extraembryonic jejuno-ileal knot (physiological umbilical hernia) being pulled back to the abdominal cavity, closing of the umbili cus and yolk stalk (omphaloenteric duct),
- hindgut rotation: cranial shift of the caecum, pulling left of colon descendens, splenic flexure, colon transversum, hepatic flexure, colon ascendens,
- remnants of the yolk stalk open at the umbilicus as faecal fistula or blindly ending Meckel's diverticulum (two schemes).

E. Urogenital system

94. Draw and label segmentation of the nephrogenic cord using transverse and sagittal sections; draw the relation to mesoderm, mesenchyme, and coelomic cavity:
- pronephros in the cervical region,
- mesonephros in the thoracic region, originated from intermediate mesoderm,
- metanephrogenic blastema in the lumbar region, developed through mesenchyme condensation.

95. Draw and label development of pronephros and mesonephros, and their ducts; note the further destiny of mesonephros and their duct in male and female fetus:
- pronephros: mesodermal tubule at the cranial part of nephrogenic ridge,
- mesonephros: glomeruli of segmental aortic branches; mesonephric (Wolffian) duct and paramesonephric (Müllerian) duct opening in the cloaca, in relation to nephrogenic ridge,
- female: disappearance of mesonephros and its canal,
- male: ductuli efferentes testis from mesonephros; ductus epididymis, d. deferens, and d. ejaculatorius from mesonephric duct.

96. Draw and label development of metanephros:
- metanephric (ureteral) bud growing from the mesonephric (Wolffian) duct towards the metanephrogenic blastemal,
- branching ureteric bud giving rise to the ureter, renal pelvis, major and minor calyces, and collecting tubules,
- connection of renal collecting tubules to distal tubules of nephron.

97. Draw and label partitioning of the cloaca and its further development:
- terminal part of the colon and mesonephric (Wolffian) duct ending in the cloaca,
- cloacal septum dividing the cloaca to the ventral urogenital sinus and dorsal rectum,
- origin of urine bladder, fate of allantois (*i.e.*, urachus).

98. Draw and label indifferent stage of gonads, their relation to coelom, mesonephros, mesonephric (Wolffian) and paramesonephric (Müllerian) duct, and to the cloaca:
- indifferent gonads proliferated from the coelomic epithelium, medial to the mesonephros; paramesonephric (Müllerian) ducts running towards the cloaca and fusing in the middle line,
- migration of primordial gonocytes through the dorsal mesentery to the base of gonads,
- sex cords in gonads,
- mesonephric duct being medial to the paramesonephric ducts, then running laterally,
- mesonephros lateral to the gonad, mesonephrotic duct entering cloaca paramesonephric (Müllerian) duct run laterally at first but enter the cloaca medially.

99. Draw and label the development of ovary, fallopian tube, uterus, and vagina. Draw the development of the paramesonephric (Millerian) and mesonephric (Wolffian) duct in females:

- ovary situated in dorsal part of the coelom, gonocytes, and primordial follicle,
- paramesonephric (Müllerian) duct lateral to ovary, running to cloaca, differentiation of fallopian tube, origin of uterus due to fusion of right and left paramesonephric (Müllerian) ducts,
- vagina developing from the paramesonephric (Müllerian) ducts and luminisation of vaginal bud from endoderm flows into sinus urogenitalis,
- regression of mesonephros, mesonephric (Wolffian) duct remnants.

100. Draw and label indifferent stage of external genital organs; describe what these organs differentiate in male and female fetus:

- genital tubercle (phallus): penis in male, clitoris in female,
- urethral (internal) swellings: corpus spongiosum penis in male, labia minora in female,
- genital (external) swellings: fusion onto the scrotum in male, labia majora in female,
- perineum and anus in both males and females.

F. Skeletal system, face development

101. Draw and label development of extremities:

- limb bud (day 24 in the thoracic limb; day 26 in the pelvic limb), limb fin, ectodermal ridge, and mesenchyme,
- stylopodium with one bone element, zeugopodium with two bone elements, autopodium (carpus and metacarpus or tarsus and metatarsus, digits),
- digital rays within the autopodium, apoptosis between the digital rays.

102. Draw and label division of body somites into three mesenchyme populations; name the structures developing from these three parts of somites; explain how the bodies of vertebrae originate:

- somite divided into dermatome (lateral), sclerotome (medial), and myotome,
- cranial and caudal part of sclerotomes, origin of vertebral body by fusion of the adjacent parts of sclerotomes,
- fate of chorda dorsalis,
- dermis originating from the dermatome.

103. Draw and label development of vertebral body and processes:

- resegmentation of sclerotomes, intervertebral muscles from myotomes,
- body of vertebra originating from the inferior half of the upper sclerotome fusing with the superior half of the lower sclerotome,
- neural processes surrounding the spinal cord and closing the vertebral canal,
- costal processes growing in the ventral direction.

104. Draw and label skull of a newborn (including its circumference) – lateral and cranial view, age of obliteration of at least two of the fontanelles:

- frontal bone, parietal bone, temporal bone, occipital bone,
- frontal suture, coronal suture, sagittal suture, lambdoid suture,
- anterior fontanelle (fonticulus), posterior f., sphenoidal f., mastoid f.,
- 34 cm in circumference; closing due 1.5 year (anterior f.), 6th month (posterior f.), 3rd month (sphenoidal and mastoid fontanelles).

105. Draw and label development of the face including the nose:

- frontal processes, eye, maxillar and mandibular processes, stomodeum,
- olfactory (nasal) placodes, invaginating nasal vesicles,
- medial and lateral circumnasal ridges around the nostrils; nasolacrimal duct – maxillary prominence,
- fusion of medial circumnasal ridges results to nasal field and philtrum.

106. Draw and label development of the secondary palate (the frontal and lateral view), and describe cleft defects (view to the palate from the bottom up):

- premaxilla and primitive choanae, secondary (definitive) choanae as the entrance to the nasopharynx,
- relation of maxilla and premaxilla,
- horizontalization of palatal processes of the maxilla, fusion of palatal processes with the nasal septum,
- Difference of cleft lip (cheiloschisis), cleft jaw (gnathoschisis in front of foramen incisivum), palatoschisis.

107. Draw and label histological sections of the umbilical cord. Draw and label placenta and its parts. Describe differences in the placental barrier of mature and immature placenta:

- umbilical cord – two umbilical arteries, single umbilical vein, Wharton's jelly, ductus omphalonentericus, allantois, the amniotic epithelium on the surface,
- placenta – fetal part: chorion and villi; maternal part: decidual part and blood supply, intervillous space,
- immature placenta – intervillous space, syncytiotrophoblast, cytotrophoblast, extraembryonic mesenchyme, blood vessels in the centre of the villus,
- mature placenta – reduction of cytotrophoblast, blood vessels on the periphery of the villus.